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On-Station Evaluation of Biomass Yield and Nutritive Value of Perennial Grasses Intercropped with Multipurpose Tree Forage

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Abstract: The experiment was conducted at Adami Tulu Agricultural Research Center with the objectives to determine the effect of integration of grasses and legumes on the growth, total forage biomass yield, nutritive quality and identify compatible forage varieties in their integrations with rain fall and supplementary irrigation at dry season. Factorial combination of three forage grasses (Panicum maximum, Chloris gayana and Cenchrus ciliaris) and two multipurpose tree forages (Cajanus cajan and Leucaena leucocephala) were arranged in Randomized Complete Block Design with three replications. Plant heights for both forage showed significance (p<0.001) difference between treatments and cuttings. From Multipurpose tree forages (MPTFs) and grass the maximum plant height was recorded from Leucaena sole and Chloris gayana integrated with cajanus cajan 186.14 and 124.50cm, respectively. Among MPTFs the highest forage biomass yield was obtained from cajanus cajan integrated with Rhodes grass (7.39 t/ha) treatment and combined result also obtained from integration of Rhodes grass and cajanus cajan (29.20 t/ha). The highest LER was obtained from the integration of Rhodes grass and cajanus cajun (2.05). Ash and organic matter contents showed significance (P< 0.05) difference except CP contents of grasses united with MPFLs. Chloris gayana integration with Cajanus cajan recommended for the study areas and similar agro-ecologies due to its good in total forage biomass yield and other agronomic performance among the tested forage components.

Keywords: Biomass Yield, Multipurpose Tree Forage, Nutritive Quality and Perennial Grass

1. Introduction

The major problem facing livestock production in the study area is insufficient quality pasture due to seasonal fluctuation and expansion of cropping land [5]. The main feed resources for livestock are natural pasture, crop residues and crop aftermath, which are low in quantity and quality for sustainable animal production throughout the year [15]. In order to solve the shortage of feed and improve livestock productivity, it is necessary to produce and cultivate high-quality forages with high yielding ability.

Among the improved and the adaptable forage grass in the study area, *Panicum maximum, Chloris gayana and Cencheris ciliaris* grasses could play an important role in providing high biomass yield with high quality when associated with legume forage. Forage grass mainly grows in pure stands; it can be cultivated in association with multipurpose tree forage legumes. Such associations have higher nutritional value than alone and can produce higher dry matter yields [13, 3]. *Panicum maximum + Cajanus cajan* combinations produce 19 t/ha and pure *Panicum maximum* stands produce for 9.8 t/ha dry matter [2]. Their association increases forage productivity and quality in terms of crude protein content 11.22% and pure stand produce 7.11% [2]. Legumes improve the nutritive value of lower quality native pastures grown with them and are important components of farming system since they have high nutritive value and able to rehabilitate nutrient depleted from the soil. Multipurpose Tree Forages (MPTFs) provided high quality fodder in the dry season [2]. This has produced interest in their use in pastures leading to the development of tree based forage production systems such as alley farming system.

MPTFs are pruned and subsequently managed through periodic pruning of the re-growth so that inter planted grasses get enough light. Legume-grass mixtures have reduced weed encroachment and erosion and have led to greater stand longevity than legume or grass monoculture farming [17]. Usage of commercial concentrates as livestock supplements are limited due to inability of farmers to purchase those [15]. A farmer who buys concentrates can reduce costs by combining grass forage with forage legumes. Grass forage is low in crude protein though high in carbohydrates, there is a need for integrating it with forage legumes which rich in crude protein [21].

Forage used for the trial were perennial types which were suitable for the farmers for increasing availability with quality for livestock feed in the study area throughout the year and also forage legumes were multipurpose type (used for construction, fuel, animal feed, improve soil fertility, fence and bee forage). After the end of this research, the farmer can be easily utilized this technology to livestock by planting on board line, road side, backyard and margin land. As a result, this experiment was design with the intention to control soil erosion and increase green feed availability throughout the year in study areas. Therefore, the objectives of this study are to determine the effect of integration and cutting frequencies of grasses-legumes on the growth, total forage biomass yield and nutritive quality and to identify compatible forage varieties in their integrations.

