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Research Article

Effect of Intercropping Oats (Avena Sativa L.) With Alfalfa (Medicago Sativa) on Dry Matter Yield and Nutritive Value

Daniel Wana[1]*; Metekia Tamiru[2]; Jane Wamatu[3]

[1]Oromia Agricultural Research Institute, Finfinne, Ethiopia, Adami Tulu Agricultural Research center, Ethiopia

[2]Jimma University, College of Agriculture and Veterinary Medicine, Ethiopia

[3]International Centre for Agricultural Research in Dry Areas, Ethiopia

***Corresponding author:** Daniel Wana, Oromia Agricultural Research Institute, Finfinne, Ethiopia, Adami Tulu Agricultural Research center, Batu, Ethiopia PO Box 35 Ziway, Ethiopia.
Email: danielwana2015@gmail.com

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Abstract

There is limited information on planting density for oats and alfalfa when intercropped to achieve a mixture of high nutritional quality for use as animal feed. A field experiment was carried out to study the effect of seeding ratio on yield components (TDM and seed yield) and chemical composition (CP, OM, NDF, ADF, ADL, and Ash). The experiment was conducted at Adami Tulu Agricultural Research Center under irrigation conditions during February–June 2022/2023 in Oromia Regional State, Ethiopia. Treatments consisted of one adapted oats (bate) variety and one alfalfa (magna 788) variety in an additive design at three plant densities (25%, 50%, and 75% of their recommended sole seed rates of 80 and 15 kg per hectare for oats and alfalfa, respectively) and the recommended 100% plant density of sole oats and sole alfalfa. The experiment was laid out in a randomized complete block design (RCBD) with four replications. Data were organized and analyzed with excel and SAS software. Results showed statistically significant differences (P<0.05) in all tested parameters of agronomic yield, and chemical composition of the forage. The highest DMY (14.64 t/ha) was recorded from T4, followed by T3 (14.51 t/ha). The OM, CP, Ash, NDF, ADF, ADL, and IVDMD revealed significant variation (p<0.05) among the treatments in the forage. The OM and CP content of oats and alfalfa produced in intercrops, particularly from the T4 seed ratio (92.08 and 17.33), tend to be better due to the alfalfa component in the intercrop than that of sole oats (92.03 and 11.53), but lower than that of pure alfalfa (93.53 and 21.2), respectively. Generally, the seeding ratio combinations of T4 and T3 performed the best in most agronomic practices and nutritional values. *So they are recommended for fodder production in the studied area and related agro-ecologies. Further studies should be conducted to test by feeding forage produced by inter cropping of oats and alfalfa on animal performance.*

Keywords: Alfalfa; Chemical Composition; Oats; Seed ratio

Introduction

Livestock production remains an important industry for feeding the world's population [69]. Today's feed industry is working to meet the growing global demand and further enhance its sustainability [68]. Livestock farming represents an important livelihood for the agricultural, agro-pastoral, and pastoral societies that make up over 80% of the Ethiopian population. Despite the large livestock resource base economy, and the sector is very important to millions of small holder farmers, pastoral communities, and the wider national economy, livestock production remains underdeveloped, and the available potential has not been fully exploited. Under nutrition and malnutrition are major factors constraining animal production in Ethiopia. Nutritional stress leads to low growth rates, poor fertility, and high mortality, which is compounded by diseases.

Feed shortages in terms of both quantity and quality are the major problem affecting livestock productivity in Ethiopia [66,67]. The traditional livestock production system is based primarily on poor pastures and crop residues, which are usually insufficient to support reasonable livestock production (Tsige, 2000). Towards the end of the dry season, livestock feed is usually scarce and of poor quality. Residues from cereals are the main source of feed, but these are low in protein and have poor digestibility. The production of adequate quantities of good – quality dry – season forages to overcome the dry – season feed problem that affects livestock production in Ethiopia. Improved forages provide a reasonable source of nutrients for animal production while conserving soil fertility, water resources, and air quality [65].

Improvement in livestock production and productivity requires a concomitant intensification in feed production using improved or cultivated forage crops in addition to efficient utilization of natural pasture and crop residues. The current understanding in the ongoing Economic growth and Transformation plan as regards the livestock sector is to transform the small-scale production system in to a specialized and market-oriented production system that includes high quality cultivated pasture production. Improved forage crops have multiple functions and play an important role in sustaining the livelihoods of farmers, mainly because of their positive effects on livestock production and contribution to economic and environmental sustainability.

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Oats are a potential fodder crop for livestock feeding and have been growing in the central highlands of its hardy nature, which makes it perform better under stressful conditions with minimal management inputs. It is used as livestock feed in the form of hay, silage, and grazing or green feed and provides an abundance of excellent forage at a time when other succulent, high – protein feeds are scarce. Similarly, Alfalfa (*Medicago sativa* L.) is one of the recommended forage legumes with high potential as a fodder crop. Alfalfa refers to the crucial perennial legume forage; it can be used to achieve symbiotic N_2 fixation (Dai & Jia, it can also be harvested multiple times in the growing season [64].

Alfalfa (Medicago sativa L.) is one of the best leguminous fodder crops for livestock, especially for dairy production in Ethiopia, due to its superior herbage yield, palatability, nutritional value, wide adaptability, and suitability for irrigated production systems. Its agronomic advantages, including fast growth, persistence under prolonged dry conditions, and versatility in its soil requirements, have made it a popular forage crop for intensive livestock production systems such as dairy production. In Ethiopia, alfalfa exhibits excellent performance over a wide range of altitudes, from 2400m above sea level to warm lowlands below 1000 m.a.s.l., and in a range of soil types. It is often grown in pure stands as a source of protein to supplement low-quality feed or in mixtures with grasses (Sisay, 1975; Astatke Haile, 1977). The chemical composition of forage grass varies with soil type, landscape, management practices, and other environmental factors that influence forage yield and quality [62].

