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Effect Of Seed Rate On Forage Yield, Morphological Characteristics, and Chemical Composition 0f Sudan Grass (Sorghum Sudanense) and Vetch (Vicia Dasycarpa) Intercropping Grown under Irrigation Condition in North Mecha District of Ethiopia

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SCHOOL OF ANIMAL SCIENCE AND VETERINARY MEDICINE

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M.Sc. Thesis

By

Tenaw Temesgen Mengstu

December 2022

Bahir Dar, Ethiopia

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M.Sc. Thesis

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Tenaw Temesgen Mengstu

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (M.Sc.) in Feeds and Animal Nutrition

Major Advisor: Yeshambel Mekuriaw (PhD)

December 2022

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Tenaw Temesgen Mengstu** entitled "**Effect of Seed Rate on Forage Yield, Morphological Characteristics, and Chemical Composition of Sudan Grass (*Sorghum sudanense*) and Vetch (*Vicia dasycarpa*) Intercropping Grown under Irrigation Condition in North Mecha District of Ethiopia**". We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in **Feeds and Animal Nutrition.**

Board of Examiners

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DECLARATION

This is to certify that this thesis titled "**Effect of Seed Rate on Forage Yield, Morphological Characteristics, and Chemical Composition of Sudan Grass (*Sorghum sudanense*) and Vetch (*Vicia dasycarpa*) Intercropping Grown under Irrigation Condition in North Mecha District of Ethiopia**" submitted in partial fulfillment of the requirement for the award of the degree of master of science in "**Feeds and Animal Nutrition**" to the graduate program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Tenaw Temesgen Mengstu** (ID. No. BDU/1300507) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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(Major Advisor)	Signature	Date

SATEMENT OF THE AUTHOR

I hereby affirm that this thesis is my original work and that all sources of information utilized in this thesis have been properly cited. This thesis was submitted in partial fulfillment of the M.Sc. degree requirements at Bahir Dar University and has been deposited in the University's Library to be made public. I solemnly declare that this thesis is not being submitted to any other institution for the award of any academic degree, diploma, or certificate anywhere. Brief quotations from this thesis are permitted without specific permission as long as the source is properly acknowledged.

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LIST OF ABBREVIATIONS

A	Aggressiveness
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BNF	Biological Nitrogen Fixation
CP	Crude Protein
CPY	Crude Protein Yield
CR	Competitive Ratio
CSA	Central Statistics Agency of Ethiopia
DM	Dry Matter
DMY	Dry Matter Yield
DWss	Dry Weight subsample
FAO	Food and Agriculture Organization of United Nation
FLDP	Fourth Livestock Development Project
FWss	Fresh Weight subsample
GDP	Growth Domestic Product
Ha	Hectare
IGAD	Intergovernmental Authority on Development
Kg	Kilogram
LL	Leaf Length
LSD	Least Significant Difference
LW	Leaf Width
M.a.s.l	Meter above sea level
ME	Metabolisable Energy
mm	millimeter
N	Nitrogen
NDF	Neutral Detergent Fiber
NFC	Non-Fibrous Carbohydrates
NLPT	Number of Leaf Per Tiller

List of Abbreviations (*Continued*)

NN	Number of Nodule
NRCS	Natural Resource Conservation Service
NTPP	Number of Tiller Per Plant
OM	Organic Matter
RCBD	Randomized Complete Block Design
RL	Root Length
RN	Root Number
SAS	Statistical Analysis System
t	Ton
TFW	Total Fresh Weight

Effect of Seed Rate on Forage Yield, Morphological Characteristics, and Chemical Composition of Sudan Grass (Sorghum sudanense) and Vetch (Vicia dasycarpa) Intercropping Grown under Irrigation Condition in North Mecha District of Ethiopia

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ABSTRACT

Sudan grass is an annual forage grown with fine stems and it has been gaining increasing importance in animal feed due to its rapid establishment. To maximize the quality and quantity of Sudan grass grown with legumes is recommended. Hence, intercropping of Sudan grass (Aden gode) and Vetch (Vicia dasycarpa) with different seed rate proportions may increase the nutritive values of the forage grown. Therefore, the experiment was conducted in the North Mecha district with the objectives of identifying the effect of seed rate on forage quantity and quality of sudan grass (Aden gode) and vetch (vicia dasycarpa) intercropping grown under irrigation condition. The experiment was laid with randomized completed block design (RCBD) with five (5) seed rate treatments (100%, 75%:25%, 50%:50%, 25%:75%, and 100%) and intercropped under three (3) replications on a 4×3m plot size. Irrigation, weeding, and hoeing were used as management practices. All data 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 that morphological, dry matter yield, and chemical compositions were significantly ($P<0.05$) affected by different seed rate treatments. Whereas, stem thickness, root length, and ADF% of Sudan grass (Aden-gode) and root length and ADL% of vetch (Vicia dasycarpa) were not significantly ($P>0.05$) affected. The highest total dry matter yield (13.21t/ha) and the lowest total dry matter yield (5.04t/ha) were found from 75%:25% seed rate 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 treatment. The highest CP% and CP *yield (12.19% & 0.96t/ha), respectively and the lowest crude fiber fractions of Sudan grass (Aden-gode) was found from 75%:25% seed rate treatment. Whereas, highest CP (24.06%) with lowest crude fiber fractions was observed from 50%:50% seed rate treatment of vetch (Vicia dasycarpa). However, the highest CP yield (1.39, and 1.33t/ha) were recorded from sole (100%) and 25%:75% seed rate treatment of vetch (Vicia dasycarpa), respectively. Morphological characteristics, forage yield, and chemical composition of the forage grown was correlated. Therefore, production of 75%:25% seed rate intercropping of Sudan grass (Aden-gode) with vetch (Vicia dasycarpa) would be more beneficial to produce optimum forage yield and better nutritive value.*

Keywords: Chemical composition, Forage yield, Intercropping, Seed rate, Sudan grass, Vetch

