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Research Article

Herbage Yield, Nutritional Quality of Desho Grass (*Pennisetum glaucifolium*) Mixed with Stylo and Silverleaf Desmodium at Assosa, Western Ethiopia

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Abstract

The study was conducted during the main cropping season of 2019/2020 at Assosa in Benishangul-Gumuz regional state. The aim of the study was to evaluate herbage dry matter yield, nutritional quality and biological compatibility of desho grass mixed with Stylo and Desmodium. The treatments included two legume species (Stylosanthes guyanensis and Desmodium unicinatum) and desho grass with four levels of seed proportions (100%, 75%, 50% and 25%) of the recommended seeding rates of the two legume forages. Randomized complete block design with four replications was used. The results revealed that number of tillers per plant (NTPP), plant height (PH) and leaf to stem ratio (LSR), plot cover and vigor score percentage, dry matter yield (DMY) tha^{-1}, and the quality parameters such as, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent Lignin (ADL), In-vitro Dry matter Digestibility (IVDMD) and crude protein yield (CPY) tha^{-1} were significantly ($P<0.05$) differed among the different seed proportions of desho grass with legume mixtures. The highest total dry matter yield (11.05 t ha^{-1}) was obtained from the sole desho grass planted with Nitrogen fertilizer followed by sole desho grass planted without fertilizer (10.17 t ha^{-1}) from the mixed cropping groups mixed crop containing 75% desho grass and 25% Stylo gives a higher total dry mater yield (7.44 tha^{-1}). On the other hand desmodium sown in pure stands had lower DMY compared to legume-grass mixtures (3.37tha^{-1}). In terms of quality, increasing the seed proportions of both legume species in the mixture resulted in higher CP%, CPY (tha^{-1}) and IVDMD% and lower NDF%, ADF% and ADL% contents. Relative yield total of desho grass-legume mixtures at $Desho_{75}$ $Stylo_{25}$ (1.43), $Desho_{50}$ Desmodium $_{50}$ (1.39) and $Desho_{25}$ $Stylo_{75}$ (1.33) were better compared to the other mixtures and pure stands. Generally, mixing of desho grass with legume species at different seed proportions of 75% desho grass: 25% stylo and 50% desho grass: 50% Stylo produced better dry matter yield, nutritional quality and compatibility in the study area when compared to the mixed cropped plants. However, the experiment should be conducted for more years at different locations to recommend the best desho grass legume mixtures for Assosa area of Benishangul-Gumuz Regional State. It is also suggested to do on animal performance trial of this result based on animal feeding practice and economic feasibility in order to come up with sound recommendations.

Keywords

Compatibility, Crude Protein, Digestibility, Dry Matter, Seed Proportion

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1. Introduction

Ethiopia has the largest livestock population in Africa, with an estimated population of 65 million cattle, 40 million sheep, 51 million goats, 8 million camels and 49 million chickens [1]. Despite its large livestock population, the production and productivity is very low and is limited to contribute to the national economy only about 20 % to the total GDP [2] which is very low as compared to its potential due to inadequate supply and low quality of available feeds [3]. According to the study [1], green pasture (55.2%) and crop residues (30.8%) are the main feed types available in the country which have been affecting by the different agro-ecologies, the type and accessibility of crop-produced and production-system [4, 5].

To combat these nutritional constraints, the use of locally available forage species which are adaptable to the local agro-ecological conditions and used as feed resources are globally as well as locally recommended as they are familiar with the smallholder farmers grown with low inputs [6]. Among locally available multipurpose and potential feed resource in the country, Desho grass (*Pennisetum glucifolium*) is the most appropriate one [7]. It has the potential to meet the challenges of feed scarcity as it not only provides more forage per unit area, but also ensures regular forage supply due to its perennial nature. The grass has the ability to recover after water stress even under severe drought conditions [8]. Desho is a perennial grass and is palatable to cattle, sheep and other herbivores [9].

The major feed resources are characterized by poor quality and improved forages can be limited in quantity in most parts of the country [10]. According to the reports of [11], animal feed resources in most part of the country is mainly based on natural pasture grazing and crop residues, which are low in quantity. Forage management tool such as using grass-legume mixture can achieve optimization of productivity of forages [12]. Therefore, one of the alternatives to improve livestock feeding, and thereby their productivity could be the cultivation of grass-legume mixtures and offer them to animals during critical periods in their production cycle and at times when other sources of feeds are in short supply [13].

Like other tropical grasses, desho grass is considered to be high in structural cell wall carbohydrates that increase rapidly with advance in maturity, whereas the contrary is true with its crude protein (CP) content and digestibility [14]. This implies the need for production strategies that can help improve the CP concentration and digestibility of desho grass. One such approach is to establish it in association with legume species to make use of the yield advantage of desho grass and the high CP content and digestibility of legume species. Moreover, optimization of productivity and nutritive value of grass /legume associations can be achieved by forage management tools such as altering the days at cutting [15].