Both oat and alfalfa were adapted in the study area before a long period, and different researchers [51,61] (Nabi *et al.,* 2021) reported their promising performance, especially under irrigation conditions. Oats and alfalfa produce green fodder, which plays an important role in reducing the scarcity of green fodder during the dry season, and they used as multi- cutting forage [51]. Rather than producing their pure stand, their mixture Compensates for the cp reduction in oats [60]. Even though oats produce a large amount of biomass yield, their CP content is very low. Inversely, alfalfa is low in biomass yield but has a higher CP content [54]. Different experiments were done on the effect of oats with alfalfa intercropping, and significant variations in biomass yield and nutritional values were observed.

For instance, Befekadu and Yunus, 2015 reported that oats with different varieties of alfalfa revealed significant ($P<0.05$) variation on dry matter yield and crude protein contents among the tested treatments. A similar report by Belayneh *et al*., 2020 on the effect of oats inter cropped with alfalfa on the agronomic yield and nutritional values of the mixture. As indicated by different Scholars, seed ratios significantly affect both dry matter yield and nutritional quality when oats are mixed with alfalfa and other legumes [34,50-55,57]. Inter cropping compatible forage grasses with legumes improves and maintains soil fertility through nitrogen fixation and increases productivity and profitability [49]. Species with different physiological and/or morphological characteristics can complement better use of feed resources. Until now, there is no information on the seeding ratio or density of both oats and alfalfa when they are inter cropping, so further investigation needed to determine the optimum seed ratio to fill the gap. However, management practices such as seeding rate ratio influence the yield and quality of these species as well as their compatibility when grown in mixtures [48]. The benefits of mixed forage species efficiently exploited only if proper management strategies, such as optimum proportions of seeding rates were used. There is limited knowledge on the proportions of seeding rates that influence the yield and quality of most of the cereal-legume mixture, including oats and alfalfa, Under Rift Valley conditions in Oromia. Therefore, the aim of this study was to evaluate the effect of inter cropping of oats and alfalfa, which could optimize the dry matter yield and nutritional quality of the mixtures.

Objectives

To evaluate the effect of inter cropping of oats and alfalfa on agronomic component, biomass yield and nutritive value.

Materials and Methods

Description of the Study Area

The study was conducted at the Adami Tulu Agricultural Research Center under irrigation conditions. Adami Tulu Agricultural Research Center is located in the Adami Tulu Jido Kombolcha District, which is located in the middle Rift Valley of Oromia, Ethiopia, 167 Kilometers from the capital city of the country (Addis Ababa), in the south eastern part of Oromia between 38° 20' and 38.5°5' E and 7°35 and 8° 05'N (Figure 1). It lies in an altitude range of 1500 to 2000 m.a.s.l. The average annual rainfall is 760mm. It has bimodal rainfall from March to April (short rains) and July to September (long rains) with a dry period from May to June that separates short rains from long rains (Figure 2). The average annual minimum and maximum temperature of the area were 11.8°C and 28.3°C (Metrology Station of Adami Tulu Agricultural Research Center). The soil consists of clay with a proportion of 44%, 34%, and 22% sand, Silt, and Clay, and the soil PH is 7.88 (Teshome *et al*., 2012). The chemical properties of EC (0.08mm/Kg), Na (0.21 Cmol/kg), K (4. 45 Cmol/Kg), Ca (15.2 Cmol/Kg), Mg (2.14 Cmol/Kg), and P(0.2mg/Kg) are reported [34].

Planting Material

An adapted variety of oats (*Avena sativa.L) bate variety* and one variety of alfalfa (*Medicago sativa) magna 788*) were used.

Treatments and Experimental Design

The experiment was undertaken in a randomized complete block design with four replications. The alfalfa and oat varieties adapted to the study area were arranged according to the following treatments:

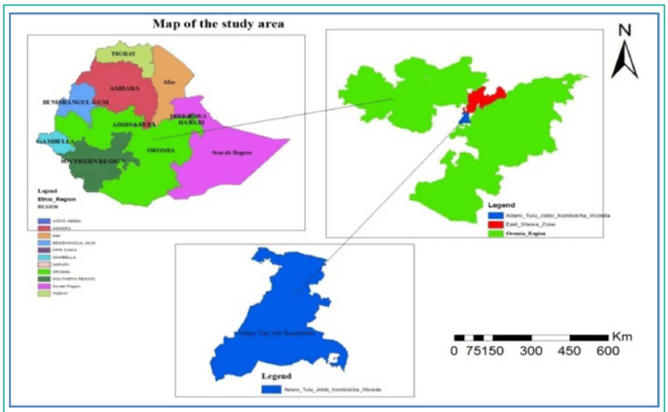

Figure 1: Map of the study area. Source: Ethiopian GIS, 2019.

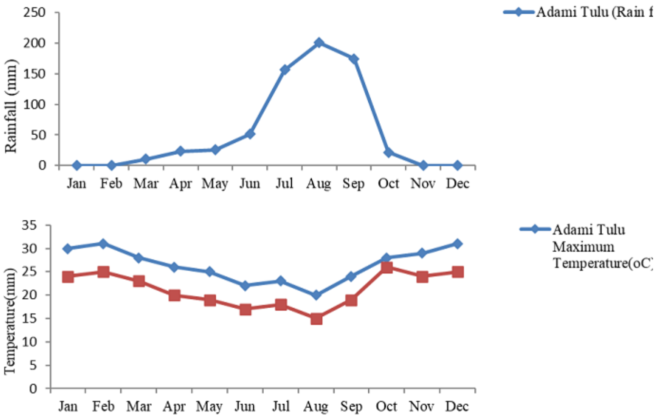

Figure 2: Monthly rainfall distribution and average maximum and minimum temperature variations over the months in the months in the study sites during the experimental (2022/2023).