2. Materials and Methods

2.1. Description of Study Areas

The study was conducted at Adami Tulu Agricultural Research Center (ATARC) from 2019 to 2021. ATARC is located at 174 km from the capital city of Ethiopia, Addis Ababa. The altitude of ATARC ranges 1650 meters above sea level and has semi-arid type of climate. The mid rift valley has erratic, unreliable and low rainfall, averaging between 500 and 900 mm per annum. The rain fall is bi-modal with the long rain June to September.

2.2. Experimental Materials

Forage grasses used for the trail were Guinea grass (*Panicum maximum (*Degun geziya*)*); Rhodes grass (*Chloris gayana (*Massaba*)*) and Buffel grass (*Cenchrus ciliaris* and MPTFs were Pigeon pea (*Cajanus cajan* (DZ16527) and Leucaena (*Leucaena leucocephala*).

2.3. Treatments and Experimental Design

The trial was designed with factorial arrangement in randomized complete block design with eleven treatments in three replications and their treatments were grasses sole, MPTFs sole and their combination. Size of plot, distance between each block, plot and plants (grass) row spacing were 3 m*4 m, 1m, 50 cm and 20 cm; respectively. Forage legumes were sown at row spacing of 1m keeping 40 centimeters distance from grass and grass forages at spacing 20 cm from grass to grass. The recommended ratio between grass and legume in a plot were 2:1 (2 row grass: 1 rows legume) [12].

Table 1. *Lists of treatments.*

SN	Treatments
1	*Panicum. maxim + Leucaena leucocephala*
2	*Chloris gayana + Cajanus cajan*
3	*Cenchrus ciliaris* sole
4	*Panicum maximum+Cajanus cajan*
5	*Chloris gayana* sole
6	*Cajanus cajan* sole
7	*Chloris gayana+ Leucaena leucocephala*
8	*Leucaena leucocephala* sole
9	*Cenchrus ciliaris + Leucaena leucocephala*
10	*Panicum maximum* sole
11	*Cenchrus ciliaris + Cajanus cajan*

Experimental Procedures

The sole seeding rate of MPTFs and grasses were 4 and 10 kg per hectare, respectively. While seeding rates for the mixed forages was half of pure stands, because of the area was taken up by both forages. The study was conducted under rain fed at the beginning of rainy season in the study area and supplementary irrigation was provided at dry season two times in a week. Germination test was done for both seed before sowing in order to determine the quality of seed for improving the lower seed germination conditions.

2.4. Collected Data

Coverage (%), Plant height (both forages), length of branch and number of branch grown per plant for MPTFs, Date of 50% and 30-40% flowering of grass and MPTFs, respectively, Biomass yield and Frequency of cuttings/harvesting.

Land equivalent ratio (LER) is the most commonly used to indicate the biological efficiency and yield per unit area of land as compared to mono-cropping system. When LER is greater than 1, mixing improved the productivity of the mixed species. In contrast; when LER is lower than 1, mixing was negatively affects the growth and yield performance of plants [11, 18]. LER was calculated as

$$\text{LER} = \frac{\text{Yield of MPTS in mixture}}{\text{Yield of MPTS alone}} + \frac{\text{Yield of grass in mixture}}{\text{Yield of grass alone}}$$

2.5. Forage Sampling Procedures

Forage samples were taken at 50% and 30-40% flowering forage grasses and MPTFs legumes, respectively by taking from the two middle of row per plot and the average plant height was measured from five plants from the ground to the tip of the main stem and length of branch was measured from the main stems of MPTFs. Number of branch grown per plants were also counted from the main stem and twigs with the diameter $\leq$ 6 mm were considered as edible parts for MPTFs total forage biomass yield determination. On the other hand, in order to measure, grass dry matter yield at 50% flowering, the two middle of row per plot was harvested by using hand suckles and fresh sample was measured in field by spring weight balance and 250 g subsample per plot was brought to ATARC animal feed laboratory and chopped in to pieces for further chemical analysis.

