Agriculture, Forestry and Fisheries
2024, Vol. 13, No. 3, pp. 81-93
https://doi.org/10.11648/j.aff.20241303.13

Research Article

Effect of Spacing of Elephant Grass Intercropping with Alfalfa on Biomass Yield and Nutritive Value of Elephant Grass in Fedis District, Eastern Ethiopia

Worku Bekuma[1,*], Tessema Zewdu[2], Meseret Girma[2]

[1]Oromia Agricultural Research Institute, Fedis Agricultural Research Center, Harar, Ethiopia
[2]Haramaya University, College of Agriculture and Environmental Sciences, Dire Dawa, Ethiopia

Abstract

The study was conducted by Fedis Agricultural Research Center (FARC) at Boko station in Fedis district. The experiment consisted of three different spacing arrangements: S1 (100 cm x 50 cm), S2 (75 cm x 50cm) and S3 (50 cm x 50 cm), and two cropping systems (intercrop and sole planting). These treatments were combined in a 3 x 2 factorial arrangement using a randomized complete block design with four replications. Forage samples were collected at ninety (90) days for elephant grass and 10% flowering for Alfalfa. The results showed that spacing and the interaction between spacing and intercropping had a significant ($p<0.05$) effect on herbage dry matter yield (DMY) and crude protein yield (CPY) of elephant grass. However, intercropping had no significant ($p>0.05$) effect on herbage DMY and CPY. Intercropping can increase the yield of herbage dry matter and total herbage dry matter when compared to pure stand elephant grass. The yield advantage can be up to 3.18% and 19.65%, respectively. Spacing does not significantly affect the dry matter yield of Alfalfa, but the cropping system does. Intercropping and narrow spacing resulted in higher total dry matter yield, due to the additive effect of intercropped Alfalfa dry matter yield. Among the three different spacing, the narrowest spacing S3 recorded the highest dry matter yield (25.62 t/ha), followed by S2 (22.28 t/ha) and S1 (18.33 t/ha). Spacing and intercropping have no significant effect on the chemical composition of elephant grass, but intercropping can increase the dry matter and decrease the ash content of elephant grass. Farmers in the study area and other regions with similar agro-ecology are advised to consider intercropping Alfalfa two weeks after establishing elephant grass. This should be done at an inter and intra-row spacing of 50 cm to achieve a higher herbage dry matter yield for both, elephant grass and total forage.

Keywords

Alfalfa, Chemical Composition, Dry Matter Yield, Elephant Grass, Intercropping

1. Introduction

Ethiopia has a large population of livestock and diverse agro-ecological zones that are suitable for livestock production. However, livestock production has mainly focused on subsistence farming and is characterized by low reproductive and production performance due to a shortage of quality and quantity of feed [28]. The supply of feed from natural pastures

*Corresponding author: workubekuma2010@gmail.com (Worku Bekuma)

Received: 12 March 2024; **Accepted:** 16 April 2024; **Published:** 3 June 2024

fluctuates following seasonal dynamics of rainfall [37]. In many areas of the country, animals are kept on poor-quality natural pastures that commonly occur on permanent grasslands, roadsides, pathways, and spaces between cropped plots [47]. Despite these problems, ruminants continue to depend mainly on forages from natural pastures and crop residues. The constraints of livestock feed are due to land degradation, land shortage, and poor soil fertility [48]. Also, due to the rapidly increasing human population pressure, cropping is expanding, and grazing areas are shrinking [2].

Elephant grass, also known as Napier grass, is a highly productive fodder that yields more than most other tropical grasses [4]. It has become the most important species due to its ability to adapt to a wide range of ecological conditions, high yield, and easy of propagation and management [21, 23]. In East Africa, it is the primary feed for cut-and-carry dairy systems [5]. However, like other tropical grasses, the structural carbohydrates in elephant grass increase rapidly with maturity, while crude protein content and digestibility decrease [50]. The conservative methods of improving elephant grass quality through fertilization or concentrate supplementation are limited because most farmers cannot afford them. One potential solution to improve livestock feed quality and quantity is to use grass-legume mixtures [3]. Integrated forage production systems that use such mixtures are recognized for their role in ensuring quality fodder availability [11, 44]. Growing mixtures of grasses and legumes also improve biomass production compared to grass monocultures [29].