To this effect, the use of tropical legumes like Desmodium (*Desmodium unicinatum*) or stylo (*Stylosanthes guinansis*) which are perennial or short term perennial species in association with productive, but high cell wall fiber containing grass species such as desho grass could be an advantage in improved supply of nutrients to livestock. For this reason, the evaluation of the potential yield and nutrient composition of the desho grass and in mixture with Stylo and Desmodium legumes at different at different seed proportion in Assosa zone of North western Ethiopia is of paramount importance. However, there is limited information on the agronomic practices, biomass production, and feeding value of Perennial grass species like desho grass when grown alone or in mixture with legumes like stylo and Desmodium. Therefore, this study is proposed with the objective to determine the agronomic parameters, yield, chemical composition and In vitro dry matter digestibility of desho grass mixed with Stylo and Desmodium.

2. Materials and Methods

2.1. Description of the Study Area

Experiments were conducted under rain-fed conditions during the main cropping season for two consecutive years (2019 and 2020) in the forage experiment field of Assosa Agricultural Research Center located in Benishangul Gumuz Region in north-western Ethiopia. Assosa is located at 100 02' 47''N latitude and 340 34'27'' E longitude with an altitude of 1560 meters above sea level. The soil texture of the experimental site is clay loam and strongly acidic with pH value of 5.04. The climate is hot to warm moist lowland plain with uni-modal rainfall distribution. The rainy season starts at the end of April and lasts at the end of October, with maximum rainfall from June to October. The mean maximum and minimum temperatures of the district during the season of the experiment were 27.6 and 15.3 ℃, respectively; the total annual rainfall was 1,436 mm.

2.2. Soil Sampling and Analysis

Soil samples were collected with the aid of soil-auger before sowing. Twenty samples were taken from fifteen sampling spots in total, five from each block of experimental field with X-pattern of sampling within the depth of 0-20 cm. They were then bulked together to get a representative composite soil sample. Then, the composite soil samples were placed in sealed labeled bags and transferred to the Holetta Agricultural Research Center soil laboratory for analysis of the selected parameters. The determined parameters were soil textural class (sand, silt and clay), soil pH, total nitrogen (N), organic carbon(OC), organic matter (OM), available phosphorous (P), cation exchangeable capacity (CEC) and exchangeable base (Ca, Mg, Na and K).

Soil pH was determined from 1:2.5 soils to deionized (distilled water) ratio suspension [16], and soil pH was recorded

using a glass electrode attached to a digital pH meter (potentiometer) after a thorough stirring. Total organic carbon content was measured by Walkley and wet oxidation method as described by [17]. Total N was determined by Kjeldahl method as described by [18]. Organic matter was calculated by multiplying the percent organic carbon by 1.724 assuming that organic matter is composed of 58 % carbon [19]. Extractable phosphorous was determined by following Olsen's sodium bicarbonate extraction method [20]. Potassium was determined after extracting the sample using the ammonium acetate extractable method and analyzed by a flame photometer [21]. Soil texture analysis was performed by Bouyoucous hydrometer method [22].

2.3. Experimental Materials

Planting materials, desho grass (Kulumsa DZF#592) and legume species (*Silverleaf Desmodium* and *Stylosanthes guyanensis*) were collected from Debrezeyit Agricultural Research Center nursery site and International Livestock Research Institute gene bank respectively.

2.4. Treatments and Experimental Design

Treatment included two perennial legume species, Stylosanthes guyanensis (Verona stylo) and Desmodium unicinatum (silver leaf desmodium) and three seeding ratios (25%:75%, 50%:50% and 75%:25% desho: Stylo and Desho: desmodium) in a four-replicate randomized complete block (RCBD) design. A root splits of desho grass was planted with 20 cm between plants and 50 cm between plant rows. Based on this 120 planting material is considers as 100 percent pure stand desho grass which is planted on 3 x 4 plot size. The legumes, Stylosanthes guyanensis (Verona stylo) and *Desmodium uncinatum* (Jacq.) DC (silver leaf desmodium) were sown based on their respective seed rates of 2.5 kg ha 5 kg per hectare respectively (23 and 24). The experiment consisted of four replications; each contains 10 experimental units resulting in 40 plots. The spacing between the plots and the replicates was 1 m and 1.5 m, respectively, and the plots in each replicate were randomly assigned to the ten treatments using the SAS software randomization method. Weeding was done by hand to eliminate the regrowth of unwanted plants.

2.5. Land Preparation and Planting

The land was plowed and fined with tractors and finally leveled by day laborers to fine the soil. Fine seedbed plots were prepared before the experimental plots were laid out. Weeding was performed by hand to eliminate the regrowth of unwanted plants and to encourage desho grass and legumes growth by increasing soil aeration. The plots were kept weed-free during the growing season. Land plowing and seed bed preparation were made in May 2019. After preparing a fine bed, planting, was done in June, 2019, the planting materials desho grass variety was root splits whereas; the planting material for legume specie was seed.