2.6. Forage Biomass Yields Determination

The representative subsample was allotted in to oven dried at 105°C for overnight for total dry matter determination (DM). Accordingly, DM yield (t/ha) estimation was calculated by using recommended formula [23]. The final DM yields were reported in tons per hectare and calculated as 10 x TotFW x (DWss /HA x FWss) Where, TotFW = Total fresh weight, DWss = Oven dried subsample, FWss = Fresh weight subsamples and HA = Harvesting area.

2.7. Chemical Analyses

The dried subsamples were ground to pass through a 1mm sieve for chemical analyses. CP was calculated as N × 6.25 (Kjeldahl methods) and NDF and ADF determined [25]. Hemicelluloses and cellulose were calculated as NDF minus ADF, and ADF minus acid detergent lignin (ADL), respectively ATARC.

2.8. Data Analysis

The data collected on DM yield, plant and branch height, number of branches, number of tiller per plant, coverage and nutritional quality parameters using the Generalized Linear Model of SAS 9.1 [22]. Where a significant effect of treatments was found, a Tukey HSD test was employed to separate means at P ≤.05. Proportional data were arcsine transformed to meet the assumptions of normality and homogeneity of variance. The following model was used for the analysis.

$$Y\text{ijk}=\mu+Ai+B\text{j}+A\times B\text{ij}+E\text{ijk}$$

Where Yijk is the measured response, μ is the overall mean; Ai is the fixed effect of treatment, Bj is the fixed effect of cut, A × Bij is the interaction effect of treatment and cut, and Eijk is the error term.

3. Results and Discussion

3.1. Agronomic Parameters and Herbage Yield Performances

Associations performance of MPTFs legumes and grasses tested for determination of agronomic qualities and compatibility at on station were presented in (Table 1). The interaction effect of treatments and cuttings shows significance variation among the collected parameters. Plant heights for both forage showed significant (p<0.001) difference between the treatments and cuttings. Among the MPFLs legumes; the highest mean values of plant height was recorded from *L. leucocephala* sole (186.14 cm) followed by *L. leucocephala* associated with *Panicum maximum* (183.72 cm) and *Cenchrus ciliaris* (175.58 cm) and *Cajanus cajan* sole (171.78 cm). The current result was lower than the finding [24] (193.4 cm) which conducted at Fedis Agricultural Research Center on *Cajanus cajan*. This difference might be due to soil moisture and rainfall availability of the study area. The shortest plant height was obtained from *Cajanus cajan* intercropped with *Chloris gayana* (122.92 cm).

From the tested grass varieties the maximum plant height was recorded from *Chloris gayana* integrated with *Cajanus cajan* (124.50 cm) followed by Rhode sole and *Panicum maximum* sole (121.71 cm and 118.75 cm) treatments, respectively, while minimum plant height was obtained from *Chloris gayana* combined with *L. leucocephala* (79.72 cm). The current finding was similar with the report [10] (103.2 cm) who had conducted on *Chloris gayana* mixed with alfalfa at on station and Shashemene. The current study result indicated that, as cutting frequencies of both forage increases plant heights also increased. This was happened due to advance development of stem and leaf which can easily utilized soil and surrounding resources. Increasing in leaf length and number stimulate better light capture for photosynthesis, and thus improved yield. This was agrees with the findings [19].

The result of combined analysis indicated that, the branches length recoded from MPFLs shows significance (p<0.0001) variation. The maximum mean value of branch length was recorded from *L. leucocephala* sole (65.37 cm) followed by *Cajanus cajan* sole (60.74 cm) and the combination between *panicum maximum* and *L. leucocephala* (54.23 cm) but the lowest mean value was recorded from *Cajanus cajan* and Rhodes grass (34.99 cm) combination.