Forage grasses are often combined with legumes to produce a larger quantity of forage with more balanced nutrition for livestock feeding [27]. Proper plant spacing and adequate nitrogen fertilization are two key components in the technology for growing grasses, which are necessary for the development of fast-growing and profuse tiller formations such as elephant grass [7]. Despite the potential of elephant grass as a forage source, there haven't been enough studies on agronomic management practices related to the different spacing of elephant grass intercropping with Alfalfa to improve its agronomic performance and herbage productivity. This study aims to evaluate the effects of different spacing of elephant grass intercropping with or without Alfalfa on biomass yield and nutritive value of the forage.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Fedis Agricultural Research Center in Fedis district at Boko station, which is located 550 km to the East of Addis Ababa and 24 km Southeast of Harar City. Fedis district is found at an altitude of 1050 to 2118 meters above sea level [15]. The district is positioned between 8°22' and 9°14' North latitude and 42°02' and 42°19' East longitude, in the mid and low land areas. The amount of rainfall in the area varies between 650 and 750 mm, while the average temperature ranges between 25 and 30°C, [51] and the soil in the study area is loam as FARC soil fertility team studied.

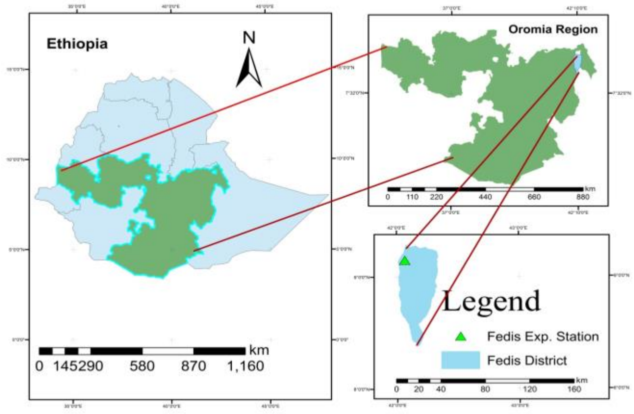

Figure 1. *Map of the study Area.*

The district's economy is mainly based on agriculture, with agro-pastoralists and pastoralists comprising the majority of the population. Fedis district holds low to midland agro-ecologies with a total population of approximately 159,502, out of which around 145,137 reside in rural areas. The primary sources of income in the district are agriculture, particularly Khat and livestock sales, self-employment through firewood sales, and local labor such as harvesting and packing khat. Sorghum and maize are grown for home consumption [1]. According to the recent data obtainable from Fedis district [13], the district's livestock population consists of 78,581 cattle, 75,729 goats, 24,423 sheep, 34,118 donkeys, 9,532 camels, and 91,540 poultry.

2.2. Experimental Design and Treatments

The study design was a randomized complete block design with a factorial arrangement of three different inter and intra-row spacing for elephant grass: S1 (100 cm x 50 cm), S2 (75 cm x 50 cm), and S3 (50 cm x 50 cm). Sole planting and intercropping with Alfalfa between the rows of elephant grass. There were four blocks, each containing six (6) plots total of twenty-four (24) plots, and each plot area was 9 m^2. The distance between plots and blocks were 1 m and 1.5 m, respectively. Plots in each block were randomly assigned to the six treatments.

The treatments are:

T1=100 cm x 50 cm spacing sole planting of elephant grass

T2=75 cm x 50 cm spacing sole planting of elephant grass

T3=50 cm x 50 cm spacing sole planting of elephant grass

T4=100 cm x 50 cm spacing elephant grass intercropping with Alfalfa

T5=75 cm x 50 cm spacing elephant grass intercropping with Alfalfa

T6= 50 cm x 50 cm spacing elephant grass intercropping with Alfalfa

2.3. Experimental Materials and Procedures

The land was prepared for planting by using a tractor to plow it, and then it was disked and harrowed. Next, the land was manually leveled and pits were prepared. On July 10, 2019, elephant grass was planted as root splits, which is a cultivar that grows well in the study area [22]. Two weeks later, between the rows the elephant grass, Alfalfa seeds were sown by drilling them with a recommended spacing of 25 cm between rows. Weeding was carried out regularly to prevent the growth of unwanted plants. The plots were kept weed-free throughout the growth period, and all other recommended management practices were followed. Finally, the forage was harvested at 90 days after planting for elephant grass and 10% flowering stage for Alfalfa.

2.4. Data Collection and Sampling

2.4.1. Dry Matter Yield Determination

The two middle rows of elephant grass were used for data collection. Elephant grass was harvested at 90 days [42] and 10% flowering stage for Alfalfa. The fresh weight was taken in the field using a field balance. Fresh subsamples (500 g) were taken from each plot and the two plant species were separately, weighed and chopped into short lengths (2-3 cm) for dry matter determination. The weighed fresh subsample (FWss) was oven-dried at 65^{0}c for 72 hours and reweighed (DWss) to obtain an estimate of dry matter production. The dry biomass yield (DMY t/ha) was calculated using the following formula:

$$\text{DM yield (t/ha)} = \text{TFW x (DWss / (HA x FWss)) x 10}$$ [41]

Where; TFW = total fresh weight kg/plot, DWss = dry weight of subsample in grams, FWss = fresh weight of subsample in grams, HA = Harvested plot area in square meters and 10 is a constant for conversion of yields in kg/m^2 to t/ha, t/ha = ton per hectare.