2.6. Data Collection, Sampling and Measurements

The establishment year (2019) and production years (2020-2021) of this study were involved to collect all agronomic and morphological characteristics of Desho grass.

2.6.1. Plant Height

A continuous follow up was done to measure the plant height. A steel tape was used to measure plant height at the time of harvesting. Four rows were randomly selected from a total of six rows within each plot to measure plant height, excluding the two border rows on each side, and then five tillers were randomly selected for plant height measurement and then the average height was taken.

2.6.2. Number of Tillers Per Plant

The number of tillers was counted and recorded on the same tagged plants. After transplanting from the net plot area, the number of tillers per plant was counted from a randomly selected five plants in the middle row of each plot at each cutting height, and the mean was obtained.

2.6.3. Number of Leaves Per Plant

On an experimental plot area, the number of leaves per tiller was counted in 10 randomly selected tillers at each cutting height of harvesting. By multiplying the number of leaves per tiller by the number of tillers per plant, the total number of leaves per plant was obtained. Five randomly selected plants per plot of each row were measured for internode length.

2.6.4. Leaf-to-Stem Ratio

LSR was determined by cutting plants from randomly selected middle succeeding rows. The plants were taken from the plot's central sections. After carefully mixing the net harvested plant, samples obtained from each plot at each harvesting cutting height were precisely measured, and fresh leaves and stems of each harvested sample were separated and weighed. Stems and leaves were obtained after the measurements for DM Analysis. The (LSR) was computed after oven-dried (65oC for 72 hours) each leaf and stem sample by dividing leaf dry weight by stem dry weight.

2.6.5. Dry Matter Yield

Desho grass was cut at 8cm from the ground level to determine biomass yield from the rows adjacent to the guard rows. A sensitive balance was used to assess fresh biomass, and then subsamples of roughly 500 g of fresh plants were obtained from the net harvested plant sample. Finally, to acquire dry weights, these subsamples were oven-dried. The leaf and stem dry weights are calculated by dividing the leaf and

stem fresh weights by 100 to calculate the DM percent for each sample. Based on this, total dry matter yields for each plot were calculated using DM percent and fresh biomass yield from the sample area of each plot and then converted to metric tons per hectare. After drying the samples in a forced drying oven set at 65 ℃ for 72 hours, the dry matter yield was determined as follows:

DMY (t/ha) = (10 x TFW x SSDW) / (HA x SSFW) (James et al., 2008).

Where:

10 = constant for conversion of yields in (kg/m^2) to (t/ha)

TFW=total fresh weight (kg) SSDW-sub-sample dry weight (g)

HA= harvest area (m^2)

SSFW =sub-sample fresh weight (g)

2.7. Biological Compatibility

DM yield of Desho grass grown in mixtures with legume species in replacement series (75%+25%, 50%+50, 25%+75%) were compared with their respective monocultures, [23].

2.7.1. Relative Yield

The relative yields (RY) of the components in the mixtures were calculated using the equations of [25] as:

$$RYG = DMYGL/DMYGG$$

$$RYL = DMYLG/DMYLL$$

Where;

DMYGG is the dry matter yield of any perennial grass 'G' as a monoculture;

DMYLL is the dry matter yield of any perennial legume 'L' as a monoculture;

DMYGL is the dry matter yield of any perennial grass component 'G' grown in mixture with any perennial legume 'L'; and

DMYLG is the dry matter yield of any perennial legume component 'L' grown in mixture with any annual grass 'G'.

2.7.2. Relative Yield Total

Relative total yield (RTY) was calculated according to the formula of [25]:

$$RTYGL = (DMYGL/DMYGG) + (DMYLG/DMYLL)$$

Where;

DMYGG is the DMY of perennial grass as a monoculture,

DMYLL is the DMY of perennial legume as a monoculture,

DMYGL is the DMY of perennial grass component grown in mixture with perennial legume, and

DMYLG is the DMY of perennial legume component grown in mixture with perennial grass. It shows that If RTYGL > 1, there is yield advantage of mixtures compared to the pure stand.

2.7.3. Relative Crowding Coefficient

This parameter was calculated to determine the competitive ability of the annual grass and legume in the mixture by measuring the component that has produced more or less DM than expected in a 50:50 grass legume mixture [25]:

The formula for the 50:50 grass - legume mixture is:

$$RCCGL=DMYGL / (DMYGG - DMYGL)$$

$$RCCLG =DMYLG / (DMYLL - DMYLG)$$

The formula for mixtures differing from 50:50 proportions was:

$$RCC\ GL= DMYGL\ X\ ZLG / (DMYGG - DMYGL)\ X\ ZGL$$

Where:

RCC= relative crowding coefficient,

ZGL=the sown proportion of grasses in combination with legumes,

ZLG = the sown proportion of legumes in combination with grasses.