T1 100% oats (sole oats of bate variety)

T2 100% alfalfa (sole alfalfa of magna 788)

T3 75% oats + 25% alfalfa (magna 788)

T4 50% oats + 50% alfalfa (magna 788)

T5 25% oats + 75% alfalfa (magna 788)

The seed proportions were calculated based on the recommended sole seed rates of 80 and 15 kg per hectare for oats and alfalfa, respectively (Dawit *et al*., 2015). The plot size was 4 m x 4 m (16 m2). A total of 15 rows per plot with a row spacing of 30 cm apart from each other was alternatively used [48]. The spacing between replications and plots was 1m. A germination test was done for both forages before sowing in order to adjust the seeding rates. The seeds were established in rows on a well-prepared seedbed and covered with soil. The forage was watered two times per week. All other cultural practices, including weeding, were kept normal and uniform across all treatments.

Data Collection

Data on yield and yield-related traits such as date of emergence, plot coverage (%), plant height (cm),fresh weight, sample weight, leaf to stem ratio, number of tillers per plant, flowering date, biomass yield and Leaf to stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality (Juan *et al.,* 1993; Kratchunov and Naydenov, 1995; Julier *et al.,* 2000; Sheaffer *et al.,* 2000). yield was collected from each treatment. The forage was harvested for biomass yield determination when 50% of the oats reached heading and alfalfa reached flowering stage. Days to forage harvest were recorded from the planting date to the date when alfalfa plants reached the 50% flowering stage and oats reached the heading stage (Aklilu and Alemayehu, 2007). Biomass yield determination was made when 50% of the oats had reached heading and 50% of alfalfa had reached flowering stage.

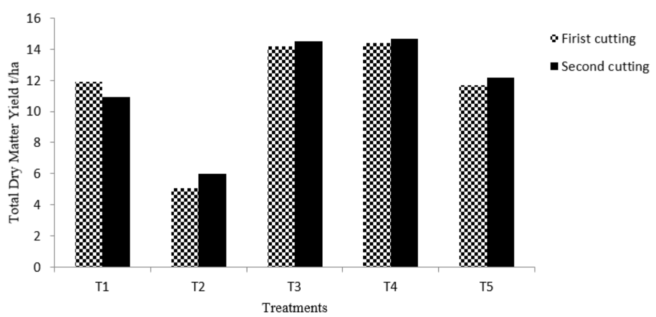

Figure 3: Total Dry Matter Yield of Oats with Alfalfa both at 1st and 2nd Cutting.

Land Equivalent Ratio (LER)

The Land Equivalent Ratio (LER) was used to assess the advantage of forage production in the mixture. LER was defined as the relative area of a mono crop plant required for the same yield obtained from its inter cropping. The LER was calculated using the formula given below.

$$LER = \frac{Yield\ of\ alfalfa\ in\ mixture}{Yield\ of\ alfalfa\ in\ pure\ stand} + \frac{Yield\ of\ oats\ in\ mixture}{Yield\ of\ oats\ in\ pure\ stand}$$

When LER is greater than 1, mixed growing favors the growth and yield of the mixture species. In contrast, when LER is lower than 1, mixed growing negatively affects the growth and yield of plants grown in mixtures (Dhima *et al*., 2007).

Dry Matter Yield Determination

The DM yield of each botanical component in each plot was determined by drying a representative sample in an oven at 60°C for 72 hours for partial DM determination. DM yields were determined at the Adami Tulu Agricultural Research Center, Animal Feed Laboratory. The DM yield of each leaf and stem of both *oats* and alfalfa were calculated separately and added together to provide the total DM yield of the plot, and the final DM yields were reported in tons per hectare. The DM production (ton/ha) was calculated as

(10 x TotFW x (DWss/FWss xHa))

Where TotFW = total fresh weight, DWss = dry weight sub sample, FWss = fresh weight sub sample, and HA = harvesting area (Tarawali *et al*., 1995).

Seed Yield (t/ha) Determination

Seed yield was determined by harvesting both alfalfa and oats from each plot when the seeds were mature and after cautiously separating the seed from the straw. Then, the seed yield (t/ha) was determined by weighing the seed and expressed at 10% moisture content for vetch and 12.5% for oats using the following formula [60].

$$Seed\ Yield\ \left(\frac{t}{ha}\right) = \frac{Seed\ yield\ per\ 0.3m*4m\ area\,(kg)*10*sample\ dry\ weight\,(g)}{Subsample\ pre\ dying\ weght\ (g)*harvest\ area\ 0.3m*4m}$$

Chemical Analysis

The feed sample was taken from each treatment and dried in an oven at 60°C for 72 hours to a constant weight and Willey mill to pass through a 1mm sieve. The ground samples were kept in airtight plastic bags prior to analysis for chemical composition. The Dry Matter (DM) was determined by an oven drying at 105°C overnight and ash content was determined by ground in a

Igniting the dry samples in a muffle furnace at 550°C for 6 hours to burn off all the organic material. The inorganic material, which does, not volatilized at that temperature is ash. The difference between sample DM and ash gives the Organic Matter (OM). Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) was analyzed (Van

Soest and Robertson, 1985). For Nitrogen (N) analysis, the Kjeldhal method was used and Crude Protein (CP) content was estimated from the N content by use of a multiplier of 6.25.

Statistical Analysis

Collected data was organized, summarized and analyzed by using SAS. LSD test at 0.05 probability levels was used to compare the treatment means (Steel and Torrie, 1984). The treatment means were separated by Least Significant Difference (LSD).