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CHAPTER ONE: INTRODUCTION

1.1. Background and Justification

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). In addition to this, the livestock sector has been contributing a significant role to the Ethiopian economy by providing food, cash income, promoting saving, social functions, and employment. 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 (Shimelis 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 of the indigenous cows, lack of extension services, and inadequate information to improve animal performance (Aynalem Haile *et al.,* 2011). Among these constraints, inadequate quantity and quality of feedstuff were identified as a major limiting factor to the development of livestock production and productivity in peri-urban and urban (Boufennara *et al.,* 2012; Belay 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 *et al.,* 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 (Addisu Jimma *et al.,* 2016; CSA, 2021) 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. Natural pastures contributes about 80-85% (Sefa Salo, 2017) of animal feed in Ethiopia and are including naturally occurring grasses, legumes, shrubs, hurbs, and also tree foliages (Adugna Tolera, 2007). Crop residue is one of the feed resources used for animal production in Ethiopia and is available in those areas in which livestock and crop production are practiced (Sefa Salo, 2017). Around 30 million tonnes of DM (Adugna Tolera *et al.,* 2012) of agricultural crop residues are produced annually on the national scale, of which 70% are used as animal feed. The major agro-industrial by products commonly used in Ethiopia are obtained from different agro-industries. The nutritional values of agro-industrial by products are excellent (Berhanu Gebremedhin *et al.,* 2009; Malede Birhan, 2014) but their productivity is small, limited, and limited to few farms in urban and peri-urban areas and they contribute much less to livestock feed (Alemayehu Mengistu, *et al.,* 2017).

Improved forage development practices in our country were more related to the objective to increase improved forage production (Muluken Shiferaw *et al.,* 2018). As pointed out by Shimelis Mengistu & Temesgen Alen (2016) different mechanisms of forage development strategies like backyard forage development, under sowing of cereal crops with forage legumes, forage development on stock exclusion area, forage development on conservation structures, and over sowing on existing grazing/pasture land are practicing in Ethiopia even though, their production potential is very low.

Purely improved forage production contribution to livestock feed at national level is very limited though almost five decades of research and development efforts have been done by governmental and nongovernmental organizations in the country. Therefore, intercropping is used to boost forage production potentials for livestock production. 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 in the productivity of forage, solving the land shortage, yield stability, pest control, and nutrient use efficiency (Hailu Gebru, 2015). However, grass forage is relatively low nutritive value as compared to legume forages (Eskandari *et al.,* 2009). Legumes are intercropped with grass due to a good source of protein (Ayan *et al.,* 2012). Asci *et al.* (2015) and Singh (2020) noted that the benefits of cereal-legume intercropping mainly depend on the choice of the right crop combination and their seed rate proportion, plant density, different growing habits, shading, and nutrition, because competition between plants could reduce the yield and quality of forages. Similarly, Mut *et al.* (2017) reported that sowing rate is extremely critical factor to achieve high yield and quality in intercropping.

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). Guleria & Kumar (2016) and Moyer *et al.* (2004) stated that Sudan grass could be used for grazing, and 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 *et al.* (2017) stated that Sudan grass had the highest crude protein content 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). Alemu Tarekegn *et al.* (2020) conducted research on five improved Sudan grass cultivars such as DRLME, Mezrut, Wichello, Michello, and Aden-gode in Ethiopia. Of these identified Sudan grass cultivars; DRLME and Aden-gode have the maximum plant height with value of 83.44 and 80.03cm respectively. As pointed by Alemu Tarekegn *et al.* (2020) these identified Sudan grass cultivars had a dry matter yield ranged from 5.78 up to 6.95t/ha, and they had total CP yield ranged from 0.61 up to 0.76t/ha.

Among the annual forage legumes, vetches are well adapted and more promising as short-term fodder crops in Ethiopia (Fantahun Dereje, 2016; Gezahegn 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 (Muluneh Minta and Angaw 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 (Gezahegn Kebede *et al.,* 2013). Therefore, *Vicia dasycarpa, Vicia villosa,* and *Vicia atropurpurea* have creeping growth habits, tall plant height, and intermediate to late maturity (Gezahegn Kebede *et al.,* 2013). Vetch species which has creeping or climbing growth habit has better compatibility with large grasses in intercropping or under-sowing systems (Gezahegn Kebede, 2018; Gezahegn Kebede *et al.,* 2020). Due to this tangible reason, vetch (*Vicia dasycarpa*) species is selected for intercropping with Sudan grass (*sorghum sudanenese* "Aden gode") to evaluate the effect of seed rate on Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping on morphological, forage yield and chemical composition of the forage grown under irrigation conditions.

1.2 Statement of the Problem

Despite the large livestock number and the importance of animal production in our country, their productivity is low due to various problems such as poor management practices, inappropriate infrastructure, feed shortages both in quality and quantity, and health constraints (Alemayehu Mengistu *et al.,* 2017; Ashenafi Mengistu *et al.,* 2019). Among these problems, the shortage of feed was identified as one of the primary constraints for livestock production in our country. Furthermore, traditional livestock feed supply mainly depends upon natural pasture and crop residues, which have low crude protein and other chemical composition. However, there is tremendous potential to alleviate feed shortages using improved forage production. To fulfill this gap, producing a stable improved forage in the livestock sector is mandatory. For that reason, the legume and grass intercropping system is important to increase biomass production and forage yield. Hence, Sudan grass (Aden gode) known with its plant height (Alemu Tarekegn *et al.*, 2020) than other cultivars and vetch (*Vicia dasycarpa*) have greater plant height and creeping growth habit that enable compatible to larger grass species and they are selectible forages to enhance the forage yield and quality. Therefore, Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) intercropping have the potential to increase the biomass and quality of forages due to legumes being a good source of protein. However, in Sudan grass-legume intercropping, sowing seed rate is an extremely critical issue to achieving high yield and quality of forages (Alla *et al.,* 2014; Ayan *et al.,* 2012; Mut *et al.,* 2017; Singh, 2020). Even though, there is typically insufficient information on their agronomic management of the ideal level of seeding rate for maximum biomass production and to increase yield and quality of grown forages, an appropriate seed rate combination must be developed to intercropping Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*). Due to the above profound problems, this research was designed.

1.3 Research Objectives

1.3.1 General objective

The general objective of the research was 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.

