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Agronomic performance, yield, and compatibility of intercropped sudan grass *(sorghum sudanense)* and vetch *(vicia dasycarpa)* with different seed ratio

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Intercropping is used to boost forage production potentials and as a result increases the productivity of forage biomass per unit area. To evaluate the agronomic performance and compatibility of Sudan grass (Aden-gode) and vetch (Vicia dasycarpa) intercropping in different seed rate proportion. The experiment has five (5) seed rate proportion treatments (100%, 75%:25%, 50%:50%, 25%:75%, and 100%) intercropped with three replications. All data of both grown forages were recorded from four middle rows (4^{th}, 5th, 6th, and 7th) of ten (10) plants with a total of 3.6m^2 area to determine forage yield. Subsamples were weighted, dried, and then grounded for chemical composition analyses. All recorded data were subjected to the GLM procedure of SAS (9.0). The results showed most of agronomic, dry matter yield, and compatibilities of grown forages were significantly (P<0.05) affected, while stem thickness, root length, and root length of vetch were not significantly (P>0.05) affected. The highest total DMY and CPY (13.21t/ha and 2.08t/ha) and the lowest total DMY and CPY (5.04t/ha and 0.47t/ha) were found from 75%:25% seed rate treatment, respectively. LER was greater than one (>1) and Sudan grass had less competitive and aggressively in 75%:25% seed rate treatment. production of 75%:25% seed rate intercropping would be more beneficial to produce optimum forage yield and better nutritive value.

Keywords: **Intercropping, Seed rate, Sudan grass, Vetch.**

INTRODUCTION

Ethiopia has the largest livestock population in Africa with an estimation of 70 million cattle, 42.9 million sheep, 52.5 million goats, 13.33 million equines, 8.1 million camels, and 57 million poultries (CSA, 2021). Livestock production has been contributing a substantial portion to the economy of the country (CSA, 2021). Therefore, livestock sectors contribute about 16.5% of the national GDP and 47% of the agricultural GDP (IGAD, 2011). Animal production is the main component of agriculture that can support the livelihoods and security of large numbers of people in a developing country (Mengistu *et al.,* 2021). However, insufficient animal production is mainly due to less nutritional and management practices, disease and parasitic occurrence, low productivity and genetic potential, lack of extension services (Haile *et al.*, 2011). Among these constraints, inadequate quantity and quality feedstuff was identified as a major limiting factor to the development of livestock production and productivities (Duguma *et al*., 2012) and the most bottleneck of livestock farming in Ethiopia is the shortage of livestock feeds in terms of amount and quality, especially during the dry season (Alemayehu Mengistu, Gezahagn Kebede, 2017).

The livestock feed resources in Ethiopia are classified as natural pasture, crop residues, improved pasture and forage, agro industrial by products, and also hay production (Central statistical agency (CSA), 2021; Jimma A, Tessema F, 2016) of which the first two feed resources are the major feed contributors for the livestock production in Ethiopia but they are lacking in protein and minerals. Improved forage development practices in our country was more related to the objective to increase improved forage production (Shiferaw *et al*., 2018). Therefore, intercropping is used to boost forage production potentials. Intercropping is the production of two or more companion forages in the same field concurrently, and as a result increases the productivity of forage biomass per unit area through efficient use of soil nutrients and water resources (Alla *et al*., 2014). Intercropping has its advantages on the productivity of forage, solving the land shortage, yield stability, pest control, and nutrient use efficiency (Gebru, 2015).

Among potential forage grasses that required knowledge is Sudan grass. Sudan grass has been gaining increasing importance in animal feed, due to its ease of cultivation, rapid establishment, and growth (Guleria &

Kumar, 2016; Najmaldin & Ali, 2019). (Gunjan & Naveen, 2016; Moyer *et al.*, 2004) stated that Sudan grass could be used for grazing, and for silage due to its high production (5.56-9.1t/ha DM) potential especially in drought. Trials at numerous places have demonstrated that Sudan grass promises high value for hay with a 12.98% CP (Lima *et al*., 2017). Similarly (Mut, 2017) stated that Sudan grass had highest crude protein content that sown with Cow pea (11.73%) compared to its sole (8.16%). Sudan grass can be intercropped with legumes such as cowpea cluster bean, soybean, etc. which are compatible with Sudan grass in terms of sowing time and irrigation (Iqbal *et al*., 2015).

Among the annual forage legumes, vetches are well adapted and more promising as short-term fodder crops in Ethiopia (Fantahun Dereje, 2016; Kebede *et al.*, 2020). Forage legumes including vetches are a rich source of nitrogen for livestock with cheaper prices compared to concentrates, especially in developing countries (Tsige, 2014). Knowing information on plant height, days to maturity, growth habit, and other growth characteristics of the forage legumes are important to integrate with other forages (Kebede *et al.*, 2013). Therefore, *Vicia dasycarpa, Vicia villosa,* and *Vicia atropurpurea* have creeping growth habit, tall plant height, and intermediate to late maturity (Kebede *et al.*, 2013). Vetch species which has creeping or climbing growth habit has better compatibility with large grasses in the intercropping (Kebede, 2018; Kebede *et al*., 2020). Therefore, the objective of this study was aimed to assess the agronomic, forage yield, and chemical composition of Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping grown under irrigation conditions in the study area.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted in Kudmi kebele, North Mecha district, Amhara Region, Ethiopia. The study area is 34 km far from Bahir Dar, the capital of the Amhara region, and situated 500 km northwest of Addis Ababa, the capital of Ethiopia. Mecha district is located at an elevation of 1800–2500 m.a.s.l. The experimental kebele (Kudmi) is located 11⁰21'0" to 11⁰24'0" N latitude and 37⁰6'0" to 37⁰9'0"E longitude. Based on six month (December 2021-May 2022) of forage growing season, the area has an average monthly maximum temperature ranges between 28.9 and 29.4°C with a mean value of 29.2°C and the average monthly minimum temperature of the area ranges between 9.1 and 9.9°C with a mean value of 9.5°C. The rainfall of the area in six month ranges between 0 and 3.9 mm with a mean value of 0.8 mm (Bahir Dar National Meteorological Agency). From the total area coverage of the district, 5,927 ha which is 4% is addressed by the Koga irrigation command area (Eyasu Elias, 2016). The soil in the district is dominated by red soil (nitisol).