The model used for data analysis was $Yij = \mu + Ti + Bj + Eij$ Where; Yij = Response variable, μ = Overall mean, Ti = Treatment effect, Bj = Block effect, Eij = Random error.

Results and Discussion

The Effect of Oat – Alfalfa Inter Cropping on Agronomic Performance

The result of all agronomic performances in both the first and second cuttings of this experiment is shown in Table 1 & 2. Except for plant height, leaf length, and leaf stem ratio, all other evaluated agronomic parameters have statistically significant differences ($P < 0.05$). The analysis of variance revealed a significant difference for all the parameters studied (Table 1 & 2). The findings of Ninama, 2020 indicated that this variance difference was due to the effect of different ratios of oats and alfalfa under an intercropping. In this trial, the number of tillers of alfalfa and oats plants grown in the seed proportion T4 (50% oats and 50% alfalfa) was statistically significantly higher ($P<0.05$) than all other treatments both at the first and second cuttings, which reveals that there was no competition for space.

Dry Matter Yield (t/ha)

The total forage dry matter yield of harvested from T1(11.91 t/ha), T2(5.05 t/ha), and T5(11.69 t/ha) was lower ($P<0.05$) than T3(14.15 t/ha) and T4(14.41 t/ha) at the first cutting, and T1(10.92 t/ha), T2(5.99 t/ha), and T5(12.18 t/ha) were lower ($P<0.05$) than T3(14.51 t/ha) and T4(14.64 t/ha) at the second cutting. The TDMY t/ha of T3 (14.15 t/ha, 14.51 t/ha) and T4 (14.41 t/ha, 14.64 t/ha) were not significantly different, respectively, at the first and second cuttings. The highest total dry matter yields of 14.64 t/ha and 14.41 t/ha were recorded from a seeding ratio of 50:50 T4 at the second and first cuttings, respectively. The lowest dry matter yield was recorded from the sole alfalfa treatment at the two cuttings. The combined analysis result also showed that significantly ($p<0.05$) the highest dry matter yield was obtained from a seeding ratio of 50% *oat:* 50% alfalfa (T4), followed by a seeding ratio of 75% *oat:* 25% alfalfa (T3), both at the first and second cutting.

The higher biomass yield obtained from these seeding ratios could be due to the fact that the proportion of oats produced much more forage yield through increased number of tiller productions than the other mixtures and sole oats. As the result shows, the biomass of the inter crop was superior and advantageous compared to their pure stands. This may be due to higher fertility levels and suitable seed ratios under intercropping system, where both crops behave as component crops. The addition of the legume crop to cereals leads to increased availability and absorption of nutrients by the plants, which results in more vegetative growth and helps increase plant height and tillers on account of enlargement of cells and enhanced photosynthesis, which results in a higher total dry matter yield. The results are in conformity with the findings of [24,36,37,46,47] number of tiller productions than the other mixtures and sole oats.

As the result shows, the biomass of the intercrop was superior and advantageous compared to their pure stands. This may be due to higher fertility levels and suitable seed ratios under the intercropping system, where both crops behave as component crops. The addition

Table 1: Descriptions of oats and alfalfa varieties used for the trial.

SN	species	Variety	DMY (t/ha)	SY (q/ha)	Altitude(m)	Year release	Breeder/Institute	source
1	*Avena sativa*	Designation	8.56	31.99	1200-3000	2018	Bako ARC/OARI	MoA, 2018
2	*Medicago sativa*	Bate (ILRI-5453)	9.8		1000-2600	2006	USA	

Table 2: The agronomic performance of oats inters cropped with alfalfa at the first cutting.

Treatment	PH		LL	Tillers		LSR	TDM (ton/ha)			SY(q/ha)			LER
	oats	alfalfa	oats	oats	alfalfa		oats	alfalfa	total	Oats	alfalfa	total	
T1	105.65		44.9	11^{b}		1.37	11.91^{ab}		11.91^{b}	24.33^{a}		24.33^{a}	
T2		92.9			12.68^{a}	1.29		5.05^{a}	5.05^{d}		9.88^{a}	9.88^{e}	
T3	105.25	93.83	45.4	10.75^{b}	9.83^{b}	1.33	12.13^{a}	2.02^{c}	14.15^{a}	19.79^{b}	1.41^{d}	21.2^{b}	0.95
T4	105	97.23	45.58	13.18^{a}	8.5^{c}	1.4	11.38^{b}	3.04^{b}	14.41^{a}	17.06^{c}	3.31^{c}	20.37^{c}	1.14
T5	103.58	93.9	46.75	10.83^{b}	9.65^{b}	1.48	8.82^{c}	2.88^{bc}	11.69^{b}	9.74^{d}	6.64^{b}	16.38^{d}	1.07
Mean	104.87	94.46	45.66	11.44	10.16	1.37	11.06	3.25	11.24	17.73	5.31	18.43	1.06
CV	1.75	7.07	5.19	8.84	6.74	16.87	3.46	18.33	6.36	2.29	5.41	2.17	
LSD	2.83	10.28	3.65	1.56	1.05	0.35	0.59	0.92	1.08	0.63	0.44	0.6	
P-value	0.44	0.8	0.73	*	***	0.2	***	***	***	***	***	***	

T1- Sole oats, T2- sole alfalfa, T3- 75% oats + 25%alfalfa, T4- 50% oats + 50% alfalfa, T5- 25% oats + 75% alfalfa, PH: Plant Height, LL: Leaf Length, TDM: Total Dry Matter, SY: Seed Yield, CV: Coefficient Variation, LSD: Least Significant Deference, PH: Plant Height, LL: Leaf Length, LSR: Leaf Stem Ratio, TDM: Total Dry Matter, SY: Seed Yield, Land Equivalent Ratio

Table 3: The agronomic performance of oats inters cropped with alfalfa at the second cutting.