1.3.2 Specific objectives

- To evaluate the effect of seed rate on Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping on morphological characteristics of the forage grown under irrigation condition
- To determine the effect of seed rate on Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping on forage yield and compatibility of the forage grown under irrigation condition
- To evaluate the effect of seed rate on Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping on chemical composition of the forage grown under irrigation condition

1.4 Research Questions

- Does seed rate of Sudan grass (*Sorghum sudanense* "Aden-gode") and vetch (*Vicia dasycarpa*) intercropping affect agronomic, forage yield, and chemical composition differences?
- What is/are the best seed rate proportion of Sudan grass (*Sorghum sudanense* "Aden-Gode") and vetch (*Vicia dasycarpa*) intercropping that was/were fit to the study area?
- What about the correlations between the morphological and chemical composition of grown forage?

CHAPTER TWO: LITERATURE REVIEW

2.1 Major Feed Resources in Ethiopia

Feed resources in Ethiopia are classified in to free grazing pasture, crop residues, improved feed, hay, industrial by-product, and other feed resources (CSA, 2021). Similarly Malede Birhan & Takele Adugna (2014); and Sefa Salo (2017) reported the most endowed feed resources used for animal production in our country Ethiopia are free grazing pasture, preserved hay, produced forage, crop residue, Agro-industrial by-products, aftermath feed, and weeds from cultivated land. From these feed resources, communal grazing pasture land is a large amount of feed resource in Ethiopia (Tilahun Amede *et al.,* 2005; Azage Tegegne *et al.,* 2011; Malede Birhan & Takele Adugna, 2014). According to CSA (2017) report 54.59, 31.06, 6.81, 1.53, and 5.11% of natural pasture, crop residue products, hay, agro-industrial by-products, forage productions, and other feed resources account for the nation's overall of livestock feed supply respectively. Similarly CSA (2021) reported that grazing pasture (54.54%) is a major type of feed resource followed by crop residue (31.13%), hay (7.35%), other feed type (4.37%), by-products (2.03%), and improved feed (0.57%). However, most of feed resources are subjected to seasonal variations and are low in nutritional value and also in quantity (FAO, 2018).

Therefore, the productivity of the livestock sector has been challenged by the availability of feed resources, quality of feed, and seasonal availability of feed, as well as lack of accessibility to veterinary services and infrastructures (Andualem Tonamo, 2016). Besides these, Coleman & Moore (2003) who outlined that the capability of animal production and reproduction is determined by the availability of quality and quantity of feed.

2.1.1 Natural pasture

Natural pasture is grassland that is suitable for herbivorous animals to graze on, and it is the greatest endowment in Ethiopia which supply 80% of the total animal feed (Sefa Salo, 2017). Natural pasture contains grasses, legumes, various herbaceous and fodder shrubs, and trees are the main sources of feed for animals (Ararsa Derara and Amanuel Bekuma, 2020). According to the reports of Belay Duguma *et al.* (2012); Endale Yadessa (2015) in certain regions of Ethiopia where mixed crop-livestock production is dominating agricultural activity, natural pasture continues to be a significant component to livestock feed.

Most brows plants have better nutritional value containing CP contents ranging from 10-25% on the dry matter basis due to they have deep root system enables to absorb sufficient amount of water and nutrients from the soil (Teferi Aregawi *et al.,* 2008). The CP content for most of immature grasses ranged from 7.2-20.20% on dry matter basis, whereas for matured grasses ranged from 5.6-11.5% on dry matter basis (Emana Megersa *et al.,* 2017).

Now a day, the development of crop production onto grazing fields, the redistribution of communal lands to the landless, land degradation, tramped all year without break and the resulting loss of fertility on the remaining pasture lands are all contributing factors to the current decline and shrinkage of natural pasture (Tadese Amsalu & Solomon Addisu, 2014; Sefa Salo, 2017). Natural pasture reduced its biomass output due to extinction of palatable species and invasion of unpleasant species, increased soil erosion, land degradation, and these cause to severe feed shortage in crop-livestock mixed agricultural system (Beyene Teklu *et al.,* 2011; Fekede Feyissa *et al.,* 2011). Similarly Mesay Yami *et al.* (2013); and Mesfin Dejene *et al.* (2014) who stated that declining of natural pasture is a common problem for feed shortage occurring in the dry season and it is a key challenge for overall feed quality and quantity.

2.1.2 Crop residues

Crop residue is one of the main feed resources for Animal production in Ethiopia, predominantly in those areas in which livestock and crop production are practiced (Sefa Salo, 2017). The major crop residues available for livestock feeding in the highland area are included residues from wheat, barley, bean, and field pea (Ararsa Derara and Amanuel Bekuma, 2020). While the major crop residues feed resources in mid-altitude areas including maize, *teff,* and haricot bean (Solomon Melaku *et al.,* 2008; Endale Yadesa, 2015; Ararsa Derara and Amanuel Bekuma, 2020).

Hence, around 1.14 billion (FAO 2017) and 30 million (Adugna Tolera *et al.,* 2012) tons of DM of agricultural crop residues are produced annually on a global and national scale, respectively, of which 70% are used as animal feed. However, the contribution of crop residues is estimated to reach up to 30-80% of the total dry matter available for livestock in the highlands of Ethiopia (Thorne, 2015).

However, smallholder farmers have used these crop by-products for different purposes including livestock feeding, domestic fuel, bedding material, source of income, housing material, and mulching crop lands (Adugna Tolera, 2007; Sefa Salo, 2017). Moreover, the availability of different types of crop residues for livestock feeding depends on multiple factors such as agro-ecology, altitude, the season of the year, and size of land allocated for different crops species by farmers (Tadese Amsalu & Solomon Addisu, 2014; Solomon Zewdu *et al.,* 2014). In addition, Poor post-harvest feed handling, low forage improvement, and inefficient utilization practices are critical problems to Accessing consistent and quality livestock feed resources in Ethiopia's livestock sector (Shapiro *et al.,* 2015; Balehegn Mulubrhan *et al.*, 2020).

The fact that the nutritional value of crop residues are poor and therefore, chemical treatments, biological treatment, use of different supplements and physical processing were acknowledged to be of substantial benefit in improving the nutritional value of crop residues (Tesfaye Agajie & Chairatanayuth, 2007). Physical processing (chopping/threshing, grinding, soaking/spraying, baling), chemical treatment (urea molasses), biological treatment (effective microorganisms) and feed supplements (salt, molasses, oil seed cakes, milling by-products, and legume forages) are used to improve the nutritive value of crop residues in Ethiopia (Tesfaye Agajie & Chairatanayuth, 2007; Getnet Assefa *et al.,* 2022).