2.4.2. Morphological Characteristics of Elephant Grass

Five plants were randomly selected from the plot using a random number technique, and the following parameters were measured: number of tillers per plant, leaf length per plant (in cm), number of leaves per tiller, and basal circumference per plant (in cm). To calculate the total number of leaves per plant, the number of leaves per tiller was multiplied by the number of tillers per plant.

2.4.3. Morphological Characteristics of Alfalfa

The number of days it took for 50% of the seedlings to emerge on each plot was recorded by visual observation. The number of days it took for 50% of the plants to reach the heading stage was noted through visual observation. At the point of harvesting Alfalfa, at 10% flowering, the height of the plants was measured by selecting ten plants, and the average height of the ten plants was taken as the plant height. Similarly, the dry biomass yield of Alfalfa was measured using the same method for elephant grass.

2.5. Statistical Analysis

The agronomic performance data, herbage dry matter yield, and chemical composition were analyzed using the Analysis of Variance (ANOVA) by the general linear model procedure of SAS (version 9.1). The means were separated using the least significant difference at a 5% level of significance.

The model was

$$Y_{ijk} = \mu + S_i + I_j + SI_{ij} + B_K + e_{ijk}$$

Where: Y_{ijk} = individual observation, μ = overall mean, S_i = i^{th} row spacing effect, I_j = j^{th} intercropping effect, SI_{ij} = ij^{th} spacing and intercropping interaction effect, B_k = k^{th} block effect, e_{ijk} = residual error

3. Results and Discussion

3.1. Morphological Characteristics of Elephant Grass

ANOVA result revealed that the survival rate of elephant grass was not significantly affected by spacing and intercropping. However, there was a significant interaction effect ($p<0.05$) between spacing and intercropping on the survival rate of elephant grass. The mean survival rate of pure stand elephant grass and intercropping with Alfalfa was higher than the figure (73.4%) reported by [14] and 55.6% reported by [34]. The survival rate of pure stand elephant grass was comparable to that of intercropping with Alfalfa. The results showed that both methods had a higher survival rate than the figure 59.4% reported by [8], but lower than the 89.9% reported for different accessions of elephant grass [45]. The variation in these was due to differences in cultivar used, agro-ecology, rainfall, and soil condition (moisture and fertility). The average plant survival rate for this study was 87.08% for pure stand elephant grass and 85.5% for intercropping with Alfalfa. Interestingly, intercropping of Alfalfa only reduced the survival rate of elephant grass by 1.58%, which was statistically insignificant.

The spacing of elephant grass significantly affected the number of tillers per plant ($p<0.01$), as shown in Table 1. The highest number of tillers (27.42) was obtained at a spacing of S1 (100 cm*50 cm), followed by S2 (75 cm*50 cm) (25.05), while the lowest was at S3 (50 cm*50 cm) (20.62). The average number of tillers per plant in this study was lower than the range reported by [18]. Differences in cultivars used and harvesting stages might have led to the variations in tiller performance. Wider spacing resulted in a higher number of tillers, while closer spacing led to higher competition for nutrients, water, and solar radiation. This finding is consistent with [8] report that lower spacing causes more competition among plants. The intercropping of elephant grass with Alfalfa did not significantly affect the number of tillers per plant (p>0.05), which is consistent with [14] report that vetch intercropping with elephant grass has no significant effect. However, the interaction between spacing and intercropping had a significant (p<0.05) effect on the tiller performance of elephant grass. Spacing and the interaction of spacing and intercropping had a significant (p<0.05) effect on plant height at harvesting while intercropping with Alfalfa had no significant effect on plant height at harvesting. At lower spacing S3 (50 cm*50 cm) the plant competes for light, space, moisture, and nutrients and became taller than the wider plant spacing S2 (75 cm*50 cm) and S1 (100 cm*50 cm), respectively. It is possible that the reason for the increased competition of Alfalfa intercropping at lower spacing (high density) of elephant grass could be attributed to the need for more light. This result is in agreement with the finding of [40] who observed that taller stevia plants were achieved by the closer (lower) spacing of 50 cm × 20 cm. The increase in plant height with increased plant density could be explained by an increase in the activity of stem growth hormone for plant sunlight competition. The results of our study differ from previous findings. [16] found that different spacing of Desho grass (10*50, 30*50, 50*50 cm) did not significantly affect the plant height at harvest, and [8] reported that different spacing of elephant grass (S1: 75 cm*75 cm, S2: 100 cm*50 cm, S3: 125 cm*25 cm, and S4: 50 cm * 50 cm) also did not significantly affect the plant height at harvest. However, these variations could be attributed to differences in the cultivar used, types of grass, soil fertility, and agro-ecology.