Treatment	PH		LL	Tillers		LSR	TDM (ton/ha)			Sy (q/ha)			LER
	oats	Alfalfa	oats	oats	alfalfa		oats	alfalfa	total	Oats	alfalfa	total	
T1	109.5		46.75	13^{b}		1.07	10.92^{ab}		10.92^{c}	22.98^{a}		22.98^{a}	
T2		94			12.75^{c}	1.19		5.99^{a}	5.99^{c}		10.83^{a}	10.83^{e}	
T3	109.25	93.75	48.75	12.75^{b}	13.83^{b}	1.18	11.55^{a}	2.96^{c}	14.51^{a}	18.44^{b}	2.38^{d}	20.8^{b}	1.02
T4	107.5	97.75	48.75	14.93^{a}	16.43^{a}	1.06	10.66^{b}	3.98^{b}	14.64^{a}	15.71^{c}	4.26^{c}	19.97^{c}	1.15
T5	107.75	94.75	49	12.75^{b}	13.65^{b}	1.15	8.36^{c}	3.82^{bc}	12.18^{b}	8.39^{d}	7.59^{b}	15.98d	1.07
mean	108.5	95.06	48.31	13.36	14.17	1.13	10.37	4.19	11.65	16.38	6.27	18.11	1.08
CV	1.91	4.77	6.77	7.89	5.15	16.86	4.99	14.21	6.17	2.48	4.59	2.2	
LSD	3.19	6.98	5.04	1.63	1.12	0.29	0.78	0.92	1.08	0.63	0.44	0.6	
P-value	0.44	0.5	0.75	*	***	0.79	***	***	***	***	***	***	

T1- Sole oats, T2- sole alfalfa, T3- 75% oats + 25%alfalfa, T4- 50% oats + 50% alfalfa, T5- 25% oats + 75% alfalfa, PH: Plant Height, LL: Leaf Length, TDM: Total Dry Matter, SY: Seed Yield, CV: Coefficient Variation, LSD: Least Significant Deference, PH: Plant Height, LL: Leaf Length, LSR: Leaf Stem Ratio, TDM: Total Dry Matter, SY: Seed Yield, Land Equivalent Ratio

Table 4: The Chemical composition of oats and alfalfa inter cropped forage with different seed ratios at first cutting.

Treatment	DM	OM	Ash	CP	NDF	ADF	ADL	IVDMD
T1	90.3	92.03^{b}	7.97^{a}	11.53^{e}	46.59^{a}	30.94^{a}	4.79^{a}	62.28^{d}
T2	90.23	93.53^{a}	6.47^{b}	21.2^{a}	39.29^{d}	22.65^{e}	2.14^{c}	73.3^{a}
T3	89.98	92.28^{b}	7.72^{a}	13.65^{d}	44.84^{b}	28.52^{b}	3.85^{b}	62.73^{d}
T4	90.48	92.08^{b}	7.92^{a}	17.33^{c}	42.27^{c}	26.11^{c}	2.39^{c}	65.81^{c}
T5	89.9	92.85^{ab}	7.15^{ab}	18.55^{b}	39.98^{d}	23.64^{d}	2.19^{c}	68.47^{b}
mean	90.18	92.55	7.45	16.45	42.59	26.37	3.07	66.52
CV	0.38	0.65	8.02	3.63	1.67	1.58	5.54	0.56
LSD	0.51	0.9	0.9	0.9	1.07	0.63	0.26	0.57
P-value	0.15	0.01(*)	0.01(*)	***	***	***	***	***

Means with the same letter are not significantly different at $P<0.05$. T1-Sole oats, T2- sole alfalfa, T3- 75% oats + 25% alfalfa, T4- 50% oats + 50% alfalfa, T5- 25% oats + 75% alfalfa, DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, ADL: Acid Detergent Lignin, IVDMD: *in vitro* Dry Matter Digestibility, ME: Methabolizable Energy, CV: Coefficient of Variation, LSD: Least Significant Deference.

Table 5: The Chemical composition of oats and alfalfa inter cropped forage with different seed ratios at second cutting.

Treatment	DM%	OM	Ash	CP	NDF	ADF	ADL	IVDMD
T1	86.78	94.1^{b}	5.91^{a}	13.02^{e}	39.91^{a}	29.44^{a}	3.62^{a}	63.96^{d}
T2	84.18	95.65^{a}	4.35^{b}	22.8^{a}	30.67^{e}	20.01^{e}	2.02^{c}	74.99^{a}
T3	87.1	94.27^{b}	5.73^{a}	14.27^{d}	39.15^{b}	27.29^{b}	3.47^{a}	64.28^{d}
T4	87.98	94.06^{b}	5.95^{a}	18.27^{c}	35.8^{c}	25.35^{c}	2.89^{b}	67.42^{c}
T5	85.55	94.91^{ab}	5.09^{ab}	19.19^{b}	32.62^{d}	21.82^{d}	2.63^{b}	70.03^{b}
mean	86.28	94.59	5.4	17.51	35.63	24.78	2.93	68.14
CV	2.64	0.62	10.82	1.92	1.01	1.82	7.36	0.62
LSD	3.43	0.88	0.88	0.5	0.54	0.68	0.32	0.77
P-value	0.21	0.04(*)	**	***	***	***	***	***

Means with the same letter are not significantly different at $P<0.05$. T1-Sole oats, T2- sole alfalfa, T3- 75% oats + 25% alfalfa, T4- 50% oats + 50% alfalfa, T5- 25% oats + 75% alfalfa, DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, ADL: Acid Detergent Lignin, IVDMD: *in vitro* Dry Matter Digestibility, ME: Methabolizable Energy, CV: Coefficient of Variation, LSD: Least Significant Deference.

of the legume crop to cereals leads to increased availability and absorption of nutrients by the plants, which results in more vegetative growth and helps increase plant height and tillers on account of enlargement of cells and enhanced photosynthesis, which results in a higher dry matter yield. The results are in line with the findings of [24,36,37,46,47]. In line with this study, scholars emphasized the advantages of a grass-legume mixture [34,45]. It was also reported that the total dry matter yield of mixed grass and legume pastures was greater than that of grass-based pastures, and the overall feed value was better maintained throughout the grazing season when pastures included legumes (Lusture *et al*., 2014).