2.1.3 Agro-industrial by-products

The major agro-industrial products commonly used in Ethiopia are obtained from different agro-industries such as flour milling industries (wheat bran, wheat short, wheat middling, and rice bran), edible oil extracting plants (Noug cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake, etc), breweries and sugar factories (molasses) (Malede Birhan & Takele Adugna, 2014). But agro-industrial by-products and manufactured feed contribute much less to livestock feed (Alemayehu Mengistu, *et al.,* 2017). Additionally, the country's contribution from agro-industrial byproducts is small, limited, and limited to few farms in urban and peri-urban areas (Alemayehu Mengistu, *et al.,* 2017). The reports of FAO (2019) the total annual agro industrial by-products in Ethiopia is about 7.58 million tonnes (DM) and

762,846 tonnes and $73.34x10^9$ MJ of CP and metabolizable energy (ME) respectively. According to the author Sefa Salo (2017) particularly in peri-urban and urban livestock production systems, agro-industrial byproducts are valuable for feeding animals.

The nutritional qualities of these agro-industrial by-products are excellent and the availability and utilization of these feed resources are limited only to towns where different agro-industries are found and the beneficiaries of the products are mainly livestock fattening operations and urban and peri-urban dairies located in the area with better accessibility to the resources and even when they go down to the smallholder farmers, transportation costs are increased time to time (Berhanu Gebremedhin *et al.,* 2009; Malede Birhan, 2014).

2.1.4 Non-conventional feed resources

All feeds that haven't been utilized traditionally for feeding cattle and are not used commonly in the production of livestock feeds are often called non-conventional feed sources (Alemayehu Mengistu & Sissay Amare, 2003). Therefore, non-conventional feeds includes vegetable refusals, sugarcane leaves, enset leaves and fish offal, kitchen waste, and coffee residues are used as animal feed. However, the categories of non-conventional feeds are vary according to the feeding habit of the society (Endale Yadessa *et al.,* 2016). Thus, non-conventional feeds could partly fill the gap in the feed supply and contribute to self-sufficiency in nutrients from locally available feed sources.

However, non-conventional feeds are rare and made a limited contribution to livestock feeding and due to their low cost and availability, small-holder farmers frequently use by-products from nearby breweries and distilleries as a source of non-conventional feed (Yosef Mekasha *et al*., 2003; Ajebu Nurfeta, 2010).

2.1.5 Improved forage production

Improved forage crop production has diversified advantages. Forages can be divided into three categories: legumes, grasses, and multipurpose browses (fodder trees). Improved forages, especially legumes, are required to increase the nutritional content of crop residues even in the presence of abundant crop residues, which are frequently fed to ruminants. The main aim of improved forage production in Ethiopia is to increase feed availability and enhance the intake and digestibility of the low nutritional value hay and the crop residues through fresh green forage supplementation (Getachew Assefa, 2021). The attempts to establish improved forages have been reported an inefficient and limited success rate (Abebe Mekoya *et al.*, 2008) and having a contribution of less than 1% (CSA, 2018) which requires additional extension and research work in the country.

Improved forages can play much more important to the traditional feed resources by providing 8 to 10 times more yield than naturally grown pastures and these forages are of sufficient quality to promote income generation and optimal livestock productivity (Fantahun Dereje *et al.,* 2020; Kindu Mekonnen *et al.,* 2022). Forage legumes are important for nitrogen fixation and can be utilized as a protein supplement for animals due to the high crude protein content, rich in minerals (calcium, phosphorus), and vitamins A and D (Lukuyu *et al.,* 2012). However, in the present country's condition fodder crops including oats, vetch, alfalfa, and fodder beet are not well established (Alemayehu Mengistu, 2005).

2.2 Improved Forage Production in Ethiopia and its Challenges and Opportunities

Despite the introduction of new forages, Ethiopia has poor management and utilization of forage resources (Solomon Tefera, *et al.,* 2019). Hence, the contribution of improved forage to the total feed resource is still low (0.32%) because of factors such as type of livestock production system, lack and un adoptable forage technologies, poor extension services, and others (CSA, 2018). To enhance or improve forage production, these criteria such as selection of forage species, forage development strategies, preparation and servicing of extension practice, and formulation of forage seed production system are the main consideration (Getachew Assefa, 2021).

2.2.1 Opportunities

A good possibility for the production of improved forages is the integration of pasture and forage crops into the current farming system. As a success of forage production in Ethiopia, Farmers raised the improved forage production used for their dairy and fattening animals increased their income, increase animal products, reduced their feed cost due to compensating concentrate cost, and enhanced the feed availability year-round (Getachew Assefa, 2021). However, integrated feed and forage development practices such as forage development and grown fodder trees can address livestock feed and forage-related challenges and improve livestock productivities (Kindu Mekonnen *et al.*, 2022). Similarly Alemayehu Mengistu (2006) stated that the integration of pasture and forages into the farming system is one of the best opportunities for highland farmers to utilize land effectively. Some of the potential for forage production in Ethiopia include fourth livestock development project (FLDP), forage development strategies, availability of water, and presence of sizable livestock population (Alemayehu Mengistu, 2006).

2.2.2 Challenges

In Ethiopia, the failures of green forage production in many areas are due to a shortage of land and water for irrigation. Forage crops cannot be produced in sufficient quantities due to the increasing demand for land resources and increased cropping intensity from populations that are expanding at an alarming rate (Alemayehu Mengistu, 2002). Similarly in the highlands of Ethiopia, where a mixed crop-livestock farming system exists, farmers give priority to crop production rather than producing green forage for their livestock (Getachew Assefa, 2021). Low availability of forage seed and seed production is also a problem for the adoption of improved forages, which must be addressed (Muluye Fekade, 2019). Devastating of improved forage produced by some farmers with the animals of the others due to the reason open/free grazing system is adopted and this problem may reduce forage production and adoption in Ethiopia (Getachew Assefa, 2021). Generally, land scarcity, overpopulation, particularly in pastoral areas, seasonal variations in the availability of forage seeds, lack and high cost of planting materials, poor extension service, drought, lack of awareness, and low adoption of improved forages at the level of smallholder farmers are the main forage-related constraints (Getnet Assefa *et al.*, 2012).