Site selection, land preparation, and management practices

The experimental site was selected purposely based on the potential for forage production and irrigation capacities of the area. After selecting the experimental site, the land was cleaned and harrowed. The land was leveled out to maintain a well prepared seedbed. The cultivars of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) were purchased from Debre Birhan and Gondar agricultural research centers, respectively and sown in deep soil cover on a well-prepared seedbed. The sowing plots were irrigated three times per week and weeding management was held by hand weeding practice. Follow-up activities were held throughout the experimental period (until forages were harvested).

Experimental design and treatment allocation

Experimental design and treatment allocations were employed using a randomized complete block design (RCBD). Plant materials have consisted of Sudan grass (Aden-gode) and vetch species (*Vicia dasycarpa*) with five seeding rate proportions (100%, 75%:25%, 50%:50%, 25%:75%, 100%) of Sudan grass (Aden-Gode) and vetch (*Vicia dasycarpa*), respectively and it was intercropped under three (3) replications. The experiment has a total of fifteen (15) experimental units. Therefore, the experimental area was laid down by using a 3, 4, and 5 triangular method and the total experiment size was 288m² (24m*12m) with 12m² (4m*3m) individual plot size (Appendix 7.3). The space between plot and block was 1m and 1.5m respectively. 25 kg/ha for vetch (*Vicia dasycarpa*) of and 10 kg/ha (Webb *et al.*, 2010) of Sudan grass (Aden-gode) were sown in each experimental plot with respective to their seed rate proportions. The vetch species was intercropped between two consecutive rows of Sudan grass which have 30 cm space between the vetch species and Sudan grass and also one plot had 10 rows. The two varieties of grown forages of Sudan grass (Aden-gode) and vetch species (*Vicia dasycarpa*) were sown at the same time.

Table 1. Treatment setup of the Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) intercropping

Treatments	Intercropping seed rate
T1(Sole Sudan grass)	100% S
T2	75% S:25% V
T3	50%S:50% V
T4	25%S:75% V
T5 (Sole vetch)	100% V

T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, S= Sudan grass (Aden-gode), V= Vetch (Vicia dasycarpa), kg/ha= kilogram per hectare

Data collection

Agronomic parameters were collected at the first heading stage for Sudan grass (Enchev, 2021) and vetch species when it reaches the fifty percent flowering stage and ten plants from each Sudan grass and vetch species were randomly selected from the middle rows of each plot leaving outer edge rows due to border effect. Therefore the following agronomic data were measured and recorded methodically.

Agronomic parameter data collection methods

Plant Height of both forages were measured using measuring tap meter from the soil surface to the tips of the tallest leaf (Natural standing height) for Sudan grass (Rayburn et al., 2007). Stem thickness (stem circumference) was measured by using measuring tap meter after avoiding all leaves from the steam. Leaf width was measured by ruler from three parts of the leaf; at the base of the leaf blade, at the middle of the leaf, and below the tip parts of the leaf according to (Van Arendonk & Poorter, 1994). The root length was measured from the crown root part to the tip of the longest root for Sudan grass (Aden gode) and from the base of the branch root part to the tip of the tap root for vetch (*Vicia dasycarpa*). Number of Leaf per Tiller and Number of Tillers per Plant of sudan grass (Aden gode) was counted and the mean was calculated. Root Number, Branch number, and Number of Nodules of vetch (*Vicia dasycarpa*) were counted and mean was recorded. Leaf to stem ratio was determined through leaves and stems were alienated carefully and the fractioned subsample of leaf and stem were dried and then dividing leaf dry weight to stem dry weight (Nguku *et al.*, 2016).

Sampling methods for fresh biomass and dry matter yield (ton/ha)

Fresh biomass was collected for vetch species when it reaches the fifty percent flowering stage and first heading stage for Sudan grass (Enchev, 2021). Four middle rows (4^{th}, 5^{th}, 6^{th}, and 7^{th}) with a net harvestable area of ($3.6m^2$) per plot. Fresh biomass yield was measured using field balance for each sole and both components in the intercropping. The dry matter percentage was determined through the dry weight of the subsample divided by the weight of the fresh subsample and multiplied by 100. The dry matter yield (DMY) of forage grown in the study area was calculated through (Tarawali, 1995) formula, (10×TFW×DWss/(HA×FWss)). Therefore, CPY was determined through multiplying DMY with the CP content of the feed samples.