This revealed that the overall yield is not affected by the competition effects of oats as the companion crop (Table 1 & 2). The analysis of this trial has suggested that the total dry matter yield of alfalfa grown without oats was greater ($P<0.05$) than that grown with oats. However, this difference was not associated with the effect of companion plants on the performance of alfalfa; rather, it could largely be attributed to the proportion of land used and seed proportions for growing this plant. The land area used for growing alfalfa with companion plants was about half of the land used for growing alfalfa without companion plants, indicating that the dry matter yield per area of land was greater for alfalfa grown without oats than alfalfa grown with oats. This result was supported by Befekadu and Yunus, 2015, who reported that the total dry matter yield of alfalfa grown without companion was greater ($P<0.05$) than that of those grown with companion plants.

On the other hand, the lowest performance of the seeding ratio (25% oats and 75% alfalfa) as compared to the other mixtures could be due to the fact that alfalfa dominates and suppresses the growth of oats in terms of light and nutrient utilization. Other findings also indicated that mixtures gave higher green forage yields than pure stands (Karadau, 2003). In addition, other scholars who reported that a higher mean biomass yield was obtained from the mixture as compared to its components grown in monoculture [42]. Generally, the result shows that a seeding ratio of 50% oats: 50% alfalfa and 75% oats: 25% alfalfa showed the highest total biomass yields.

The basic reason for higher forage biomass productivity might be due to the utilization of symbiotically fixed nitrogen (whitehead, 1995), more enhanced interception of light [41], Allelopathic and synergistic effect (Pudnam & Duke, 1978), and some other effects. These factors created a microenvironment that favored higher yields than those obtained from sole legume or grass stands [40] Besides, Legumes can cover the N_2 demand of grasses from atmospheric N_2, and therefore legumes inter cropped with grasses compete for less soil mineral N_2. Eskandari *et al*., 2009a indicated that there was an increase in forage quality compared to cereal monoculture and an increase in dry matter in comparison to legume monoculture. Several studies showed that the dry matter yield increased with the increasing rate of oats in mixtures with legumes [35,38].

Plant Height

The average plant height of alfalfa and oats grown in a sole was not different ($P > 0.05$) from those grown in an inter crop on the same plot both at the first and second cuttings under this experiment (Table 1). The non-significant ($p > 0.05$) differences observed for alfalfa and oat plant height illustrate the mutual benefits of the forage crops from inter crop establishment. This indicates that alfalfa grown with oats on the same plot was not affected by the height and root of oats used as companion crops to obtain sun light and nutrients, respectively, if oats were seeded at 30cm intervals in a row with alfalfa. Dawit *et al*., 2022 reported that a non-significant ($p > 0.05$) effect was observed on plant heights for the mixture of alfalfa among the tested seeding ratios. However, Meyer and Nudell, 2008 indicated that companion crops compete with under-seed alfalfa, which can affect the stand that can be established. In contrast to this study, plant height recorded at different forage growth stages showed significant differences between inter cropping treatments of alfalfa and oats [33]. The data also indicated that all seed ratios of oats and alfalfa showed a yield advantage over sole oats and sole alfalfa. The increase in total dry matter yields in the intercropping systems might be owing to better utilization of space and light interception, coupled with the nutrient contribution of leguminous fodder to cereal. The results are in agreement with those of Kumar, 2005, sharma *et al*., 2009, and Deore *et al*., 2013.

Total seed yield (q/ha)

The total seed yield (table 1) has a statistically significant difference (P<0.05), which indicates an increment order of T1 (24.33). T3(21.2)>T4(20.37)>T5(16.38)>T2(9.88) at first, and T1(22.98)>T3(20.8)>T 4(19.97)>T5(15.98)>T2(10.83) at second cutting. In this experiment, the seed yield of sole oats was significantly higher than that of oats inter cropped with alfalfa. The highest seed yields were obtained from sole oats (T2) with 24.33 t/ha, followed by T3 (75% oats + 25% alfalfa) with an average yield of 21.2 t/ha. The lowest mean seed yields (10.83 t/ha and 15.98 t/ha) were recorded from T2 (sole alfalfa) and T5 (25% oats + 75% alfalfa) seed ratios, respectively. The sole oats were significantly different from the sole alfalfa and them inter crop groups and produced the highest seed yield in the present study. The yield differences between the treatments might be due to the effective tiller in oats attributed to the differences.

Land Equivalent Ratio (LER)

LER's values were calculated for inter cropping treatments in two consecutive cuttings (Table 2). All the inter crops showed LER greater than one except T3 of the first cutting. The maximum LER values were obtained from T4 (50% oats + 50% alfalfa) seed proportion of oats + alfalfa inter cropping system, followed by T5 (25% oats + 75% alfalfa) and T3 (75% oats + 25% alfalfa) both at first and second cutting. The reason for the higher LER values for the seeding ratio of 50% oats and 50% alfalfa could be due to the better benefit of the oats from the fixed nitrogen through the alfalfa. The values of LER greater than one from the results show that inter cropping is advantageous. Inter cropping systems that constantly give LER ranged from 0.95 to 1.14 in the first cutting and from 1.02 to 1.15 in the second cutting.