2.3 Advantage of Supplementation of Fresh Forage to the Livestock

Green forages have a cooling effect on the Animals, are also more palatable, and have easily digestive nutrients. According to Khan *et al.* (2012) description, green forage tends to contain more minerals than matured or dry forage. The leaves contain 20–30 times as much vitamin E as the stems for the maintenance of cellular membranes, immunity, and reproductive function.

Green herbage is also an exceptionally rich source of β-carotene, a precursor of vitamin "A" and used for vision, normal growth and development, spermatogenesis, and maintenance of skeletal tissue and epithelial tissue. Green feeds also provide vitamin K to animals for the synthesis of proteins. Green feed is also used to reduce methane emissions to the environment (Prusty *et al.,* 2014). The enteric methane emission was reduced by 5-12% by feeding green fodder-based rations to river buffaloes (Prusty *et al.,* 2014). The authors Nathani *et al.* (2015) also reported that increasing green fodder proportion in the diet might have also reduced the active genes for the production of methane by reducing the methanogenic archaea population in the rumen.

2.4 Over View of Intercropping Forage Production System

Intercropping is the way of producing or cultivating two or more forages together on a specific piece of land during the same cultivation period (Guleria & Kumar, 2016). Production of two or more forages together has the effect to increase forage biomass production. One of the most affordable and efficient agronomic techniques to increase forage biomass output, nutritional quality, and financial returns is grass-legumes intercropping (Iqbal *et al.,* 2019). In highland, moderate altitude, and lowland areas, intercropping of annual leguminous species with grass provides the predominant quantity and quality of forage production strategies (Muluye Fekade, 2019). However, sometimes nutrient competition occurs between intercropped forage crops or mixed forage crops and this competition might indicate the compatibility of these forage growing together for better quality and quantity of forage (Usman *et al.,* 2017).

Intercropping is thus typically carried out in four different methods. Row intercropping is the first intercropping technique. Row intercropping can be done in two different methods. The first is additive series (no sacrifice of main crop lines) and the second is replacement series (main crop row is reduced for each intercrop row) (Iqbal *et al.,* 2017). On the other hand, mixed intercropping is a technique in which the seeds of various fodder crops are blended, mixed, and sown in the same row, or broadcast. (Iqbal *et al.,* 2019). Relay intercropping techniques include sowing a second crop in a standing crop that is almost finished with its production cycle before harvest (Fitsum Reda *et al.,* 2005). Strip intercropping involves sowing two or more crops in strips that are both wide enough to accommodate numerous rows and near enough to allow for interactions (Li *et al.,* 2001).

2. 5 Advantages of Grasses and Legumes Intercropping System

2.5.1 Grass-legumes intercropping for herbage yield and nutritive value

Forage legume and grass intercropping are climate-smart options that has potential for enhancing herbage production simultaneously. Previous studies have reported that legume intercropping can enhance biomass and yield over corresponding monoculture (Zhang *et al.,* 2011; Zafaranieh, 2015). According to the author Rusdy (2021) the way to overcome the feed shortage problems sustainably is through establishment of grass-legume intercropping. Grass-legume intercropping also has the advantage to improved forage yield, reduced weed invasion, and improved forage nutritive value and animal production.

In the study conducted by Sturludóttir *et al.* (2014); Unathi *et al.* (2018) grass grown in association with legumes also contain a higher percentage of protein. Besides, Eskandari *et al.* (2009); Mousavi & Eskandari (2011) reported that grasses intercropping with legumes contained higher crude protein than grasses harvested from the monoculture. Generally, intercropping has various advantages such as increasing forage biomass production, crude protein yield, increase in economic profitability, and the efficiency of land use, and also has its effect on soil conservation mechanism. From these advantages Dhima *et al.* (2007) showed that vetch intercropped with cereals resulted in higher forage yields and profitability.

2.5.2 Advantage of grass-legumes intercropping for nitrogen fixation

According to the authors Unathi *et al.* (2018) producing legumes for biological nitrogen fixation has additional advantages that used as ecosystem, economic, and environmental advantages. Furthermore, due to biological nitrogen fixation (BNF) process, intercropping legumes with grass has the potential to be a nitrogen-saving approach (Iqbal *et al.,* 2019). The researchers Weisany *et al.* 2013; Unathi *et al.* (2018) stated that legumes intercropped with grass have a unique ability to fix atmospheric nitrogen. Legumes can fix atmospheric free nitrogen into the soil by symbiotic living with bacteria of *Rhizobium* species and sustaining soil fertility (Demissie Negash *et al.,* 2017).

The improvement in nutritive value is due to a slower decline in digestibility with advancing maturity and higher levels of protein in legumes (Unathi *et al.,* 2018). When compared to grass monocultures legumes can improve palatability, digestibility, nutritional value, and often herbage yield by increasing the nutritive content of the low-quality grass cultivated inside them (Kumar *et al.,* 2016, 2018). One of the strategic interventions for optimizing the productivity of a given land use system is the integration of forage legumes into the grass-based forage production system using various ways (Gezahegn Kebede, 2018).

2.5.3 Advantage of grass-legumes intercropping for biological competitiveness

2.5.3.1 Land equivalent ratio

The land equivalent ratio measures the proportion of a single forage relative area needed to produce the yield obtained through intercropping (Azraf *et al.,* 2006). Land equivalent ratio is also the relative area of land under monocrop which is needed to obtain the yield produced in intercropping (Belel *et al.,* 2014). Grass and legume intercropping has been acknowledged as a productive method that maximizes fodder production per unit area and unit time while also using better resources (Guleria and Kumar, 2016). Grass and legume intercropping was the obvious intercropping method and the most productive, stable, and advantageous in respect to the land equivalent ratio under irrigated conditions.

However, the authors Azraf *et al.* (2006) reported that there is no yield benefit if the LER value is one, but there is a yield advantage if the LER value is more than one. Grass and legumes intercropping is the most efficient intercropping system and resulted in better land equivalent ratio (Naim *et al.,* 2013; Rathor, 2015). Intercropping of sorghum with cowpea gave the higher value of land equivalent ratio (1.88) which indicating a significant effect of intercropping over sole grown forages (Mohammed *et al.,* 2008). Similarly Makoi & Ndakidemi (2010) reported that grass and legume intercropping system is most advantageous in land equivalent ratio ranged from 1.29-1.61 with respect to sole sown forages. Therefore grass and legume intercropping system is most effective in land equivalent ratio compared from grass and legumes sown as a pure stand.