2.7.4. Aggressivity Index

The aggressivity index (AI) of perennial grass against the perennial legume mixture was calculated as described by [26] and [27]:

$$AIGL= (DMYGL/DMYGG)-(DMYLG/DMYLL)$$

$$AILG = (DMYLG/DMYLL)-(DMYGL/DMYGL)$$

Where,

AIGL=Aggressivity index of perennial grass component grown in mixture with perennial legume,

AILG=Aggressivity index of perennial legume component grown in mixture with perennial grass,

DMYGL=DMY of perennial grass component grown in mixture with perennial legume,

DMYLG=DMY of perennial legume component grown in mixture with perennial grass.

2.8. Chemical Analysis and Yield Determination

The partially dried forage samples were ground using a cyclone mill to pass through a 1 mm screen for laboratory analysis and in-vitro dry matter digestibility determination. Total ash and CP contents were determined using standard procedures of [28]. Accordingly, ash was determined upon complete burning of the feed samples in a muffle furnace at 500 ℃ for 6 hours. The total N content was determined by

Kjeldahl wet digestion method. Crude protein content was calculated as 6.25 X N assuming that protein contains 16% N. The Neutral Detergent Fiber (NDF), Acid Detergent Lignin (ADL) and Acid Detergent Fiber (ADF) were determined according to the procedures of [29]. Crude protein yield (CPY) was determined as the product of CP contents and herbage DM yields [30]. The CP yield (t/ha) was calculated by multiplying CP% with total dry matter yield.

2.9. In Vitro Dry Matter Digestibility

The two stage [31] method was used to determine IVDMD. Rumen liquor was collected from three fistulated steers and transported to the laboratory using thermos flasks that had been pre-warmed to 390C. Steers were fed natural pasture hay adlibitum and 2 kg concentrate mixture per day. The chemical composition of concentrate mixture was 18 % CP and 10 MJ/kg DM of ME. Rumen liquor was taken in the morning before steers were offered with feed. A duplicate sample of 0.5 g was incubated with 10 ml of rumen liquor and a buffer in 50 ml test tube in incubator at 390C for a period of 48 hour for microbial digestion followed by another 48 hour for enzymatic digestion with acid pepsin solution. Blank samples containing buffered rumen fluid were incubated in duplicates for adjustment.

IVDMD = (Sample weight * % DM) - (Residue weight– blank weight) x 100

Sample weight * % DM

Where: IVDMD = In vitro Dry Matter Digestibility

2.10. Statistical Analysis

The Analysis of variance (ANOVA) procedures of R software was done using general linear model (GLM). For the comparison of means, the least significant difference (LSD) at a 5% significance level was utilized. The model used for the Analysis was:

$$Yij = \mu+Bi+Tj+Yk+Eij$$

Where: Yij=Response of parameters, μ- Overall mean, Bi=ith block effect, Tj- jth treatment effect, Yk =kth year effect, Eij- Random error

3. Results and Discussion

3.1. Agronomic Parameters

The results of effect of mixed cropping of Desho grass with Stylo and Desmodium at different seed proportion on some plant morphological characteristics of Desho grass were presented in Table 1. All of the agronomic parameters in this study were significantly affected by mixed cropping of Stylo and Desmodium with different seed proportion with Desho grass ($p<0.05$).

3.1.1. Plant Height

Plant height of Desho grass was affected ($P<0.05$) by desho grass mixed cropping with Stylo and Desmodium at three different seed proportion Table 1. This is in contrast with the report of [32] that stated different legumes mixed with Desho grass by different ratio had no much variation on plant height. The longest plant height was recorded for desho grass planted with Nitrogen fertilizer followed by desho grass mixed cropped with stylo and desmodium 1:1 and 1:3 seed proportion.

Table 1. *Mean values of establishment performance.*

Proportion	Parameters				
	PH (cm)	NTPP (count)	LSR	Vigor (%)	Plot cover (%)
Stylo	56.00^{c}	31.75^{d}	1.21^{a}	88.35^{a}	94.25^{a}
Desho	64.50^{c}	41.25^{c}	1.23^{a}	77.10^{c}	75.50^{f}
$Desho_{75}$ $Stylo_{25}$	66.75^{b}	44.75^{ab}	1.11^{a}	70.12^{d}	77.10^{ef}
$Desho_{50}$ $Stylo_{50}$	72.00^{ab}	52.75^{a}	1.21^{a}	76.49^{c}	81.40^{d}
$Desho_{25}$ $Stylo_{75}$	75.00^{ab}	51.75^{a}	1.20^{a}	81.06^{bc}	90.00^{b}
Desmodium	65.75^{bc}	48.25^{ab}	0.79^{c}	89.86^{a}	95.80^{a}
$Desho_{75}$ Desmodium $_{25}$	73.75^{ab}	44.75^{bc}	1.65^{b}	74.85^{cd}	79.75^{de}
$Desho_{50}$ Desmodium $_{50}$	74.00^{ab}	48.75^{ab}	1.36^{a}	80.18^{bc}	85.20^{c}
$Desho_{25}$ Desmodium $_{75}$	67.75^{bc}	50.75^{ab}	1.18^{a}	85.75^{ab}	92.00^{ab}
Desho with fertilizer	78.25^{a}	47.00^{abc}	1.32^{ab}	84.61^{ab}	89.45^{b}