Therefore, 0.05% to 14% of the first cutting and 2% to 15% more land should be used in mono cropping in order to obtain the same yield as inter cropping, which indicated the advantage of intercropping over mono cropping in terms of the use of water, nutrients, carbon dioxide, and light for plant growth. It was found that LER greater than one was primarily due to nutrient cycling and an increase in nitrogen content [29]. The present study result is in line with the report of Ganvit *et al*., 2018, which ranged between 1.24 and 1.44). In addition, legume-grass mixtures generally provide more consistent and greater forage yields across a range of environments than grass or legume monoculture [28]. Hence, the value of LER for seeding ratios shows that inter cropping of alfalfa and is more advantageous than sole cropping. Where it was more than 1, indicating the suitability of the practice in the quantitative term. The present findings are in accordance with those of patel and Rajgopal, 2003, Kumar *et al*., 2005, Surve *et al*., 2012, and Ganvit *et al*., 2018.

The Chemical Composition and Variability of the Forage

The results of the analysis of the nutrient contents of oats and alfalfa with different seeding ratio combinations are indicated in Table 3 and 4. The result indicated that the combinations of different seeding ratios did not significantly (P> 0.05) influence the percent of dry matter under both mixtures and pure stands in DM content. However, numerically, the DM percent ranged from 89.9% to 90.48% and 84.18% to 87.98%, with an overall mean of 90.18% and 86.28% for both the first and second cuttings, respectively, under pure stand and mixture. The result of the current study is lower than the result of Tesfaye *et al*., 2020, who reported that DM % was between 91.8% and 93.78% in both mixtures and pure stands, respectively.

The DM percentage recorded in the first cutting being higher than that of the second cutting may be due to the maturation effect. On the other hand, the different seeding ratios of oats and alfalfa inter cropped showed a significant (P<0.05) variation among the values of OM%, Ash%, CP%, NDF%, ADF%, ADL%, and IVDMD both at first and second cutting. The highest OM% (93.53%, 95.65%) was observed from the pure stand of alfalfa both at the first and second cuttings, respectively. The percentage content of OM % is directly related to the protein content, which means that when OM% increases, the CP% content will also increase.

Total ash content of oats and alfalfa: Total ash content was affected (P>0.05) both at the first and second cuttings (Tables 3 & 4). A higher ash content was recorded at the first cutting. The ash content of the first cutting mean data is higher than that of the second cutting, which may be due to the maturation stage difference between the first and second cutting, which may be due to the maturation stage difference between the first and second cutting periods. The ash content obtained in this study was in agreement with the results of Yehalem, 2004, who reported an increase in total ash contents with advancing plant maturity. However, the results of the current study disagree with those of Diriba and Vaars, 2000, who reported that the mineral contents of plants declined during the maturing process due to the natural dilution and translocation of nutrients from the vegetative part to the root system. McDonald *et al*., 2002 also reported that mineral concentration declines with age and is influenced by soil type, soil nutrient levels, and seasonal conditions. In general, variation in the concentration of minerals in forages can be induced by factors like varies, plant developmental stage, morphological fractions, climatic conditions, soil characteristics, and fertilization regime [20,21].

Crude Protein Yield of Oats-Alfalfa Inter Cropping

The highest CP% content (21.2%, 22.8%) was recorded from the pure stand of alfalfa (T2), followed by the seeding ratios T5 (25% oats: 75% alfalfa) (18.55%, 19.19%), T4 (50% oats: 50% alfalfa) (17.33%, 18.27%), and T3 (75% oats: 25% alfalfa) (13.35%, 14.27%), while the pure stand of oats produced the least T1 (11.53%, 13.02%) CP value both at the first and second cutting, respectively. The CP content of the intercropped groups in the present study is similar to the report of Ninama SD *et al*., 2020, 16.72% from oats and alfalfa. The average values of CP content were directly related to the alfalfa seeding ratios in the intercrop. The CP content of oats-alfalfa produced in a mixture is much improved due to the alfalfa component in the intercrop. Similarly, alfalfa is an excellent forage because of its high yield, rich content and high quality of protein, abundant vitamins and minerals, good palatability, and high digestibility [19], and because it produces more protein per unit area than other forage legumes [18].

The current result agrees with Diriba and Vaars, 2000 who suggested a higher CP% as indicative of the importance of the forages. The CP% result of the present study similar to the report of Shoaib *et al.,* 2014, crude protein yield was significantly influenced by the seed proportions of inter crops. Studies also indicated that the production of grass- legumes inter crop increased fresh fodder yield and protein contents, as well as enhanced fodder palatability [15,16]. Even though the value of CP% content in 25% oats: 75% alfalfa seeding ratio was higher than other seeding ratios in the intercrop, the high proportion of alfalfa in this ratio is undesirable since these normally have a low dry matter yield.

Fiber and Lignin Contents

Of the tested seeding ratios, the pure stand of oats had the highest NDF (46.59%, 39.91%), ADF (30.94%, 29.44%), and ADL (4.79%, 3.62%) content, followed by the seeding ratios of 75% oats and 25% alfalfa, which produced NDF (44.84%, 39.15%), ADF (28.52%, 27.29%), and ADL (3.85%, 3.47%) both at the first and second cutting, respectively (tables 3 and 4). The lowest values of NDF (39.29%, 30.67%), ADF (22.65%, 20.01%), and ADL (2.14%, 2.02%) were recorded from the pure stands of alfalfa, both at the first and second cuttings, respectively. The fiber result of the present study is lower than the previous finding reported [11]. The NDF, ADF, and ADL concentrations in forage were directly proportional to the oats percentage in the intercrop. As the seeding ratios of the oats increased in the intercrop, the content of NDF, ADF, and ADL increased. Findings from Paulson et al., 2008 also suggested that the grass contains higher fiber content than the legumes.