2.5.3.2 Competitive ratio

Another method of determining how much one forage competes with other crops is competitive ratio (CR). Competitive ratio is a ratio of competitiveness of the intercropped or mixture of grass and legumes to individual forage land equivalent ratio with respect to sown seed proportion (Dinesh *et al.,* 2021). Whereas, the author Yahuza (2011) stated that an index that measures the impact of competition between two species in an intercropping system is called the competition ratio (CR), which reflects how much one species competes with the other in an intercrop. Intercropping of cowpea in forage sorghum is the most efficient system of intercropping with forage sorghum due to cowpea is most competitive than other legumes (mungbean, clusterbean, and susbania) (Azraf *et al.,* 2006).

2.5.3.3 Aggressiveness

Biological compatibility especially aggressiveness in grass and legume intercropping have its positive and negative effect in forage yield. When forage is cultivated in combination with another forages, aggressiveness is a crucial competitiveness function to evaluate the potential to compete and when the grown forage aggressiveness values is zero, it means that component forage are equally compete (Azraf *et al.,* 2006). Ahmad *et al*. (2006) reported that in Sorghum and legume intercropping system sorghum appeared dominant crop with positive aggressiveness. Singh *et al.* (2008) revealed that positive aggressiveness in intercropping of sorghum and cowpea was observed, which have the yield advantage of intercropping over sole crops. Moreover, Verma *et al.* (2005) revealed that intercropping of fodder sorghum with pigeon pea in row intercropping and obtained the higher values of aggressivity index (0.53) and this positive value indicates that there have a yield advantage in intercropping.

2.6 Over View of Sudan Grass Origination and Used for Forage Production

Important fodder that originated in Sudan is Sudan grass. Sudan grass is an important grass due to its being very leafy with very fast growth (Guleria & Kumar, 2016; Najmaldin & Ali, 2019). Sudan grass (*Sorghum sudanense*) is an annual forage grass that yields a lot, and grows quickly (Guleria & Kumar, 2016; Mut, 2017). Sudan grass is annual forage with fine stems that works well in short periods. Sudan grass can tolerate both warm and drought and can be a promising crop to solve the forage dry matter shortage during winter season and emergencies (Najmaldin & Ali, 2019). Sudan grass (*Sorghum sudanense*) a promising fodder that may be cultivated under irrigation, which has been neglected in Sudan for a long time (Najmaldin & Ali, 2019). The plant develops only fibrous roots and does not have rhizomes, but a single seed can produce many stems (tillers). Its tiller is extensively and have rapid re-growth potential (Armah-Agyeman *et al.,* 2002). During a time of scarcity, this grass can fill the gap of feed shortage (Najmaldin & Ali, 2019).

2.7 Effects of Seed Rate Intercropping on Morphological Development of Sudan Grass (*Sorghum sudanense*)

2.7.1 Plant height

Plant height is affected by the seed rate (Najmaldin & Ali, 2019). The plant height of Sudan grass (*Sorghum sudanense*) is higher in intercropping than its sole cropping due to the seed rate probably create suitable growth condition in the intercropping. In addition, the seed rate proportion of sown forages has its effects on plant height (Najmaldin & Ali, 2019). It is possibly due to light competition between forages grown together or component crops in the intercropping (Basaran *et al.,* 2017).

Hence, the differences in plant height are due to intercropping seed rate of both grass and legume components, Sudan grass planted combined with legumes gave the tallest plants (Hassan *et al.,* 2017). When Sudan grass intercropping with leguminous fodder, overall height increased dramatically regardless of the seed content (Awad & Ahmed, 2012). Seed rate in Sudan grass has a significant effect on plant height and where seed rate increased in Sudan grass sown as sole and leads to decreasing plant height due to intra-specific competition for nutrients (Najmaldin & Ali, 2019). Basaran *et al.* (2017) stated effect of seed rate of Sudan grass with Soybean intercropping on plant height of Sudan grass hybrid was significantly increased in plant height compared to alone sowing.

2.7.2 Leaf development parameters

Leaf number is one of the advantageous morphological parameters of Sudan grass that contribute to the total dry matter yield. It is known that fresh matter and then dry matter yields are formed by photosynthesis in leaves, so it is important to determine the effect of technological measures such as seed rate on leaf development and leaf surface formation in the plant. In the experiment, Sudan grass seed rate affected the leaf developments (Atabayeva *et al.,* 2021). Therefore, values recorded for the number of leaves per plant for forage *sorghum-sudanense* are generally between 14 and 17 (Monteiro *et al.,* 2012; Gnanagobal & Sinniah, 2018).

Leaf growth has been illustrated widely for plant growth is mostly reflected in increases in leaf length accompanied by relatively small increases in width (Gnanagobal & Sinniah, 2018).

Increasing leaf lengths is important for the survival and contribution of the forage biomass of individual plants (Barre *et al.,* 2015). Leaf length and width observed for Sugar graze were 95±2.0cm, whereas leaf width was (6±0.58 cm) (Gnanagobal & Sinniah, 2018). Another scholars Singh *et al.* (2014) revealed that leaf length and width of sorghum hybrids were 45–70 cm and 4–7 cm, respectively.

2.7.3 Tiller number and root development parameters

The number of shoots per plant is an important yield contributing character that may affect the forage yield of Sudan grass (*Sorghum sudanense*). The intercropped Sudan grasses (*Sorghum sudanense*) gave better tillers number per plant (Hassan *et al.,* 2017). Hence, the seed rate increased the number of tillers per plant decreased. Higher seed rate had a negative relationship with the tiller number per plant and hence, the tiller's number per plant increased with low rates of seeds (Najmaldin & Ali, 2019). Although, with seed rate intercropping of Sudan grass and legumes affected tiller number. Significant differences had observed between solid crops and their intercropped (Hassan *et al.,* 2017).

The development of root length as densely would have competition between plants. The much greater plant populations would have resulted in substantially greater root length. As a result, the densely would have had a better opportunity to utilize soil water and nutrients than at wider spacing, resulting in higher DM yields (Gnanagobal & Sinniah, 2018).