Biological compatibility

Land equivalent ratio (LER)

Land equivalent ratio (LER) was determined as the sum of the two fractions of the yield of the intercrops relative to their sole crop yields according to the following formula (Willey, 1979).

$$LER = \frac{YsI}{YsS} + \frac{YvI}{YvS}$$

Where,

LER = land equivalent ratio

YsI = yield of Sudan grass in intercropping

YsS = yield of Sudan grass in sole cropping

YvI = yield of vetch species in intercropping

YvS = yield of vetch species in sole cropping

Competitive ratio (CR)

The following formulas can be used to determine the CR (Fuller, 2017).

$CRs = (LERs/LERv) \times Zvs/Zsv)$

$CRv = (LERv/LERs) \times (Zsv/Zvs)$

$CRs/CRv = (LERs/LERv) \times Zvs/Zsv)/ (LERv/LERs) \times (Zsv/Zvs)$

Where;

CRs and CRv = competitive ratio of Sudan grass and Vetch,

$LERs$ and $LERv$ = the Land Equivalent Ratio of Sudan grass and Vetch

Zsv = Sown ratio of Sudan grass in the intercropping

Zvs = sown ratio of Vetch in the intercropping

Aggressiveness (A)

The aggressiveness of Sudan grass and vetch in this experiment was determined by using the dry matter yield of both forages. The following formula (Kingwell-Banham, 2015) was used to calculate the aggressiveness of forage grown in the experiment.

$$Asv = \frac{Ysv}{Ys*Zsv} - \frac{Yvs}{Yv*Zvs}$$

Where;

Asv = the Aggressiveness of Sudan grass and vetch

Ysv = dry matter yield of Sudan grass in the intercropping

Yvs = dry matter yield of Vetch in the intercropping

Ys and Yv = dry matter yield of Sudan grass and vetch on their sole stand

Zsv and Zvs = Intercropping proportion of Sudan grass with vetch and vetch with Sudan grass, respectively

Nutritive value determination

The nutritive value of the forage samples were carried out at Bahir Dar University, Animal nutrition laboratory. Fresh subsamples were dried in a forced-air draft oven at 65°C for 72 hours for partial dry matter determination and other chemical composition analysis. The dried samples were ground with a mill and allow passing a 1mm Aperture width sieve (Zaklouta et al., 2011). Representative grounded samples were subjected to chemical analysis following the methods(AOAC, 1990) to determine nitrogen (N) (Kjeldahl procedure). Crude protein was determined through determine nitrogen contents of sample forages and multiply by 6.25.

Statistical analysis

SAS version 9.0 software package was used for checking data normality and analysis. The general linear model procedure (Proc GLM) of the statistical analysis system was used to analyze all variables. Data on morphological characteristics, total DM yields, and compatibility were subjected to Analysis of Variation (ANOVA). Significant (P<0.05) differences between treatment means were compared by applying the Least Significant Difference option of the SAS package. Pearson correlation (r) was used to describe the relationships between agronomic, dry matter yield, and nutritive value. The model for data analysis was:-

$$Y_{ijk} = \mu + B_i + S_j + e_{ijk}$$

Where:

Y_{ijk} = result from variable of agronomic characteristics, forage yield, and biological compatibility

μ = over all mean

B_i = block effect

S_k = treatment effect (seed rate effect) in the Sudan grass and vetch intercropping

e_{ijk} = experimental error effect.

RESULTS

Effects of seed rate on agronomic performance of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*)

All morphological parameters of Sudan grass (Aden gode) were significantly (P<0.05) affected by seed rate other than root length and stem thickness as presented in Table 2.

Plant height

Plant height in the current study was significantly (P<0.05) affected by intercropping seed rate treatments. The highest plant height (161.17cm) was recorded in 75%:25% of seed rate intercropping. The shortest plant height (144.03cm) was recorded from Sudan grass sown alone. Highest plant height (161.17cm) recorded from 75%:25% seed rate of Sudan grass (Aden gode) was greater than the finding of (Asem et al., 2020) they found (145cm) plant height recorded from 100%:25% Sudan grass (*Sorghum sudanese*) and cow pea (*Vigna unguiculata*) intercropping.

Number of tiller per plant

The number of tillers per plant in present study was significantly (P<0.001) influenced by the Seed rate intercropping as shown in Table 2. The greater number of tillers per plant (19.67) was recorded from 75%:25% while, the lowest numbers of tillers per plant (5.67, & 7.33) was obtained from Sudan grass (Aden gode) sown alone and from 25%:75% seed rate intercropping treatments, respectively. The highest value of numbers of tiller per plant (19.67) was due to legumes *i.e.* vetch (*Vicia dasycarpa*) able to fix atmospheric nitrogen.

Leaf to stem ratio

Leaf to steam ratio is the most essential factor which helps determine the digestibility and palatability of any forages. Leaf to stem ratio of the current result was statistically significant (P<0.001) on seed rate intercropping treatment (Table 2). In the current study, the highest leaf to steam ratio (2.05) was obtained from 75%:25% seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*). The lowest value of leaf to stem ratio (1.50) was found from 25%:75% seed rate intercropping treatment plot. Leaf number per tiller, leaf length, leaf width, and tiller number is the most important characteristics used to determine the leaf to stem ratio and forage quality.

Plant height

Statistically, plant height of vetch (*Vicia dasycarpa*) was significantly (P<0.001) affected by intercropping of seed rate with Sudan grass (Aden gode) in present study (Table 2). In the present results, the highest plant height (136.23cm) was obtained from the 75%:25% seed rate intercropping treatment. Whereas, shortest plant height (109.85cm) was obtained from 100% seed rate of vetch (*Vicia dasycarpa*) sown as a pure stand. The highest value of plant height in the current result was due to the intercropping and light competition within inter-species and might be increasing plant height.