The result from forage biomass yield was indicated that a significance variation among the treatments and cuttings frequencies. From MPTFs the highest forage biomass yield was obtained from *Cajanus cajan* integrated with *Chloris gayana* (7.39 t/ha) treatments and also from the combined mean value total forage biomass yield was collected from the them (integration of Rhodes grass and *Cajanus cajan* (29.20 t/ha). The current results confirm the finding [7, 10, 16] reported that grass-legume integration improves forage productivity as compared with h monocultures without any other inputs. The current result is inverse to the work [8] which reported 10 to 17 t/ha for pure stand and 1-7 t/ha for integrated forages. This dissimilarity was may be due to harvesting stage, season of harvest, forage combination condition and management practices.

From the result of combined analysis the lowest total forage biomass yields were recorded from both sole MPTFs (*Cajanus cajun* and *L. leucocephala*). *Cajanus cajan* intercropped with *Panicum maximum* produced the lowest biomass yield (3.6 t/ha). Among forage grasses tested in the current research, maximum forage biomass yield was recorded from *Chloris gayana* alone (24.39 t/ha) followed by Rhodes grass integrated with *cajanus cajan* (21.81t/ha). The minimum mean value of forage grass biomass yield was obtained from *Cenchrus ciliaris* intercropped with *L. leucocephala* and *Panicum maximum* with *L. leucocephala*

(15.05 and 15.10 t/ha), respectively.

The highest total forage biomass yield was harvested during the 4th cuttings (26.26 t/ha) followed by 3rd cuttings (23.68 t/ha), while the lowest was collected during 1st cuttings (21.41 t/ha). The average mean of the present finding is higher than the report [2] (19 t/ha). Total forage biomass yield was increased as cutting interval is increasing. This might be due to additional tiller, leaf formation, leaf and branches elongation and stem development. Increasing total forage biomass yield with advancement in age agreed with the author [4] who stated that at advance age, both grass and legume were relatively more established and utilizes more soil resources for optimum growth. Also, Njarui, D. M. G. et al. [20] confirmed that early harvested produce lower yield due to the fact that forages are yet to develop longer roots needed for competing for nutrients and water.

Number of tiller per plant of the tested forage grasses were significantly different ($p<0.001$) between treatments and cuttings. The highest number of tiller per plant was recorded from the integration of *Chloris gayana* and *Cajanus cajan* (73.59). This result was may be due to *Chloris gayana* growth characters which is semi erected/prostrate. This can made to more efficient use of resources such as light when grown together than when grown separately [6]. The lowest mean value was achieved from *Panicum maximum* intercropped with *Cajanus cajan* (29.8). The highest number of tiller per plant was counted from 4th cutting (52.23) and the lowest were from the rest cuttings as indicted in (table 1). Due to cutting interval, additional formation of the tiller may be happened. This result is also similar with the finding [4].

There were significant variations in number of branch grown per plants of MPTFs ($p<0.0001$) between treatments and cuttings. The largest number of branches grown were collected from the integration of *Cajanus cajan* (32.58) intercropped with *Chloris gayana* treatment at 4th cutting (40.71). The lowest mean value was gained from *L. leucocephala* integrated with *Panicum maximum* treatment at cutting 1st. Average mean value of the current work is lower than previous reported value by the research [9](45.83). The 1st cutting was provided the lowest number of branch grown per plants (17.88). Increasing number of branch grown per plants with increasing age at harvesting is supported with the finding [4].

As indicated in the table 1, the integration of MPTFs and forage grasses produced greater than 1.0 value of LER. Integrations of legumes and grasses produced more DM yield as compared to the yield of pure stands of both forages. The highest LER was calculated from the integration of *Chloris gayana* and C*ajanus cajun* (2.05) while the lowest value was from the combination of *panicum maximum* and *Cajanus cajun* (1.27). Reasons of the highest LER for the integration of *Chloris gayana* and *Cajanus Cajun* could be due to the better benefiting of the grasses from the fixed N through the *Cajanus canas*. Other studies also reported that N transfer from the fixed N by legumes to the grasses in the legume-grass integration [14].