The results of the ANOVA analysis indicate that the spacing of elephant grass, intercropping with Alfalfa, and their interaction did not have a significant effect (p>0.05) on the leaf-to-stem ratio (LSR) of elephant grass, as shown in (Table 1). Similarly, the number of nodes per plant was not significantly affected by spacing, intercropping with Alfalfa, or their interaction (p>0.05). However, the ANOVA results revealed that the internode length per plant was significantly influenced by spacing and the interaction between spacing and intercropping (p<0.05), but not by intercropping with Alfalfa (p>0.05), as displayed in (Table 1). The length of the internodes per plant ranged from 15.78 to 18.99 cm, and this was influenced by the spacing between the plants. The plants that planted further apart produced a lower internode length per plant. The current results were different from the results of [20], who reported a mean of 8.2 cm (ranging from 5.6 to 10.8 cm) for internode length per plant. The difference in stem elongation may be due to variations in the stage of harvesting, soil moisture, soil fertility, cultivars or genotypes, and agro-ecology.

Table 1. *Morphological characteristics of Elephant grass under intercropping and sole planting with different spacing.*

Treatments	SR	NTPP	Pht (cm)	LSR	NPP	INL
Spacing						
1 m × 0.5 m	84.88	27.42^{a}	127.9^{b}	1.175	7.90	15.78^{b}
0.75 m × 0.5 m	87.12	25.05^{b}	131.7^{b}	1.091	8.25	16.93^{b}
0.5 m × 0.5 m	86.88	20.62^{c}	146.8^{a}	1.038	8.68	18.99^{a}
SEM	0.781	0.524	2.12	0.054	0.370	0.638
LSD (5%)	2.353	1.578	6.39	0.163	1.115	1.922
P-value	NS	**	**	NS	NS	**
Intercropping						
With Alfalfa	85.50	23.82	135.2	1.125	8.20	17.42
Without Alfalfa	87.08	24.92	135.8	1.078	8.35	17.04
SEM	0.637	0.427	1.73	0.044	0.302	0.521
LSD(0.05)	1.921	1.288	5.21	0.133	0.910	1.569
P-value	NS	NS	NS	NS	NS	NS
Interaction effect						
1 m × 0.5 m * w	83.75^{c}	26.60^{a}	127.0^{b}	1.226	7.50	15.90^{b}
0.75 m × 0.5 m * w	87.75^{ab}	23.90^{b}	133.3^{b}	1.154	8.20	6.75^{ab}

Treatments	SR	NTPP	Pht (cm)	LSR	NPP	INL
0.5m × 0.5m * w	85.00^{bc}	20.95^{c}	145.1^{a}	0.996	8.90	19.60^{a}
1 m × 0.5 m * w/o	86.00^{abc}	28.25^{a}	128.8^{b}	1.125	8.30	15.65^{b}
0.75 m × 0.5 m * w/o	86.50^{abc}	26.20^{a}	130.1^{b}	1.029	8.30	17.10^{ab}
0.5 m × 0.5 m * w/o	88.75^{a}	20.30^{c}	148.5^{a}	1.081	8.45	18.38^{ab}
SEM	1.104	0.740	3.00	0.076	0.523	0.902
LSD(0.05)	3.328	2.232	9.03	0.230	1.576	2.718
P-value	*	*	*	NS	NS	*

Note: * = significant different, ** = highly significant different, NS = none significant, SR=survival rate, NTPP = number of tillers per plant, Pht=plant height at harvesting, LSR=leave to stem ratio, NPT= node per plant, INL= inter node length, w = with alfalfa, w/o = without alfalfa, LSD= Least significant difference, m=meter, cm= centimeter, SEM= Standard Error of Means

There was no significant effect on the number of leaves per tiller by spacing, intercropping with Alfalfa, or the interaction of spacing and intercropping (Table 2) as per the results of the study. The number of leaves per tiller ranged from 14.58 to 15.20 for different spacing of elephant grass. This finding is consistent with the report of [46], which showed that the number of leaves per tiller ranged from 14 to 15.3. The spacing of plants and their interaction with intercropping had a significant effect on the number of leaves per plant ($p<0.05$). However, intercropping with Alfalfa did not have a significant effect on the number of leaves per plant ($p>0.05$) as seen on Table 2. The number of leaves per plant varied from 313.1 to 400.7, depending on the spacing. The difference in the number of leaves per plant was due to the varying performance of tillers among the treatments.