Number of branches

The number of branches in legume forage production is more important for increasing the forage biomass and dry matter yield. Number of branches in the current study was statistically significant (P<0.001) within seed rate intercropping treatment. Highest value of branch number (27.00) was obtained from 50%:50% seed rate intercropping treatment. Whereas the lowest branch number (9.33) was obtained from 100% vetch (*Vicia dasycarpa*) sown alone. Numbers of branches were decreased with increasing seed rate in intercropping due to intra-species nutrient competition. This might be due to the reason increasing seed rate may be decreasing branch number. The highest branch number in 50%:50% treatment might be due to the reason less nutrient competition between and within species.

Number of nodules

Root nodules have more importance for nitrogen acquisition through symbiotic nitrogen fixation in the leguminous plants. Root nodules are also used for converting atmospheric nitrogen into soluble nitrogenous compounds and used for increasing leguminous forage production as well as grass forages when intercropping with leguminous forage plants. Therefore, root nodules in the present study was statistically significant (P<0.001) variations were observed under seed rate intercropping treatments (Table 2). Significantly higher root nodules (31.67) were obtained from the 75%:25% seed rate intercropping treatments. Whereas, the smallest number of root nodules (11.01) obtained from 100% seed rate vetch (*Vicia dasycarpa*) sown as a pure stand. This greater number of root nodules in the present study was due to intra-species competition could be decreasing root nodules.

Biological compatibility of Sudan grass and vetch species in intercropping

Land equivalent ratio

Land equivalent ratio (LER) was used to evaluate the

Table 2. Morphological parameters of sole and intercropped Sudan grass and vetch

	Measured Parameters					
	Sudan grass (Aden gode)			vetch (*Vicia dasycarpa*)		
Treatments	PH (cm)	NTPP(count)	LSR	PH (cm)	NBr (count)	NN (count)
T1(Sole Sudan grass)	144.03^{c}	5.67^{c}	1.8^{ba}	-	-	-
T2	161.17^{a}	19.67^{a}	2.05^{a}	136.23^{a}	19.00^{b}	31.67^{a}
T3	156.3^{ba}	13.67^{b}	1.66^{bc}	127.33^{b}	27.00^{a}	26.09^{b}
T4	151^{bc}	7.33^{c}	1.50^{c}	117.33^{c}	15.67^{b}	17.03^{c}
T5 (Sole vetch)	-	-	-	109.85^{d}	9.33^{c}	11.01^{d}
Over all mean	153.13	11.58	1.75	122.69	17.75	21.42
SEM (±)	3.05	0.80	0.06	1.16	0.82	0.94
CV%	3.03	16.34	7.35	1.85	9.98	7.26
R^2	0.84	0.95	0.84	0.97	0.96	0.98
LSD	9.28*	3.78***	0.23**	4.55***	3.54***	3.11***

NBr = Number of Branch, NN = Nodule Number

Table 3. Biological compatibility of Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) in intercropping

	Land Equivalent Ratio			Competitive ratio			Aggressiveness		
Treatments	LER_S	LER_V	LER_T	CR_S	CR_V	CR_S/CR_V	A_S	A_V	A_S -A_V
T2	1.52^{a}	0.69^{a}	2.21^{a}	0.73^{b}	1.36^{a}	0.55^{a}	2.02^{b}	2.73^{a}	-0.71^{b}
T3	1.21^{ba}	0.48^{a}	1.68^{ba}	2.55^{a}	0.41^{b}	6.80^{a}	6.08^{a}	2.4^{a}	3.68^{a}
T4	0.77^{b}	0.78^{a}	1.55^{b}	3.12^{a}	0.34^{b}	10.52^{a}	3.09^{b}	1.04^{b}	2.05^{a}
Mean	1.17	0.65	1.81	2.13	0.71	5.95	3.73	2.06	1.67
CV%	17.41	23.05	14.50	34.98	22.42	18.53	16.89	20.21	54.49
LSD	0.46*	0.34^{NS}	0.59**	1.69*	0.36**	2.18^{NS}	1.43**	0.94*	2.06**

*T2=Treatment two, T3=Treatment three, T4=Treatment four, LERs = Land Equivalent Ratio of Sudan grass, LERv = Land Equivalent Ratio of vetch, LER_T = Total Land Equivalent Ratio, CR_S = Competitive ratio of Sudan grass, CR_V = Competitive ratio of vetch, A_S = Aggressiveness of Sudan grass, A_V = Aggressiveness of vetch, a & b = level of mean difference, CV = Coefficient of Variation, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01)*

output efficiency of intercropping. Significantly (P<0.01) land equivalent ratios were higher LER_S of Sudan grass (Aden gode) than intercropped vetch (*Vicia dasycarpa*) as shown in Table 3.

This was due to highest dry matter yield recorded and yield advantage was observed from this intercropped seed rate treatment.

Competitive ratio

The CR expresses the frequency with which one component crop is more competitive than another. When CR_S/CR_V <1, there is a benefit since there is less competition between the component crops, allowing them to be cultivated as intercrops. There is a negative effect if the CR value is more than one (CR_S/CR_V >1). Sudan grass (Aden gode) significantly (P<0.05) had less competitive in 75%:25% seed rate intercropping than others and had higher dry matter yield compared to other intercropping treatments.