Table 2. *The combined mean of agronomic parameters and biomass yield of MPTFs perennial grasses combination.*

Treatments	Plant height (cm)		Branches (MPTF)		Biomass yield (t/ha)		Grasses		LER
	MPTFs	Grasses	BL (cm)	NBP	MPTFs	grasses	NTPP	Cover	
P. maxim + L. leucoce	183.72^{a}	110.20^{b}	54.23^{abc}	24.75^{b}	4.99bc	15.10^{b}	49.30^{c}	78.58^{d}	1.51
C. gayana + C. cajan	122.92^{d}	124.50^{a}	34.99^{d}	32.58^{a}	7.39^{a}	21.81^{a}	73.59^{a}	92.00^{a}	2.05
C. ciliaris sole	-	94.40^{c}	-	-	-	15.28^{b}	57.68^{b}	87.87^{b}	-
P. maximum+C. cajan	146.74^{c}	85.98^{d}	45.00^{cd}	30.92^{a}	3.60^{c}	15.41^{b}	29.80^{e}	75.74^{d}	1.27
C. gayana sole	-	121.71^{a}	-	-	-	24.39^{a}	49.00^{c}	92.83^{a}	-
C. cajan sole	171.78^{ab}	-	60.74^{ab}	33.25^{a}	6.42^{ab}	-	-	-	-
C. gayana+L. leucoce	157.73^{bc}	79.72^{e}	49.65^{c}	25.92^{b}	5.67^{b}	16.31^{b}	42.54^{cd}	87.03^{b}	1.83
L. leucocephala sole	186.14^{a}	-	65.37^{a}	25.33^{b}	6.11^{ab}	-	-	-	-
C. ciliaris+ L. leucoce	175.58^{ab}	84.69d^{e}	53.07b^{c}	26.50^{b}	5.26^{b}	15.05^{b}	37.01^{de}	82.75^{c}	1.85
P. maximum sole	-	118.75^{a}	-	-	-	21.87^{a}	43.65^{cd}	82.83^{c}	-
C. ciliaris + C. cajan	136.42^{cd}	97.15^{c}	47.40^{c}	31.08^{a}	5.39^{b}	15.34^{b}	36.98^{de}	87.92^{b}	1.84
CV	25.78	7.24	29.13	11.81	23.78	25.45	18.99	5.41	
P-value	***	***	***	***	**	**	***	***	
Cuttings									
1	112.65^{b}	95.74^{b}	43.13^{b}	17.88^{d}	5.20	16.21^{b}	43.27^{b}	83.41^{b}	
2	100.34^{b}	101.97^{a}	40.29^{b}	25.38^{c}	5.64	16.80^{b}	43.97^{b}	83.84^{b}	
3	163.93^{a}	105.43^{a}	48.8^{b}	31.21^{b}	5.77	17.91^{ab}	46.98^{b}	86.88^{a}	
4	163.59^{a}	104.46^{a}	73.02^{a}	40.71^{a}	5.81	20.45^{a}	52.23^{a}	87.01^{a}	
LSD (0.05)	**	**	**	**	**	*	*	*	
Significance									
trt	<.0001	<.0001	<.0001	<.0001	0.0060	0.0004	<.0001	<.0001	
cut	<.0001	0.0061	0.0002	0.0041	0.0008	0.0492	0.0414	0.0247	
Trt*cut	0.0073	<.0001	0.3202	0.0034	0.9966	0.6578	0.1843	0.6074	

[a, b, c, d, e] Means in a column within the same category having different superscripts differ (from P<0.05 to P<0.001), MPTFs-Multipurpose Tree Forage, BL-Branch Length, NBP- Number of branch per plant, NTPP- Number of Tiller per plant, p. maximum- panicum maximum, L. leucoce- L. leucocephala, C. gayana- Chloris gayana, C. canus- Cajanus canus and C. ciliaris- Cenchrus ciliaris.

3.2. Chemical Composition

The nutritional contents of the perennial grasses integrated with MPFLs are indicated in Table 2. The result from CP contents was showed none significant (p>0.05) difference. Numerically the highest CP content was recorded from *Panicum maximum* integrated with *Cajanus cajan* (18.15%) where as *Panicum maximum* alone produced the least CP content. The current study was supported the finding [1] which reported that grass- legumes integration can improved fresh fodder yield and protein contents. The overall mean CP concentration of the current result was higher than the finding [2] which report (11.22%).