Table 2*. The mean number of leaves per tiller and per plant, Basal circumference, leave length per plant, and herbage dry matter yield of Elephant grass.*

Treatments	LPT	LPP	BC (cm)	LL (cm)	DMY	TDMY
Spacing						
1 m × 0.5 m	14.58	400.7^{a}	85.40^{a}	114.5^{b}	18.33^{c}	20.14^{c}
0.75 m × 0.5 m	14.63	366.8^{a}	80.40^{b}	124.7^{a}	22.28^{b}	24.17^{b}
0.5 m × 0.5 m	15.20	313.1^{b}	74.68^{c}	123.5^{a}	25.62^{a}	27.29^{a}
SEM	0.336	11.96	1.243	2.61	0.749	0.807
LSD (5%)	1.014	36.05	3.746	7.86	2.257	2.434
P-value	NS	**	**	*	**	**
Intercropping						
With Alfalfa	14.68	349.0	80.22	122.2	22.42	26.00^{a}
Without Alfalfa	14.92	371.4	80.10	119.6	21.73	21.73^{b}
SEM	0.275	9.76	1.015	2.13	0.611	0.659
LSD (0.05)	0.828	29.43	3.058	6.42	1.843	1.987
P-value	NS	NS	NS	NS	NS	**
Interaction effect						
1 m × 0.5 m * w	14.20	378.7^{ab}	84.95^{ab}	115.9^{ab}	18.44^{c}	22.06^{c}
0.75 m × 0.5 m * w	14.50	346.7^{bc}	79.80^{bc}	125.9^{a}	22.80^{ab}	26.59^{ab}
0.5m × 0.5m * w	15.35	321.5^{c}	75.90^{cd}	124.7^{ab}	26.02^{a}	29.36^{a}

Treatments	LPT	LPP	BC (cm)	LL (cm)	DMY	TDMY
1 m × 0.5 m * w/o	14.95	422.6[a]	85.85[a]	113.2[b]	18.22[c]	18.22[d]
0.75 m × 0.5 m * w/o	14.75	386.9[ab]	81.00[abc]	123.4[ab]	21.76[b]	21.76[c]
0.5 m × 0.5 m * w/o	15.05	304.7[c]	73.45[d]	122.3[ab]	25.22[a]	25.22[bc]
SEM	0.476	16.91	1.757	3.69	1.059	1.142
LSD (0.05)	1.434	50.98	5.297	11.12	3.192	3.442
P-value	NS	*	*	*	*	*

Note: * = significant different, ** = highly significant different, NS = none significant, LPT = leaves per tiller, LPP = leaves per plant, BC = basal circumference and LL= leave length, DMY=dry matter yield, TDMY=total dry matter yield cm = centimeter, w = with alfalfa, w/o = without alfalfa, LSD= Least significant difference, SEM = Standard Error of Means

According to current study result, the spacing of plants and the interaction between spacing and intercropping with Alfalfa had a significant effect ($p<0.05$) on the basal circumference per plant. The basal circumference per plant ranged from 74.68 to 85.4 cm due to spacing and 73.45 to 85.85 cm due to the interaction effect. The plant spacing of 100 cm*50 cm showed the highest basal circumference per plant (85.5) while the spacing of S3 (50 cm*50 cm) recorded the lowest (73.45). This finding was higher than the result of [46] reported during the first year of the experiment (basal circumference of 48.33 to 70.67 cm), but lower than what the same author reported during the second year of the experiment, which could be due to the variations in the harvesting stage, agro-ecology of the study area and different cultivars or genotypes used. However, the intercropping of elephant grass with Alfalfa did not have any significant ($p>0.05$) effect on the basal circumference of elephant grass. On the other hand, the ANOVA result showed that the leaf length of elephant grass was significantly ($p<0.05$) affected by plant spacing and the interaction of spacing and intercropping with Alfalfa. The leaf length per plant ranged from 114.5 to 124.7 cm due to spacing and 113.4 to 125.9 cm due to the interaction effect. The study found that the highest leaf length of elephant grass was recorded from the lower spacing, whereas the lower value was recorded from the wider spacing. These findings align with the results of [46] study, which reported a leaf length of 116.7 to 127.3 cm. The ANOVA test showed that intercropping elephant grass with Alfalfa did not have a significant ($p>0.05$) effect on the leaf length of elephant grass.