2.8. Effects of Seed Rate in Intercropping on Nutritional Value and Yield of Sudan Grass

2.8.1 Dry matter and dry matter yield

Grass-legume combination plays a key role in higher dry matter productivity. Dry matter percentage is the part of forage without water. Fibers, crude proteins, ash, carbohydrates, and lipids are driven from dry matter content of the forage. Dry matter is also very essential as the moisture content will give indications as to how forage will preserve when stored by baling or ensiling (Schroeder, 2012). Due to this reason, efficiently knowing the dry matter content of forage is advantageous for storing dry forages.

In particular, it can be seen that the sowing rate in intercropping can affects the dry matter yield. The author Basaran (2017) noted that dry matter yield (19.54t/ha) was obtained from

50%:100% seed rate intercropping treatments of Sudan grass and cowpea (Yemsoy) compared to dry matter yield (17.19t/ha) Sudan grass sown alone. This greater results was due to intra-specifiic nutrient competition in sole and higher dry matter in intercropping was due to less seed rate of Sudan grass and may be good water use efficiency in intercropping than sole sown. There have been studies on the effects of sowing patterns and seed rates on the yield of forage Sudan grass (*Sorghum Sudanense*). Therefore Sudan grass was sown with 20 kg of seed rate per hectare and gave the dry matter yielding 111.4 q/ha which means 11.14t/ha (Atabayeva *et al.,* 2021). Sudan grass sown intercropping with cowpea on the seed rate proportion (75%:25%) had significantly increased dry matter yield (2.18t/ha) than Sudan grass sown alone (1.95t/ha) (Asem *et al.,* 2020) due to direct effect of seed rate decreasing in intercropping and contribution to forage yield. In addition to this, Najmaldin & Ali (2019) stated that seed rate had a significant effect on dry matter yield. According to Basaran *et al.* (2017) Sudan grass (*Sorghum Sudanense*) intercropped with legumes cowpea, and soybean exhibited greater hay yield. Two forages are beneficial if seed rate proportion are considered and intercropping system led to higher fodder yield (Rathor, 2015). The scholars Najmaldin & Ali (2019) results showed that there were significant differences among seed rate treatments. Generally, the seed rate have a significant effect on the dry forage yield of Sudan grass.

2.8.2 Crude protein percentage and yield

To get crude protein, multiply the forage's nitrogen content by 6.25. Crude protein percentage (CP%) of Sudan grass (*Sorghum sudanense*) in relation to intercropping with cowpea was shown to be significant because intercropping of cowpea improve CP% of Sudan grass (*Sorghum Sudanense*) (Asem *et al.,* 2020). The effects of seed rate intercropping has significant difference and the highest CP percentage (16.74%) was recorded in intercropping Sudan grass (*Sorghum sudanense*)+*Susbania-susban* and forage against the minimum (9.74%) Sudan grass (*Sorghum sudanense*) forage grown alone due to legume intercropping can increase nitrogen concentration of grass (Azraf *et al.,* 2007).

Hence, seed rate has the greatest effect on protein yield in separate and combined intercropping. Sudan grass (*Sorghum sudanense*) in intercropping has greatest protein yield than its alone sowing. Therefore, High forage quality in grass-legume intercropping might be associated with the seed rate of plants in a intercropping (Basaran *et al.,* 2017). Similarly the authors Hassan *et al.* (2017) showed that crude protein yield was influenced by intercropping.

2.8.3 Crude fiber fractions

Crude fiber percentage (CF%) of Sudan grass in respect of planting patterns with cowpea, and intercropping seed rate were significantly different (Asem *et al.,* 2020). Hence, CF% of mixed forage with the addition of cowpea in the intercropping which were (35.21%) compared with planting Sudan grass (*Sorghum sudanense*) as a pure stand which was (38.17%) (Asem *et al.,* 2020). Mixing Sudan grass with cowpea significantly improved forage quality in terms of decreasing the crude fiber and increasing the digestibility in the mixture compared to Sudan grass (*Sorghum sudanense*) grown as a pure stand (Awad & Ahmed, 2012). The crude fiber percentage of Sudan grass on average was 38.48, compared with (35.02) for mixed forage respectively (Asem *et al.,* 2020). These decreasing the crude fiber percentage was due to the intercropping of Suudan grass with legumes in decreasing seed rate and it enables increasing the nitrogen concentration of Sudan grass and as well as intercropping with legumes may improve the nutritive value of the grown forages.

From the crude fiber fractions, NDF in the forage increased, animals were able to have poor digestibility and consume less fed, which is consistent with the fact that NDF and digestibility are inversely associated. NDF can be used to forecast forage intake more accurately, allowing for the formulation of better rations (Harper & McNeill, 2015). Due to the restriction imposed by rumen fill, the higher NDF concentrations can affect overall DM intake (Alves *et al.,* 2016).

Hence, the author Erkovan (2022) showed that Sudan grass cultivated with common vetch has lower neutral detergent fiber than sole. Cross-seeding exhibited the significantly lowest NDF% and there were significant variations in the NDF% content. Cross-seeding row conducted significant decrease in NDF% content compared to the sole. The seed rate of sorghum (*Sorghum bicolor* L.) have significant effect on neutral detergent fiber. Differences in seeding rate are the main effect of the total variation in NDF (Aklilu Mekasha *et al.,* 2020). The reduction in NDF with decreasing in seeding rate could be associated with a decrease in plant stalk. However, Aklilu Mekasha *et al.* (2020) noted that increasing seed rate shows a significantly decreased in acid detergent fiber (ADF). Generally, different authors have revealed the chemical composition of Sudan grass can be affected by seed rate in intercropping. Hence, the table below is the summary of the chemical composition of sole Sudan grass and intercropped Sudan grass revealed by the authors.