Dominance of aggressiveness

Aggressiveness (A) zero means, neither of the forages is thought to be aggressive or both forages are equally capable of competing. Hence, in recent study significantly (P<0.01) Sudan grass (Aden gode) was aggressive over intercropped vetch (*Vicia dasycarpa*) where aggressiveness is positive in all intercropped treatment except 75%:25% intercropping treatment. Vetch (*Vicia dasycarpa*) in 75%:25% intercropped treatment was aggressive or dominant over Sudan grass (Aden gode) where A_T value turns negative. Whereas, A_T in a recent study (Table 5), revealed the aggressiveness of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) was less at 75%:25% intercropping. This might be due to less inter-species competition in 75%:25% seed rate and increasing inter-species competition in 50%:50% and 25%:75% seed rate intercropping.

Effects of seed rate on dry matter yield and crude protein yield

Seed rate intercropping of Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) in the current study was statistically significant (P<0.01, P<0.05, and P<0.001) on Sudan grass dry matter yield, vetch dry matter yield, and total dry matter yield, respectively as shown in (Table 4). Meanwhile, 5.75±0.37, 5.77±0.28, and 9.21±0.53 mean values of DMYt/ha of Sudan grass, vetch, and Total (Sudan grass and vetch intercropping) was obtained from all seed rate intercropping treatment, respectively as shown in Table 4.

Dry matter and crude protein yield of sudan grass (aden gode)

Dry matter yield of Sudan grass (Aden gode) in present study was statistically significant (P<0.01) on seed rate intercropping as shown in Table 4. The mean value (5.75±0.37t/ha) dry matter yield of Sudan grass (Aden gode) was obtained in present study. The highest value of DMY (7.84t/ha) of Sudan grass (Aden gode) in the current study was harvested from 75%:25% seed rate intercropping plots. Whereas, lowest DMY (4.02t/ha) was found from 25%:75% seed rate intercropping compared to the Sudan grass (Aden gode) sown as a pure stand. This might be due to the reason, increasing in plant height, number of leaves per tiller, number of tillers per plant, and other morphological parameters of Sudan grass (Aden gode) could be increasing forage yield in 75%:25% seed rate intercropping treatment. On the other hand, the dry matter yield (6.10t/ha) was revealed from 50%:50% seed rate intercropping that compared to dry matter yield (5.04t/ha) harvested on Sudan grass (Aden gode) sown as a pure stand. The harvested dry matter yield in the current study was relatively highest in intercropping Sudan grass (Aden gode) than from its alone. Dry matter yield in the current study show that relatively increasing when decreasing seed rate in intercropping. And then, decreasing the dry matter yield was observed when seed rate intercropping becomes low. Therefore, to low seed rate leads to decreasing the dry matter yield and also pure stand cultivation might be decreasing dry matter yield.

Crude protein yield was significantly (P<0.01) affected by seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) as shown in Table 4. From these significant results, the highest CP yield (0.96t/ha) was found from 75%:25% seed rate intercropping treatment followed by 50%:50% (0.70t/ha), 100% (0.47t/ha), and the lowest value of CP yield was found from 25%:75% (0.40t/ha) seed rate intercropping treatment with a mean value of CP yield (0.63±0.06t/ha). Relatively, crude protein yields were increased with decreasing seed rates of Sudan grass (Aden gode) in intercropping. The difference in crude protein yield observation was due to the seed rate intercropping effect. Whereas, the variations of crude protein yield in the present study might be due to the variations of crude protein contents and dry matter yield difference.

Dry matter and crude protein yield of vetch (*Vicia dasycarpa*)

Dry matter yield of vetch (*Vicia dasycarpa*) was statistically (P<0.05) influenced by seed rate intercropping (Table 4). Significantly higher dry matter yield (7.89t/ha) was found from 100% seed rate of vetch sown as a pure stand compared to intercropping vetch as shown in (Table 5). Whereas, the lowest dry matters yield (3.62t/ha) was found from 50%:50% vetch intercropping with Sudan grass. These significant variations was due to increasing seed rate would have able to increase dry matter yield. Intermediate dry matter yields (6.19 & 5.37t/ha) were found from 25%:75% and 75%:25% of vetch (*Vicia dasycarpa*) seed rate intercropping with Sudan grass (Aden gode), respectively. In the recent study, the highest dry matter yield was obtained from pure stand plots of vetch (*Vicia dasycarpa*) than the other intercropping seed rate treatments.

Crude protein yield was significantly (P<0.05) affected by seed rate intercropping of vetch (*Vicia dasycarpa*) with Sudan grass (Aden gode). Crude protein yield (CPY) is the result of the plant total dry matter yield multiplied by the concentration of CP, which is supported by the numbers acquired from CP percent and the dry matter yield derived from each treatment. Sole vetch (*Vicia dasycarpa*) and 25%:75% seed rate treatments were not significantly different with having higher CP yield (1.39 & 1.33t/ha) whereas, 1.12t/ha CP yield was found from 75%:25% treatment and lowest CP yield (0.90t/ha) was recorded from 50%:50% with the mean value of 1.18±0.07t/ha. This CP yield difference is due to the seed rate in intercropping had its value to increasing CP yield.

Total dry matter and total crude protein yield of forage grown

Total dry matter yield in the recent study was significantly (P<0.001) affected by seed rate intercropping (Table 4). The mean dry matter yield (9.21±0.53t/ha) was obtained from seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) and from both sole sown forages. Highest dry matter yield (13.21t/ha) was found from 75%:25% seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) in the current result as shown in Table 4. This might be attributed from highest values of measured morphological parameters in 75%:25% seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) and are responsible for increased total dry matter yield. Whereas, no significant mean differences of dry matter yield between 50%:50% and 25%:75% seed rate intercropping treatments as shown in Table 4. On the other hand, lowest total dry matter yield (5.04t/ha) was obtained from Sudan grass (Aden gode) sown as a pure stand (100% seed rate) and it is lower than the dry matter yield (7.89t/ha) obtained from vetch sown as alone. This was due to legume forages had higher dry matter yield than the grass forage species.