3.2. Herbage Dry Matter Yield (DMY) of Elephant Grass

The results of the ANOVA test indicate that the yield of herbage dry matter in elephant grass was significantly different ($P<0.01$) based on spacing and the interaction between spacing and intercropping with Alfalfa (as shown in Table 2). The herbage dry matter yield of elephant grass ranged from 18.33 to 25.62 t/ha due to spacing, and from 18.22 to 26.02 t/ha due to the interaction of spacing and intercropping with Alfalfa. The highest mean yield was obtained with a spacing of 50 cm x 50 cm, intercropped with Alfalfa, followed by a spacing of 50 cm x 50 cm as sole-planted elephant grass and a spacing of 75 cm x 50 cm intercropped with Alfalfa. The lowest yield was obtained with a spacing of 100 cm x 50 cm as sole-planted elephant grass. In the study, a significant difference was found in the dry matter yield (DMY) of elephant grass due to spacing. This finding is consistent with [39] research, which also reported a significant effect of plant spacing on DMY, indicating that DMY increases when inter and intra-row spacing is decreased. Similarly, [46] found significant differences in DMY among various plant densities in elephant grass, with DMY increasing as plant density increased. However, this study's significant difference in DMY with spacing contrasts with previous findings. For example, [9] found no significant effect of plant spacing on the DMY of elephant grass. In contrast to current study result, [49] found that spacing did not significantly affect the dry matter yield of elephant grass. [33] found a significant effect of plant spacing, with higher inter and intra-row spacing resulting in higher DMY than lower spacing, which differs from the current study's findings.

There was no significant effect ($p>0.05$) on the dry matter yield (DMY) of elephant grass when intercropped with Alfalfa. However, intercropping had a significant effect ($p<0.05$) on the total DMY. This finding is consistent with [12] research result, which also found that intercropping elephant grass with Alfalfa did not significantly affect the DMY of elephant grass. The lack of a significant difference in the DMY of elephant grass due to intercropping was further supported by [49] study, which did not observe a significant effect on the DMY of elephant grass when intercropped with lablab.

The spacing, intercropping, and interaction of both had a highly significant effect ($P<0.01$) on the overall yield of forage DMY as shown in Table 2. Dry matter yield (DMY) was observed to increase when Alfalfa was intercropped with elephant grass as compared to the sole elephant grass. This was due to the additive effect of Alfalfa intercropping on the total forage production. These results were in agreement with the findings of [42], who reported that the combination of elephant grass with lablab produced significantly higher dry matter yield as compared to sole elephant grass. This result was also in line with [31], who reported a higher total DMY of the elephant grass and legume mixture than the sole elephant grass.

3.3. Morphological Characteristics and Herbage Dry Matter Yield of Alfalfa

It was found that intercropping and spacing did not affect the time required for 50% emergence. This was because there was enough moisture in the soil for the seedlings to emerge, which was facilitated by the rainfall that occurred after Alfalfa was sown. There were no significant differences in the number of days required for heading among the observed treatments ($p > 0.05$). It has been noted that using a specific Alfalfa cultivar (FG-10-09(F)) used for intercropping reached 50% heading takes 65 days. This is in line with a previous study by [10], which reported 50-77 days for different Alfalfa accessions at the Jinka Agricultural Research Center in Ethiopia. The height of Alfalfa was significantly affected ($p < 0.05$) by intercropping with elephant grass at different spacing. This implies that the spacing of elephant grass had an important effect on the height of Alfalfa, with an average plant height ranging from 67.83 to 80.16 cm. This finding is consistent with the results of [38], who reported that the average plant height of Alfalfa at harvesting ranged from 66.6 to 79.6 cm for different Alfalfa cultivars grown in lowland Raya Valley, Northern Ethiopia. The significant plant height observed in the present study is due to the difference in the spacing of elephant grass. Alfalfa plants grown in the narrowest spacing of elephant grass (50 cm x 50 cm) were taller than those grown in wider spacing (75 cm x 50 cm and 100 cm x 50 cm), likely because of increased competition for nutrients, solar radiation, and shading.

The ANOVA result showed that the spacing did not significantly affect the dry matter yield (DMY) of intercropped Alfalfa, but the intercropping system did. The average DMY in this study was 3.59 t/ha, which is lower than the results reported by [19] and [38] for the FG-10-09(F) Alfalfa cultivar. They reported 6.32 t/ha and 4.59 t/ha, respectively, for this cultivar in different regions of Ethiopia. The higher DMY of the sole-planted Alfalfa cultivar could be due to the absence of competition, resulting in more dry matter accumulation in the stems, branches, and leaves. This finding is consistent with [24] observation that sole-cropped Alfalfa had a higher dry biomass yield than intercropped. Similarly, [17] found that the dry biomass of forage legumes was significantly affected by the cropping system when intercropped with maize. Also, [6] reported that the total dry matter yield of Alfalfa grown alone was higher than that of Alfalfa grown with wild Oats.