The present study shows that the DM, NDF, and ADF contents increased with advancing maturity for first-cutting forage. This is due to the moisture and leaf-to-stem ratio decreasing and the cell wall content in the stem increasing with advancing maturity. Grasses tend to increase the fiber fractions, such as NDF and ADF, of mixtures owing to the abundant cell wall materials [2], and legumes are usually richer in CP than grasses due to their substantial biological fixation of N from the atmosphere [13]. Similar to the current study, increasing the alfalfa proportion in mixtures increased CP and decreased NDF, ADF, hemicelluloses, and cellulose concentrations, Similar to the current study, increasing the alfalfa proportion in mixtures increased CP and decreased NDF, ADF, hemicelluloses, and cellulose concentrations, suggesting that forage mixtures improved nutritive values and reduced the need for purchased protein supplements in ruminant rations [1]. Other studies also showed significant positive correlations between legume inclusion in pastures and forage quality traits like crude protein and negative correlations with NDF, ADF, and ADL [12]. In other ways, the fiber content of the first cutting is higher than that of the second cutting, as supported by NinamaSD, 2020), who stated that there was an increase in fiber content with the advancement of the growth stage.

The *in vitro* dry matter digestibility of oats was significantly affected by the treatment. The highest IVDMD (73.3, 74.99) was observed from the pure stand of alfalfa (T2) both at the first and second cuttings. The IVDMD result observed from the second cutting was higher than that of the first cutting due to the regrowth at the second cutting, which implies the best result of IVDMD. On the other hand, the lowest IVDMD (62.28, 63.96) was observed from the pure stand of oats (T1) sole oats both at first and second cutting. The IVDMD results of the three inter cropped groups (T3, T4 and T5) were higher than those of the pure stand of oats but lower than those of the pure stand of alfalfa, which revealed an improvement in digestibility. Similarly, inter cropping improved the forage yield of dry matter, crude protein, and dry matter digestibility (Metekia *et al*., 2023).

In the present study, the increase in the alfalfa proportion in the mixtures increased the IVDMD and OMD compared with that from sole oats for both harvests. In agreement with a previous study [10], IVDMD increased when the proportion of alfalfa increased in axonopus – alfalfa and tall fescue- alfalfa mixtures. The present study indicates that digestibility could be increased when alfalfa is mixed with other crops [7-9]. This may be because balanced digestibility nutrients from oats and alfalfa silage mixtures set off a ruminal synergistic effect on the fractional rate of degradation and the extent of fermentation, followed by better nutrient availability and utilization efficiency for rumen microorganisms [6]. The association between fermented nutrients from grass and legume mixtures may also lead to synergistic effects on the dominant microbial populations and shifts in the microbial community composition [5], and different metabolic pathways might be simultaneously driven through niche compartmentalization and functional dominance between abundant bacteria [4]. Higher fiber content means a lower degradation rate and longer fermentation time [3], and indigestible fiber, e. g , ADL, in particular, is the main physical barrier interfering with microbial attachment and degradation, and this is negatively correlated with fiber digestibility [2].

Conclusion and Recommendation

Conclusion

Leguminous forages cultivation not only provides high-quality and quantity feed for livestock, but by fixing nitrogen, they could maintain and improve soil fertility and reduce the cost of chemical fertilizers, in which prices are increasing rapidly from time to time. The compatibility of legumes forages with grasses depends on the morphology and physiological characteristics of the legume and grass, in combination with the response of the management imposition, climate, soil, and biotic conditions under which the crop was growing. Considerable variations were existed among the tested seed ratios, indicating the potential for selecting higher-performing forage biomass yield and quality. The highest forage yield in the oats – alfalfa intercrop was obtained from the seed ratio (50% oats + 50% alfalfa) and (75% oats + 25% alfalfa).

However, the highest seed yield was obtained from oats in pure stands. The analysis of variance also showed a great variation in the chemical composition (DM, Ash, OM, CP, NDF, ADF, ADL and IVDMD) of the tested treatments. The OM% and CP% content in the pure stand of alfalfa were significantly higher than those in pure stand oats and oats-alfalfa inter cropped. The crude protein content of the intercropped groups increased as seed ratio of alfalfa increased in the combination of forage. Even though the NDF content of sole oats was higher than that of other treatments, all treatments were observed to be below the critical level (55%) of NDF, which indicates higher digestibility and intake.

The crude protein and neutral detergent fiber were the most important nutrients that determine the quality of forages. Due to this, the highest total nutrient yields of CP% and NDF% were obtained in mixed treatments compared to pure stands. Generally, in the present study, the oats-alfalfa mixture increased forage biomass yield, and improved chemical compositions.

Recommendations

Based on the results of the present study, the following recommendations are proposed: The mixture of (50% oats + 50% alfalfa and 75% oats +25% alfalfa) seed ratio combinations performed the best in most agronomic parameters like biomass yield, and chemical compositions. It is recommended for fodder production in the studied area and related agro-ecologies to enhance dry season feed shortage and improve livestock productivity. When rowing oats for seed purposes, it is preferable to use oats in a pure stand as it gives a comparatively higher seed yield. Furthermore, the impact of oats and alfalfa inter cropping on animal performance should be investigated (feeding trial).

Author Statements

Credit Authorship Contribution Statement

Daniel Wana: writing – review and editing, performed the experiment, and methodology. Metikia Tamiru: advising – review and editing. Jane Wamatu: advising – review and editing.

Data Availability

Data will be made available on request

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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