Total crude protein of the forage grown was significantly (P<0.001) affected by seed rate treatments and higher total CPY (2.08t/ha) was obtained from 75%:25% seed rate treatment, while no statistically mean difference was observed between 50%:50% and 25%:75% seed rate treatments. Lowest values of total CPY (0.47 and 1.39t/ha) was obtained from both sole Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) seed rate treatments, respectively. The variation of total CPY between seed rate treatments was attributed from morphological difference of both forages. High total CPY (2.08t/ha) obtained from 75%:25% seed rate treatment was due to better morphological characteristics of both forages grown under irrigation and also might be due to legumes could be enhance CP content of grass in the intercropping.

Table 4. Dry matter and crude protein yields of Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) on their alone and intercropping

	Sudan grass		vetch		Total	
Treatments	DMYt/ha	CPYt/ha	DMYt/ha	CPYt/ha	DMYt/ha	CPYt/ha
T1(Sole Sudan grass)	5.04^{c}	0.47^{cb}	-	-	5.04^{d}	0.47d
T2	7.84^{a}	0.96^{a}	5.37^{c}	1.12^{b}	13.21^{a}	2.08a
T3	6.10^{b}	0.70^{b}	3.62^{d}	0.90^{b}	9.72^{b}	1.61b
T4	4.02^{d}	0.40^{c}	6.19^{b}	1.33^{a}	10.21^{b}	1.73b
T5 (Sole vetch)	-	-	7.89^{a}	1.39^{a}	7.89^{c}	1.39c
Over all mean	5.75	0.63	5.77	1.18	9.21	1.44
SEM (±)	0.37	0.06	0.28	0.07	0.53	0.09
CV%	14.46	20.50	16.24	13.35	12.08	11.52
R^2	0.84	0.85	0.87	0.75	0.89	0.95
LSD	1.68^{**}	0.26^{**}	1.98^{*}	0.32^{*}	2.16^{***}	0.32^{***}

*T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, DMYt/ha = Dry Matter Yield in ton per hectare, CPYt/ha = Crude protein yield in ton per hectare, SEM = Standard Error of Mean, CV% = Coefficient of Variation percent, R^2 = Coefficient of determination, a, b & c = level of mean difference, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01), *** (p<0.001)*

DISCUSSION

Plant height

Highest plant height (161.17cm) recorded from 75%:25% seed rate of Sudan grass (Aden gode) was greater than the finding of (Asem et al., 2020) they found (145cm) plant height recorded from 100%:25% Sudan grass (*Sorghum sudanese*) and cow pea (*Vigna unguiculata*) intercropping. The same result was found by (Basaran *et al*., 2017) and their results showed that plant height was significantly affected by intercropping seed rate (100%:100%; 50%:100%, 100%:50%) of Sudan grass hybride (Aneto) with cow pea (Ulkem) and soybean varieties. The increasing plant height in intercropping forages from forages grown alone might be due to the reason competition of associated forages to light and resulted in increasing plant height. On the other hand, the shortest plant height (144.03cm) was obtained from Sudan grass sown alone. This result is also similar with the authors (Mekasha *et al*., 2020) who showed that decreasing in plant height with increasing seed rate of forage Sorghum (*Sorghum bicolar L*.). These results might be due to high plant density in a specific area causing for intra-specific nutrient competition.

Number of tiller per plant

The highest value of numbers of tiller per plant (19.67) was due to legumes *i.e.* vetch (*Vicia dasycarpa*) able to fix atmospheric nitrogen and this was supported by the authors (Shahrajabian *et al*., 2021) who showed plant density had a significant effect on the numbers of tillers per plant. This significant result was also in line with the finding of (Moosavi, 2012) who revealed that significant effect of plant density on the number of tillers per plant. Tiller numbers (19.67) found in the current study was highly comparable with the finding of (Lopes *et al*., 2020) who showed that 19.50 tiller number was obtained from Sudan grass cultivars. Meanwhile, this result was supported by (Moosavi, 2012) who outlined that significantly decreasing tillers number per plant was observed with increasing seed rate density. This result was due to the reason less translocation of assimilates towards lower parts of the plants.

Leaf to stem ratio

The current results of leaf to stem ratios (1.50-2.05) were in line with the finding of *(Millner et al.*, 2011) who outlined that leaf to stem ratio ranges (1.6-2.1) from Sudan grass varieties. The current result was greater than the value of leaf to steam ratio studied by (Ates & Tenikecier, 2019) who observed that nitrogen levels had a significance result in the leaf to stem ratio (0.69 and 0.71) of two varieties of Sorghum-Sudan grass Nutri Honey and Aneto, respectively. Greater leaf component clearly suggests its potential for carbon sequestration by absorbing and lowering atmospheric CO_2 levels, and larger leaf to stem ratio strongly suggests its competitive advantage to light for photosynthesis.