3.4. Chemical Composition

There was no significant effect ($p>0.05$) on the dry matter and ash contents of elephant grass as a result of spacing and the interaction of spacing and intercropping, as shown on Table 3. However, intercropping had a significant effect on dry matter and ash contents ($p<0.05$). Intercropping increased the dry matter but decreased the ash content of elephant grass. The findings of this study supported by the results of [49], who found that intercropping lablab with elephant grass significantly affects the dry matter and ash contents of the grass. Similarly, [31] observed that intercropping *Seca stylo* with elephant grass also has a significant impact on the dry matter and ash contents of elephant grass. There was no significant effect on the CP (crude protein) contents of elephant grass with spacing, intercropping, and the interaction of spacing and intercropping. This was consistent with the findings of [49] who observed that intercropping elephant grass with lablab had no significant impact on the CP content of elephant grass. Additionally, the studies of [31, 32] reported non-significant increases in the CP content of elephant grass when intercropped with other legumes. The CP content of elephant grass in this study was higher than the 10.63% reported by [43] when harvested at 90 days with a spacing of 1 m*0.5 m. However, the CP content of elephant grass (11.04%) in this study was lower than the 14% reported by [49] when intercropped with lablab. This difference in CP content could be attributed to several environmental factors such as variations in climatic conditions, soil fertility, and the type of legume used for intercropping. It is noteworthy that the CP content of all treatments tested was above the minimum level of 7% required for optimum rumen function [50].

The NDF, ADF, ADL, cellulose, and hemicellulose content of elephant grass were not significantly affected ($p>0.05$) by spacing, intercropping, or the interaction of spacing and intercropping. This finding is consistent with [49] study, which also found no significant impact of spacing, intercropping, and their interaction on the aforementioned factors. Additionally, the results align with [46] research result, that found plant density does not significantly affect the NDF, ADF, ADL, cellulose, and hemicellulose content of elephant grass. According to [31] findings, the fiber levels of elephant grass were not affected when grown with legumes. However, this result contradicts [42] study that obtained intercropping elephant grass with lablab significantly affects NDF, ADF, ADL, and hemicellulose contents of elephant grass. The difference in results could be attributed to the type of legumes used, soil fertility and agro-ecology.

Roughage diets are categorized based on their NDF (Neutral Detergent Fiber) content. Feeds with NDF content ranging between 45-65% are considered medium quality, while those with less than 45% are considered high quality [36]. A decrease in NDF content is linked to an increase in feed intake and digestibility [30]. The NDF percentage of elephant grass in this study was less than the average value of 66.2% reported for tropical grasses, making it a medium quality feed [50]. Roughages with less than 40% ADF (Acid Detergent Fiber) are classified as high quality, and those with over 40% are considered poor quality [26]. The ADF value of elephant grass in this study was less than 40%, indicating an improvement in its feeding value when intercropped with Alfalfa or planted alone. In all treatments, the ADL (Acid Detergent Lignin) value of elephant grass was below 10%, which limits DM (Dry Matter) intake [35].

There was no significant effect of spacing (p>0.05) on the chemical composition of Alfalfa. Alfalfa composite had a higher content of DM and CP, and lower content of ash, NDF, and ADF than the intercropped and sole-planted elephant grass. The NDF content of Alfalfa was within the range of high quality feeds, as roughage diets with an NDF content of less than 45% are considered as high quality feeds [36]. In terms of ADF content, Alfalfa was within the range of high quality, as legumes with less than 31% ADF value are rated as having superior quality, whereas those with values greater than 55% are considered inferior quality [25]. The cellulose and hemicellulose content of the Alfalfa composite was lower than that of intercropped and sole-planted elephant grass.

Table 3. *Chemical composition is influenced by different spacing of Elephant grass and intercropping with Alfalfa or sole planted.*

Treatments	**Chemical composition (%)**							
	DM	**CP**	**Ash**	**NDF**	**ADF**	**ADL**	**Cell**	**H/cell**
Spacing								
1 m ×0.5 m	90.62	10.71	14.05	64.02	38.55	6.09	32.46	25.48
0.75 m ×0.5 m	91.09	11.13	14.09	63.66	38.01	6.21	31.80	25.65
0.5 m ×0.5 m	91.36	10.93	13.72	63.90	37.97	5.98	31.99	25.93
SEM	0.563	0.132	0.289	0.201	0.300	0.138	0.324	0.286
LSD	1.775	0.414	0.912	0.635	0.947	0.435	1.022	0.902
P-value	NS	NS	NS	NS	NS	NS	NS	NS
Intercropping								
With Alfalfa	91.42[a]	11.04	13.47[b]	63.61	38.21	6.21	32.00	25.40
Without Alfalfa	90.63[b]	10.80	14.43[a]	64.11	38.13	5.97	32.16	25.98
SEM	0.460	0.107	0.236	0.165	0.245	0.113	0.265	0.234
LSD	0.750	0.338	0.745	0.518	0.773	0.355	0.835	0.736
P-value	*	NS	*	NS	NS	NS	NS	NS
Interaction effect								
1 m ×0.5 m * w	91.51	10.73	13.41	63.60	38.03	6.277	31.75	25.57
0.75 m ×0.5 m * w	91.36	11.20	13.49	63.74	38.38	6.357	32.02	25.37
0.5 m ×0.5 m * w	91.39	11.21	13.51	63.49	38.23	5.997	32.24	25.26
1 m ×0.5 m * w/o	89.73	10.68	14.68	64.44	39.06	5.90	33.16	25.38
0.75 m ×0.5 m * w/o	90.83	11.06	14.68	63.57	37.64	6.053	31.58	25.93
0.5 m ×0.5 m * w/o	91.33	10.65	13.93	64.32	37.71	5.967	31.74	26.61
Alfalfa Composite	91.8	20.94	13.41	39.12	29.22	6.52	22.7	9.9
SEM	0.797	0.186	0.409	0.285	0.425	0.195	0.459	0.405
LSD	2.511	0.586	1.29	0.985	1.421	0.614	1.587	1.376
P-value	NS	NS	NS	NS	NS	NS	NS	NS