Proportion	Parameters				
	PH (cm)	NTPP (count)	LSR	Vigor (%)	Plot cover (%)
LSD	9.18	6.15	0.68	5.93	3.74
Coefficients of variation (%)	9.20	9.24	30.48	5.08	3.01

Means followed by different superscript letters in a column are significantly different each other at p< 0.05, LSD=Least significant difference, Ns = non-significant. *, **, ***, significant at 5%, 1% and <1% respectively; NTPP= Number of tiller per plant; PH= plant height; LSR= Leaf to stem ratio.

3.1.2. Number of Tillers Per Plant

Number of tillers per plant (NTPP) of Desho grass was significantly (p<0.05) affected by mixed cropping of Stylo and Desmodium by three different seed proportions. The desho grass mixed cropped with Stylo at 1:1 proportion had highest (NTPP) as compared to the other treatments. While sole desho grass planted without Fertilizer had lower Number of tiller per plant (NTPP) when compared with other treatment. The result is in line with the finding of [33] who recorded highest mean values of plant height for *Panicum maximum* when intercropped with *Stylosanthes hamata* and Canavalia than for the sole *Panicum maximum*.

3.1.3. Leaf-to-Stem Ratio of Desho

The mixed cropping of desho grass with stylo and desmodium at different seed proportion had a significant (p<0.05) effect on the leaf-to-stem ratio (LSR) of desho grass (Table 1). The highest LSR was recorded from desho+stylo (1:3), desho+desmodium (1:1 and 1:3), seed proportion, while the lowest LSR was recorded from sole desmodium. Reduced LSR is a major cause of the decline in forage quality with maturity, and also the loss in quality that occurs under adverse hay curing conditions [34] indicated that LSR reflected the variation of leaf stem mass with harvest and is a trait that can affect preference during grazing.

3.1.4. Plant Vigor and Plot Cover

Statistical analyses (Table 1) had revealed significant (P < 0.05) variations were observed in the plant vigor and vigour score among the treatments, values for the sole crops stylo showed significantly (P<0.01) higher value for plant vigor and plot cover when compared to mixed crops and sole desho grass with and without N fertilizer application. The lowest values for plant cover and plot cover was observed in desho to stylo 1:3 seed proportion.

3.2. Dry Matter and Crude Protein Yield

3.2.1. Dry Matter Yield

The average total dry matter yields of the pure sowings and mixtures were significantly different (P < 0.01) (Table 2). The highest total dry matter yield (11.05 t ha-1) was obtained from the sole desho grass planted with Nitrogen fertilizer followed by sole desho grass planted without fertilizer (10.17 t ha-1) from the mixed cropping groups mixed crop containing 75% desho grass and 25% Stylo gives a higher total dry mater yield, and the lowest yield (3.32 t ha-1 and 3.37) was obtained from the pure stylo and desmodium sowing (Table 2). The differences between the yield values of the studies might have resulted from the differences in the mixture rates of legumes and desho grass.

3.2.2. Crude Protein Yield

Significant differences were found (p<0.05) in average total crude protein yields (Table 2). Average crude protein yield ranged from 0.45 t ha-1 for pure desmodium to 0.94 t ha-1 desho grass with N fertilizer. From mixed cropped plant desho grass mixed with 3:1 seed proportion yield the 0.75 t ha-1 and exhibit the highest yield when compared mixed cropped of other seed proportions. The high total dry matter yield difference exhibited in this trial could be the main reason for the variation.

Table 2. *Dry matter and crude protein yield for pure stands and mixtures of Desho grass (penisetum glaucifolium) with Stylo and Desmodium in three seeding proportion (Desho grass-legumes 75:25, 50:50 and 25:75). Means are averaged over two growing seasons (2019/2020).*

Proportion	TDMY	TCPY
	Yield (ton ha^{-1})	
Stylo	3.20^{f}	0.64^{cde}
Desho	10.17^{b}	0.75^{bc}

Proportion	TDMY	TCPY
	Yield (ton ha^{-1})	
Desho$_{75}$ Stylo$_{25}$	9.27^{c}	0.86^{ab}
Desho$_{50}$ Stylo$_{50}$	7.14^{d}	0.76^{bc}
Desho$_{25}$ Stylo$_{75}$	5.73^{e}	0.57^{def}
Desmodium	3.37^{f}	0.45^{f}
Desho$_{75}$ Desmodium $_{25}$	7.44^{d}	0.67^{cd}
Desho$_{50}$ Desmodium $_{50}$	6.20^{e}	0.65^{cde}
Desho$_{25}$ Desmodium $_{75}$	5.95^{e}	0.52^{ef}
Desho with fertilizer	11.05^{a}	0.94^{a}
LSD	0.88	0.14
Coefficients of variation (%)	8.72	14.00

Means followed by different superscript letters in a column are significantly different each other at p< 0.05, LSD=Least significant difference, Ns = non-significant. *, **, ***, significant at 5%, 1% and <1% respectively.