Plant height

In contrast to present study, the plant height of common vetch (*Vicia sativa* L.) was insignificant (P>0.05) with Sudan grass (*Sorghum sudanense* (Piper.)) intercropping in different row configuration as shown by (Erkovan, 2022). Plant height of vetch (*Vicia dasycarpa*) was significantly (P<0.001) affected by intercropping of seed rate with Sudan grass (Aden gode) and the mean value of plant height (122.69cm) was obtained in the current study. Plant height of vetch species noted by the authors (Desalegn & Hassen, 2015) was statistically significant (P<0.05) and 130cm of vetch (*Vicia dasycarpa*) was obtained and compared with the current study of plant height (136.23cm). These result was also in line with the finding of (Denekew *et al*., 2005) who noted that the plant height (131.15cm) of vetch (*Vicia villosa*) was intercropping with maize in Mecha woreda. In contrast, the smallest (73.32cm) vetch (*Vicia dasycarpa*) was obtained by the authors (Eshetie Alemu, 2018) from oats–vetch mixtures at different harvesting stages. This less plant height was due to both vetch and the component grass genetic variation, and environmental.

Number of branches

The number of branches (17.75±0.82) in the current study was significantly higher than the result obtained by (Malede Birhan, 2018) who noted that the mean value of branch number of vetch (*Vicia villosa* R.) mixture with Triticale (*Xtriticosecale wittmack*) in different seed rate proportion in North Gondar Ethiopia. In contrast, the highest value of number of branch (14.62) was found from the 100% vetch sown as a pure stand as noted by the author (Malede Birhan, 2018) whereas, the greater value of branch number (27.00) was obtained from 50%:50% seed rate intercropping treatment in present study. This variation was due to environmental factors, soil type, and also might be the component grass variations.

Number of nodules

Root nodules in the present study was a significant difference among seed rate treatments similar to the finding of (Kosev & Vasileva, 2018). A recent study of root nodule numbers ranged from (11.01-31.67) which was higher than nodule number of vetch varieties ranged from (26.47-29.73) noted by the authors (Kosev & Vasileva, 2018). In addition, lowest nodule numbers (11.3-13.33) were obtained by the scholar (YANG YONG, 2017) intercropping of common vetch with oat compared to the recent study of seed rate intercropping with Sudan grass.

Biological compatibility of Sudan grass and vetch species in intercropping

Land equivalent ratio

These positive effects of LER_T on seed rate intercropping were similar to the finding of (Hassan *et al.*, 2017) who noted that the yield advantage was obtained from Sudan grass (*Sorghum sudanense* ((P.) Staph) intercropped with cow pea (*Vigna sinensis* L.), guar (*Cyamopsis tetragonoloba* L.), and lima bean (*Phaseolus vulgaris* L.). LER_T in current results ranged from 1.55 to 2.21 and it was higher than the scholars (Dariush et al., 2006) who revealed that LER_T (1.70-1.89) obtained from Sorghum intercropped with legumes and had yield advantage of intercropping over pure stand forages. The higher LER_T (2.21) was obtained from 75%:25% seed rate intercropping and this indicated that almost 121% of more land would be required for plants the sole forages to produce the same amount of dry matter yield.

Competitive ratio

In all other seed rate intercropping, the values of CR_S were mostly greater than the value of CR_V in the recent study and it is in line with the finding of (Hassan *et al.*, 2017) noted that Sudan grass (*Sorghum sudanense* ((P.) Staph) more competitive than cow pea (*Vigna sinensis* L.), guar (*Cyamopsis tetragonoloba* L.), and lima bean (*Phaseolus vulgaris* L.). Sudan grass was more competitive in 25%:75% and vetch (*Vicia dasycarpa*) in 75%:25% seed rate intercropping. Therefore, the value of CR_S/CR_V (0.55) was obtained from 75%:25% treatment and yield advantage was observed in this treatment. Recent results were in line with the previous scholars (Abuneran, 2013; Al-Bakri *et al*., 2003; Singh & Tarawali, 2007).

Dominance of aggressiveness

Similar results were observed by the authors (Nabi *et al*., 2006; Vermam *et al*., 2005) showed that intercropping space of forage sorghum (*Sorghum bicolor*) with pigeon pea (*Cajanus cajan*) had significantly effect on aggressiveness (0.53). The study of (Oseni & Aliyu, 2010) who showed that forage sorghum (*Sam-sorg* 10) intercropped with cow pea (*Yar-Itas*) under different intercropping, forage sorghum remained the dominant of aggressiveness.

Effects of seed rate on dry matter yield and crude protein yield

Dry matter and crude protein yield of Sudan grass (Aden gode)

Dry matter yield of Sudan grass (Aden gode) was statistically significant ($P<0.01$) differences on seed rate treatments in intercropping as shown in Table 4. This significant difference was confirmed by (Hassan *et al*., 2017) who reported that intercropping pattern significantly increases dry forage yields. In addition, the scholars (Basaran *et al*., 2017) who showed that intercropping Sudan grass hybride (Aneto) and cow pea (Ulkem) had highest dry matter yield in intercropping than Sudan grass hybride (Aneto) sown as alone. This could be due to legumes have the ability to fix atmospheric nitrogen and provide nutrient for intercropping grass as noted by (Abera *et al*., 2022) conducted research on herbage accumulation and nutritive value of mixtures of desho grass (*Pennisetum glaucifolium*) and *Vicia spp*. in southern Ethiopia.

These results were in agreement with the results of (Ginwal *et al*., 2019). But, decreasing dry matter yield was observed when decreasing seed rate as shown in Table 4. This result also in line with the finding of (Shahrajabian *et al.*, 2021) who stated that seed rate has a significant effect on dry matter yield and they reported that when decreasing seed rate in intercropping may decreasing the dry matter yield tone per hectare. The greater dry matter yield in present study was due to sowing rate has an extremely critical value for increasing dry matter yield.