Note: * = significant, NS = non- significant, ADF = Acid detergent fiber, NDF = Neutral detergent fiber, ADL = Acid detergent lignin, Cell = Cellulose, H/cell = Hemicelluloses, CP = Crude protein, DM = Dry matter, m = meter, SEM = Standard Error of Means, w = with Alfalfa and w/o = without Alfalfa

4. Conclusions and Recommendation

The purpose of the study was to evaluate the effects of different spacing techniques for intercropping elephant grass, with or without Alfalfa (*Medicago sativa*), on the herbage biomass yield and nutritive value of elephant grass. The study used three spacing techniques (1 m * 0.5 m, 0.75 m * 0.5 m, and 0.5 m * 0.5 m) and two cropping systems (with Alfalfa and without Alfalfa), arranged in a 2 x 3 factorial arrangement in a randomized complete block design (RCBD) with four replications. Data and forage samples were collected 90 days after planting for elephant grass and at the 10% flowering stage for Alfalfa. Chemical compositions were analyzed at the Holeta Agricultural Research Center of the Ethiopian Institute of Agricultural Research. The spacing technique and interaction between spacing and intercropping had a significant effect ($P < 0.05$) on the dry matter yield (DMY) and crude protein yield (CPY) of elephant grass. Intercropping did not have a significant effect ($P > 0.05$) on the dry matter yield (DMY) and crude protein yield (CPY) of elephant grass. There was no significant effect on the chemical composition of elephant grass due to spacing and the interaction of spacing and intercropping with Alfalfa. Chemical composition such as crude protein (CP), NDF, ADF, ADL, cellulose, and hemicellulose content of elephant grass remained unaffected. However, intercropping of elephant grass with Alfalfa increased the dry matter and decreased the ash content of elephant grass. The study also found that 0.5 m * 0.5 m spacing intercropping with Alfalfa resulted in the highest dry matter yield (DMY), while the lowest DMY was obtained from 1 m * 0.5 m spacing of sole planted elephant grass. Therefore, it is recommended to use 0.5 m * 0.5 m spacing of elephant grass intercropping with Alfalfa for higher herbage dry matter yielder in the study area and similar agro-ecologies.

Abbreviations

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
CP	Crude Protein
CPY	Crude Protein Yield
DMY	Dry Matter Yield
DM	Dry Matter
FARC	Fedis Agricultural Research Center
NDF	Neutral Detergent Fiber
S1	Space One (100 cm x 50 cm)
S2	Space Two (75 cm x 50 cm)
S3	Space Three (50 cm x50 cm)
TDMY	Total Dry Matter Yield

Acknowledgments

I would like to express my deepest gratitude to my major advisor, Professor Tessema Zewdu, and my co-advisor, Meseret Girma (PhD.), for their guidance, technical advice, material support, field supervision and constructive comments on the final write-up of my thesis.

I would also like to thank the Oromia Agricultural Research Institute for allowing me to pursue an MSc study and Dr. Dagnachew Lule (Ph.D.) AGP-II focal person for the financial support provided for my thesis research.

Author Contributions

Worku Bekuma: Conceptualization, Data curation, Software, Formal Analysis, Investigation, Writing - original draft, Methodology

Tessema Zewdu: Conceptualization, Supervision, Validation, Visualization, Writing - review & editing

Meseret Girma: Supervision, Validation, Visualization, Writing - review & editing

Data Availability Statement

Data supporting the study's findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Figure A1. *1 m *0.5 m spacing + Alfalfa.*

Figure A2. *1 m *0.75 m spacing + Alfalfa.*

*Figure A3. 0.5 m *0.5 m spacing + Alfalfa.*

Figure A4. During Fresh Biomass taken from Elephant grass.

Figure A5. During Fresh Biomass taken from Alfalfa.

Figure A6. Leaf sample taken from Elephant grass

Figure A7. Stem sample taken from Elephant grass.

Figure A8. Sample preparation from Alfalfa.

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