Ash contents of grass forage integrated with MPTFs was showed significant (p<0.05) variation. The maximum ash contents was obtained from *Chloris gayana* integrated with *L. leucocephala* (13.12%) followed b*y Panicum maximum* associated with *L. leucocephala (*12.77%) and *Chloris gayana* with *Cajanus cajan (*11.83 and the lowest was from *panicum maximum* and *Cajanus cajan* (9.45%) integration. Organic matter content of the grass integrated with MPTFs of the current work was indicated significance (p<0.05) difference. The highest average mean value was recorded from *Chloris gayana* and *Cajanus cajan* integration and the lowest value was from the integration of *Chloris gayana* with *L. leucocephala* and *panicum maximum* with *L. leucocephala* treatments.

Table 3. *The combined mean value of Chemical composition of perennial grasses integrated with MPTFs.*

Treatments	Parameters		
	CP%	Ash%	OM%
P. maxim + L. leucoce	16.89	12.77^{ab}	74.82^{b}
C. gayana + C. cajan	17.06	11.83^{ab}	77.733^{a}
C. ciliaris sole	15.37	11.18^{abc}	75.77^{ab}
P. maximum + C. cajan	18.15	9.45^{c}	76.13^{ab}
C. gayana sole	15.19	11.48^{abc}	76.13^{ab}
C. gayana + L. leucoce	16.87	13.12^{a}	74.27^{b}
C. ciliaris + L. leucoce	16.09	11.72^{abc}	75.43^{b}
P. maximum sole	14.62	11.00^{abc}	75.68^{ab}
C. ciliaris + C. cajan	15.77	10.68^{bc}	76.18^{ab}
Overall mean	16.22	11.47	75.79
CV (%)	24.11	17.50	2.49
LSD (0.05)	4.55	2.33	2.1926
P- value	ns	*	*

$^{a, b, c}$ Means in a column within the same category having different superscripts differ (from P<0.05 to P<0.001), trt- treatments MPTFs- Multipurpose TreeForage, BL- Branch Length, NBP- Number of branch per plant, NTPP- Number of Tiller per plant, p.maximum-panicum maximum, L. leucoce- L. leucocephala, C. gayana- Chloris gayana, C. canus- Cajanus canus, and C. ciliaris- Cenchrus ciliaris.

4. Conclusions and Recommendations

The results of the current study showed that legume introduction to the grass had a positive effect on the forages agronomic performance. It had an effect on plant height, total forage biomass yield, number of branches grown per plant and length of branches. The highest plant height was measured from the integration between *Panicum maximum* and *L. leucocephala* and the lowest average mean value was from the integration of *Chloris gayana* and *Cajanus cajan*. From forage grass the highest plant height was recorded from *Chloris gayana* integrated with *Cajanus cajan* and the lowest value was from Rhodes grass combined with *L. leucocephala*. The maximum total forage biomass yield was obtained from the integration of *Chloris gayana* and *Cajanus cajan* and the lowest mean value was from the sole of *Cajanus cajan* and Leucaena. As cutting interval increases plant heights, numbers of branches per plant, length of branches, number of tiller per plants were also increased.

The integration of MPTFs legumes and grasses produced greater than 1.0 value of LER. The maximum LER was recorded from the integration of *Chloris gayana* and cajanus Cajun and the minimum value was from the combination of *Panicum maximum* and *Cajanus cajun*. Treatments which occurred in integrations were improved the productivity of the mixed the species because of the obtained values of LER were greater than 1.0. Numerically, the maximum CP content was recorded from *Panicum maximum* integrated with *Cajanus cajan* and the minimum was from *Panicum maximum* sole. *Chloris gayana* integration with *Cajanus cajan* recommended for the study areas and similar agro-ecologies due to its good in total forage biomass yield and other agronomic performance among the tested grasses.

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