3.3. Biological Competition and Yield Advantages of Desho Grass-Legumes Mixtures

3.3.1. Land Equivalent Ratio (LER)

The values of land equivalent ratio (LER) in different mixed cropping systems were found to be greater than unity indicating higher land use efficiency of mixed cropping systems over the respective monoculture (Table 3). Yield advantages occurred in mixed cropping was mainly due to the development of both temporal and spatial complementarities. However, the total LER value (1.43) was highest in desho (75 %) + stylo (25%), where desho grass and stylo achieved 73 and 71 % of their sole yields, respectively indicating higher biological and economic efficiency.

3.3.2. Relative Crowding Coefficient (RCC)

Relative crowding coefficient (RCC) of desho grass and legumes was more than unity indicating greater non-competitive interference than the competitive one. The mixed cropped legumes at different seed proportion had higher relative crowding coefficient values than the mixed cropped desho grass. In this study, 50% desho grass + 50% desmodium had the maximum RCC value (4.03) and after that 50% desho grass + 50% stylo and 75% desho + 25% stylo with 3.03 and 1.19, respectively.

3.3.3. Aggressivity (A)

The competitive ability of the component crops in a mixed cropping system is determined by its aggressivity value. Higher aggressivity value (1.29) was calculated with desho grass (75%) + Stylo (25%) (Table 4). Results showed positive aggressivity for desho grass at (75%) + desmodium (25%) while it proved less competitive and was dominated by legumes at desho grass (50 %) + stylo (50%), desho grass (50%) + desmodium (50%), desho grass (25%) + desmodium (75%) and desho grass (25%) + stylo (75%).

Table 3. *Relative yield and relative crowding coefficient for pure stands and mixtures of Desho grass (penisetum glaucifolium) with Stylo and Desmodium in three seeding proportion (Desho grass-legumes 75:25, 50:50 and 25:75). Means are averaged over two growing seasons 2019/2020).*

Proportion	Relative yield[1]			Relative crowding coefficient[2]		
	RY $_{Desho}$	RY $_{Legume}$	RY $_{Total}$	*K* $_{Desho}$	*K* $_{Legumes}$	K $_{Totals}$
Desho$_{75}$ Stylo$_{25}$	0.73	0.70	1.43	0.26	4.58	1.19
Desho$_{50}$ Stylo$_{50}$	0.49	0.64	1.13	1.03	2.94	3.03

Proportion	Relative yield[1]			Relative crowding coefficient[2]		
	RY Desho	**RY Legume**	**RY Total**	***K* Desho**	***K* Legumes**	**K Totals**
$Desho_{25}$ $Stylo_{75}$	0.71	0.62	1.33	1.02	0.87	0.89
$Desho_{75}$ Desmodium $_{25}$	0.58	0.64	1.22	0.27	3.93	1.06
$Desho_{50}$ Desmodium $_{50}$	0.76	0.63	1.39	0.71	5.68	4.03
$Desho_{25}$ Desmodium $_{75}$	0.58	0.64	1.22	1.23	1.08	1.32

[1]Relative yield = Yield when grown in a mixture relative to yield as pure stand.
[2]Relative crowding coefficient = Yield when grown in a mixture as a proportion of (yield in pure stand less yield in mixture).

Table 4. *Aggressivity, competitive ratio for pure stands and mixtures of Desho grass (penisetum glaucifolium) with Stylo and Desmodium in three seeding proportion (Desho grass-legumes 75:25, 50:50 and 25:75). Means are averaged over two growing seasons (2019/2020).*

Proportion	Aggressivity[1]		Competitive ratio		
	***A* Desho**	**A Legume**	***CR* Desho**	***CR* Legumes**	***difference***
$Desho_{75}$ $Stylo_{25}$	1.29	-1.29	1.11	0.92	0.08
$Desho_{50}$ $Stylo_{50}$	-0.28	0.28	0.82	1.29	0.47
$Desho_{25}$ $Stylo_{75}$	-0.90	0.90	1.51	0.69	0.92
$Desho_{75}$ Desmodium $_{25}$	0.56	-0.56	0.73	1.40	0.67
$Desho_{50}$ Desmodium $_{50}$	-0.45	0.45	1.72	0.65	1.07
$Desho_{25}$ Desmodium $_{75}$	-1.34	1.34	0.92	1.22	0.30

[1]Aggressivity index = (Actual yield of component/Expected yield of component) – (Actual yield of other component/Expected yield of other component)