Similarly, (Hassan *et al.*, 2017) who noted that crude protein yields were significantly affected by the intercropping pattern of Sudan grass (*Sorghum sudanense* ((P.) Staph) intercropped with (*Vigna sinensis* L.), guar (*Cyamopsis tetragonoloba* L.), and lima bean (*Phaseolus vulgaris* L.). In addition, authors (Abera et al., 2022) showed that significantly increased crude protein yield was observed in Desho (*Pennisetum pedicellatum*) intercropped with vetch species. In contrast, higher protein yield (1.27t/ha) was found from sole Sudan grass compared to the present CP yield (0.47t/ha) of sole Sudan grass (Aden gode) as well as in intercropping of Sudan grass (Aneto) with cow pea (Ulkem) and soybean (Yemsoy) ranges from 1.31-2.16t/ha (Basaran et al., 2017). This could be crude protein yield per unit area is mostly dependent on dry matter production. These results demonstrate that to achieve high yield and quality in intercropping, the sowing rate in intercropping are crucial factor as noted by previous scholars (H. Alla *et al*., 2015).

Dry matter and crude protein yield of vetch (*Vicia dasycarpa*)

The mean value of DMY (5.77±0.28t/ha) in the present result was higher than the DMY (0.29±0.10t/ha) obtained by (Asefa, 2012) of vetch (*Vicia villosa*) intercropped with Maize (*Zea mays*) in Northwest Ethiopia. Recent results of dry matter yield revealed that increasing of vetch seed rate would have increased dry matter yield but decreased in 50%:50% seed rate, similar to the finding of (Sun *et al*., 2014). This might be due to the competition of vetch on light, temperature, and other nutrient resources in the intercropping.

In the recent study, the highest dry matter yield was obtained from pure stand plots of vetch (*Vicia dasycarpa*) than the other intercropping seed rate treatments. The reason for the highest yield in the sole stand is that the seed rate amount was greater than the intercropped one and this result is comparable to the result of (Abera *et al*., 2022) who stated that the dry matter yield of vetch species in the pure stand was greater than the intercropped vetch species. The present study also in agreement with the finding of (Unathi *et al*., 2018) who revealed that the higher dry matter yield production of legumes sown alone relative to its intercropped. This might be due to the fewer disturbances habitat in the intercropped environment and seed rate factor.

Present mean CP yield (1.18±0.07t/ha) was greater than the mean CP yield (0.75t/ha) obtained by (Eshetie Alemu, 2018) from oat (*Avena sativa*) and vetch (*Vicia dasycarpa*) mixture in different harvesting stage. This was due to harvesting age could be decreasing the CP content of forages. Lowest and highest CP yield (0.90 &1.39t/ha) in the present results were similar to the lowest and highest CP yield (0.96 & 1.6t/ha) of vetch mixtures with barley at the third harvesting stage obtained by (Birhan, 2013).

Total dry matter and total crude protein yield of forage grown

Dry matter yield in intercropped seed rate was higher than the total dry matter yield obtained from Sudan grass and vetch sown as a pure stand. Thus recent results were akin to the previous study of (Abera *et al.*, 2022) who stated that the total dry matter yield of intercropping of Desho grass (*Pennisetum pedicellatum*) with vetch species had the highest dry matter yield than the Desho (*Pennisetum pedicellatum*) and vetch species sown alone. This could be due to grass-legume intercropping had the advantage of efficiency of water and nutrient used (Lima *et al*., 2018) and also due to lower evapotranspiration and also might be the reason intercropping of legumes had the advantage to fix atmospheric nitrogen (Unathi *et al.*, 2018). In comparison with the present study (Reza *et al.*, 2013) observed a higher dry weight of sorghum when grown with lima bean (*Phaseolus lunatus*) in additive series at different planting proportions of crops.

The variation of total CPY between seed rate treatments was attributed from morphological difference of both forages. High total CPY (2.08t/ha) obtained from 75%:25% seed rate treatment was due to better morphological characteristics of both forages grown under irrigation and also might be due to legumes could be enhance CP content of grass in the intercropping. The present results were supported by the previous scholars (Abera *et al.*, 2022; Eshetie Alemu, 2018; Hassan *et al.*, 2017; Malede Birhan, 2018).

CONCLUSION

In this study, Sudan grass (Sorghum sudanese) seed rate with Vetch (*Vicia dasycarpa*) intercropping reflected on morphological parameters, dry matter yield, and chemical composition of both grown forages. The 75%:25% seed rate vetch intercropping had significant effect on all morphological parameters of Sudan grass (*Sorghum sudanense* “Aden gode”). The highest DMY (7.84t/ha) of Sudan grass was recorded from 75%:25% seed rate treatment compared from sole while, 7.89t/ha of dry matter was obtained from sole vetch and significantly higher total DMY (13.21t/ha) was found from 75%:25% seed rate intercropping treatment. LER in present study greater than one (>1) in all treatments and Sudan grass had less competitive and aggressively in 75%:25% seed rate intercropping than others and had higher dry matter yield compared to other intercropped treatments. Moreover, 75%:25% seed rate vetch intercropping had a higher 12.19 CP% and 0.96 CPYt/ha.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

DATA AVAILABILITY

All data are included within the article and on the hands of the first author if you needed

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AUTHOR CONTRIBUTION

The author has revised and approved the final version of this manuscript.

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