3.3.4. Competitive Ratio (CR)

The competitive ratio values showed variation among the mixed cropping indicating differential competitive ability of component crop as influenced by mixed crops legumes (Table 4). Desho grass showed higher value of CR (0.73-1.72) than legumes (0.65-1.40) indicating desho grass as the best competitor than intercropped legumes. Consequently, desho grass (50%) + desmodium (50%) mixed cropping system with higher difference of CR (1.07) exhibited dissimilarities in competitiveness between the component forage crops. However, desho grass (25%) + desmodium (75%) mixed cropping system with lower difference of CR (0.30) showed merely similar competitiveness between the component forage crops. The results expressed that similar competitiveness with minimum CR between component crops provided complementary utilization of growth resources for better performance of mixed cropping with higher productivity.

3.4. Chemical Composition and in Vitro Dry Matter Digestibility of Mixed and Pure Stands of Desho Grass and Legumes

3.4.1. Chemical Composition

Analysis of variance showed that there was a significant ($P<0.05$) effect of mixed cropping of desho grass with stylo and Desmodium at the different seed proportion on Ash, crude protein (CP) and neutral detergent fiber (NDF) Acid detergent fiber (ADF) Acid detergent lignin and Invitro Dry matter digestibility (IVDMD) (Table 5).

The ash content is the concentration of minerals in the forages. Forage with higher ash content indicates a high concentration of minerals. The ash content was highest ($P<0.05$) for Desho grass mixed cropped with Stylo (Desho50 Stylo50) and was least for desho grass planted as a sole crops (Desho 100%). The concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime [35, 36]. According to the study [32] observed that sole Sudan

grass planted without lablab and cowpea showed significant variation ($P < 0.05$) on the ash content of forage.

Significant variation was observed ($P < 0.05$) in the CP content of desho grass mixed cropping with stylo and desmodium of the treatments at different seed proportions. Desho grass mixed cropped with stylo (1:3 and 1:1) proportion had highest in the %CP content followed by desho grass intercropped with desmodium at a seed proportion of 1:3 (Desho25 Desmodium 75) while the sole desho grass planted without fertilizer were the least of all. The difference in %CP content of the studied desho grass might be due to atmospheric nitrogen fixation by the respective legumes mixed cropped. This result is in line with the findings of [12] who reported that Napier grass associations with lablab and desmodium resulted in higher ($P < 0.05$) CP content than sole Napier grass or when harvested forage at ninety days. The CP content of all treatments is above the minimum level of 7% required for optimum rumen function [14]. The main advantages of legume-grass mixtures have been increased CP yield relative to sole grass (Ojo et al., 2013). Legumes supply nitrogen to grass-legume mixtures, so it may produce more forage yield than grasses grown alone and grasses grown in mixed cropping with legumes also contain a higher percentage of protein. According to the study [37] concluded that crude protein of plants in intercropping system was increased when compared with those for mono-cropping maize.

The neutral detergent fiber (NDF) content of a feed is important for determining within the parameter of digestibility. Roughage diets with NDF content of 45-75% and below 45% were generally considered as medium and high quality feeds respectively [38]. Accordingly, the current results in NDF content lies in medium range signifying the good nutritional value of the forages of the current study. According to [39] reducing the contents of in NDF content has been associated with increasing digestibility and hence improve feed intake. The lower NDF content in desho grass/legume associations as compared to desho grass sole indicated improvement in nutritive value, since decrease in NDF content has been associated with increase in digestibility and hence feed intake [14]. Legumes benefited desho grass by fixing atmospheric nitrogen and therefore improving the CP content and reducing the fibers content of forages [40].

Table 5. *Chemical composition of Desho grass grown in mixtures with Desmodium uncinatum and Stylosanthes guyanensis in different seed proportion.*

Proportion	Chemical composition (% DM basis)					
	Ash	CP	NDF	ADF	ADL	IVDMD
Stylo	10.48^{a}	19.91^{a}	50.47^{e}	36.42^{f}	7.70^{b}	58.20^{a}
Desho	9.16^{cd}	7.14^{f}	71.86^{a}	41.79^{ab}	5.99^{f}	53.99^{b}
$Desho_{75}$ $Stylo_{25}$	9.90^{abc}	9.44^{de}	67.9^{b}	40.03^{cd}	6.06^{ef}	56.08^{ab}
$Desho_{50}$ $Stylo_{50}$	10.05^{ab}	10.65^{c}	65.20^{c}	38.59^{e}	6.35^{ef}	58.37^{a}
$Desho_{25}$ $Stylo_{75}$	9.94^{abc}	9.96^{c}	63.76^{c}	38.60^{e}	6.38^{ef}	58.35^{a}
Desmodium	8.79^{d}	13.17^{b}	53.46^{d}	35.28^{f}	8.88^{a}	54.36^{a}
$Desho_{75}$ Desmodium $_{25}$	9.44^{bcd}	8.99^{de}	63.76^{c}	38.60^{e}	6.54^{de}	52.96^{ab}
$Desho_{50}$ Desmodium $_{50}$	9.51^{bcd}	9.52^{c}	65.20^{c}	39.50^{de}	6.90^{cd}	58.37^{a}
$Desho_{25}$ Desmodium $_{75}$	9.70^{abc}	8.81^{de}	62.63^{c}	39.33^{de}	7.19^{c}	55.53^{ab}
Desho with fertilizer	9.48^{bcd}	8.50^{ef}	71.79^{a}	42.27^{a}	6.51^{de}	53.84^{b}
LSD	0.85	1.38	2.6	1.26	0.43	2.86
Coefficients of variation (%)	6.00	8.91	2.88	2.22	4.36	3.55

Means followed by different superscript letters in a column are significantly different each other at $p< 0.05$, LSD=Least significant difference; Ns = non-significant. *, **, ***, significant at 5%, 1% and <1% respectively; CP= crude protein, NDF=Neutral detergent fiber, ADF= Acid detergent fiber; ADL= Acid detergent lignin; IVDMD= Invitro dry matter digestibility.

Mixed cropping desho grass with stylo and desmodium at different seed proportions have a significant impact ($P<0.05$) on %NDF contents of the desho grass. The least %NDF contents was recorded from desho grass mixed copping with stylo and desmodium compared to sole desho grass planted with and without Nitrogen fertilizer. Among desho grass planted sole and mixed cropped with legumes at different seed proportions the highest value was recorded from desho

grass planted sole at with Nitrogen fertilizer application (71.86 and) followed by desho grass planted sole without fertilizer (71.79 %) while the rest treatments are statistically similar.

This current result agreed with [41] who noted that mixed cropping of desho grass with legumes has significant effect on NDF contents of the forage. According to the study. As per the research [12] noted that intercropping Napier grass with legumes has an advantage in reducing NDF content of forage. However the current result was disagreed with the finding of [42] who noted that. Generally, the mean values of NDF (63.95%) obtained in the present study was lower than the mean NDF values of reported by [32] around 70.36%. The variability in %NDF content might be attributed to varietal difference of the legumes mixed with the grass at two studies.

Acid detergent Lignin concentration were higher ($p< 0.05$) in the sole legumes (stylo and desmodium and lower in sole desho grass. Acid detergent fiber were significantly higher ($p<0.05$) in Desho planted with Nitrogen fertilizer and without fertilizer. The minimum ADF contents were observed from Sole stylo and desmodium.

3.4.2. In Vitro Dry Matter Digestibility

Desho grass at different seed proportions mixed cropped with Stylo and desmodium had significant effect ($P<0.05$) on the in vitro dry matter digestibility (IVDMD) (Table 5). Desho grass mixed cropped with stylo seed proportion of (Desho50 Stylo50 and Desho25 Stylo75) and Desmodium at seed proportion of (Desho50 Desmodium 50), has highest IVDMD with the mean result of (58.37 and 57.35%) and (57.37%) value respectively while other mean comparison were not significant ($P>0.05$). On the other hand, sole Desho grass planted at seed proportion of 100 % desho grass with and without Nitrogen fertilizer has the lowest value of the IVDMD and generally IVDMD increased with increasing seed proportion of legumes with desho grasses.

4. Conclusion and Recommendation

Mixed cropping of desho grass with stylo and desmodium at different seed proportion has significant effect ($P<0.05$) on Plant height, number of tiller per plant (NTPP), leaf to stem ratio, Vigor score and plot cover. Desho grass mixed cropping with legumes at different seed proportions resulted to higher dry matter yield (DMY), total dry matter yield (TDMY) and total crude protein yield (TCPY). Significant variation was observed among sole and mixed cropped desho grass with Stylo and Desmodium at different seed proportion on the on Ash, crude protein (CP), neutral detergent fiber (NDF), Acid detergent fiber and Acid detergent Lignin. Mixed copping of legumes increased the in vitro dry matter digestibility (IVDMD) of Desho grass than sole cropping system.

From the present study, legumes improved the overall total herbage yield and nutritive value of fodder grasses than sole one. Accordingly, desho grass mixed cropped with stylo and desmodium at a seed proportion of 50% desho grass with 50% legumes could be a better choice based on forage quantity and quality. Therefore to strengthen this research it is advisable to do on animal performance trial based on animal feeding practice and it is economic feasibility and as well as the next stage of re-harvesting desho grass with possible way of mixed cropping legumes once the desho grass established in order to come up with sound recommendations.

Abbreviations

A. O. A. C	Association of Official Analytical Chemists
CSA	Central Statistics Authority
FAO	Food and Agriculture Organization
GDP	Growth Domestic Products
GTP	Growth and Transformation Plan
MoFED	Ministry of Finance and Economic Development

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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