Table 1. Chemical composition of Sudan grass and sorghum Sudan grass hybrids in alone and intercropping

	DM%	CP%	NDF%	ADF%	Source
Sudan grass (Jumbo) alone	-	10.0	64.9	42.6	(Choi *et al.,* 2017)
Sudan grass alone	-	8.8	65	40	(Lang, 2001)
Sorghum hybride intecrop		8.40	-	-	(Basaran *et al.,* 2017)
Sudan grass alone	-	9.03	66.04	48.32	(Uzun *et al.,* 2009)
Sudan grass alone	-	15-18	57.2	33.9	(Millner *et al.,* 2011)
Sorghum hybrid alone	26.83	8.64	55.18	36.52	(Lopes *et al.,* 2020)
Sorghum hybride intecrop		9.21	-6.37	-	(Akhter *et al.,* 2013)
Sudan grass alone	-	14.66	38.63	33.12	(Erkovan, 2022)
Sudan grass intercrop	-	15.47	38.94	33.25	(Erkovan, 2022)
Sudan grass hybrid (Piper) alone	-	8.7	65.6	41.1	(Choi *et al.,* 2017)
Sudan grass alone	23.9	12.6	72.4	43.4	(Beck *et al.,* 2014)
Sudan grass alone	-	12.42	59.24	33.18	(Ates & Tenikecier, 2019)
Sudan grass intercrop		16.10	39.15	32.98	(Erkovan, 2022)
Sudan grass alone	24	10	48	28	(Lyons *et al.,* 2019)
Sudan grass hybrid (Sunstar) alone	-	10.0	63.5	39.7	(Choi *et al.,* 2017)

DM% = Dry matter percent, CP% = Crude protein percent, NDF% = Neutral detergent fiber percent, ADF% = Acid detergent fiber percent

2.9 Over View of Vetch Species Adaptation and Used for Forage Production

Vetch species are predominately found in Ethiopia's central highlands and midland areas (Fantahun Dereje, 2016). Predominantly vetch species are known by their adaptability, versatility (either in green manure or as a pasture), they are used for ruminant feed (Gezahegn Kebede *et al.,* 2020). Vetches (*Vicia spp*.) are the most common annual leguminous forage used for animal feed (Demirhan *et al.,* 2018). More research has classified vetch species based on growth behaviors, morphological variations, climatic adaption, and other factors. As a result, the growth behaviors of vetch species can be classified as erect, creeping or climbing (Fantahun Dereje, 2016; Gezahegn Kebede *et al.,* 2020). As a result, *Vicia dasycarpa, Vicia villosa,* and *Vicia atropurpurea* grow creeping or ascending, whilst *Vicia narbonensis* and *Vicia sativa* grow erect.

These differences in growing habits are the basis for variation in nutritional values and also define their production potentials. for this reason, vetch species with upright growth habits are more compatible with small cereals in intercropping systems, whereas creeping or climbing growth habits are more compatible with large cereals in intercropping/under sowing systems and yielded higher green forage yields (Gezahegn Kebede *et al.,* 2020). On the other hand, variation in forage maturity is an essential agronomic feature to consider when selecting partner crops for maximum productivity. Getnet Asefa *et al.* (2003) also noted that choosing companion or mixed crops with the best compatibility and forage yield had an advantage in terms of days to maturity.

2.9.1 Adaptability measurements of vetch species

2.9.1.1 Plant height

Forage legumes must be integrated with grass in mixed stands or in intercropping, so information on plant height and other growth traits of the forage legumes is crucial things. Plant height and growth habits should be taken into account during integration because they affect compatibility in intercropping. *Vicia dasycarpa* has greatest plant height than other *Vicia* species followed by *Vicia villosa*, and *Vicia atropurpurea* in Holleta (Gezahegn Kebede *et al.*, 2013). Alemu Tarekegn (2014) reported that plant height adaptability of vetch species at harvesting stage, *Vicia villosa* (144cm) has highest plant height and *Vicia dasycarpa* (125cm)*, Vicia atropurpurea* (132cm)*,* and *Vicia benghalensis* (114cm) *are* different from *Vicia sativa* (65.3cm) in North Gondar. In other study, *Vicia dasycarpa* and *Vicia atropurpurea* are the first in plant height at Holetta and Ginchi respectively and *Vicia narbonensis* had the shortest plant height at both locations (Gezahegn Kebede *et al.,* 2019).

2.9.1.2 Number of branch

Number of branching/tillering performance of vetch species is an important agronomic traits for selection of crops to better forage yield. Environmental, genetic variability and managemental practices have a significant impact on the branching performance of vetch species (Gezahegn Kebede *et al.*, 2019). Alemu Tarekegn (2014) found that number of branch of vetch species at harvesting stage; Vicia *villosa* (3.1)*, Vicia benghalensis* (2.9)*, Vicia dasycarpa* (2.8)*,* and *Vicia atropurpurea* (2.8) *are* different from branch number of *Vicia sativa* (2.4) in North Gondar. *Vicia dasycarpa* (10.8) and *Vicia villosa* (14.5) gave the highest branches at Holetta and Ginchi respectively, while *Vicia narbonensis* (1.3-2.4) gave the lowest branches at both locations (Gezahegn Kebede *et al.*, 2019).

2.9.1.3 Dry matter yield

As reported by Gezahegn Kebede *et al.* (2013) vetch species DM yields were ranged from 1.39 to 5.84 and 1.99 to 7.62 t/ha at Holetta and Ginchi respectively and *Vicia villosa* gave relatively higher total DM yield followed by *Vicia dasycarpa* in Holetta. Whereas, Alemu Tarekegn (2014) reported that highest herbage yield was obtained from *Vicia villosa (*32.0t/ha) while the lowest herbage yields from *Vicia sativa (*9.6t/ha). On the other hand, *Vicia villosa* (8.2t/ha), *Vicia atropurpurea* (6.9t/ha), and *Vicia dasycarpa* (6.7t/ha) are more adaptive and productive in dry matter yield than others in North Gondar. The dry matter yield of vetch species in the Highland of Guji Zone reported by Usman Semmana *et al.* (2019) ranged from 0.17-5.83t/ha and from these vetch species *Vicia sativa* (5.83) have highest dry matter yield followed by *Vicia villosa* (3.77), *Vicia dasycarpa lana* (3.38), *Vicia atropurpureum* (3.19), *Vicia villossa Holeta* (2.82), and *Vicia dasycarpa namoi* (0.17).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in Kudmi kebele, North Mecha district under irrigation condition. North Mecha district is one part of West Gojjam Zone, Amhara Regional state, Ethiopia. The study area is 34 km far from Bahir Dar, the capital city 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 at 11^{0}21'0" to 11^{0}24'0" N latitude and 37^{0}6'0" to 37^{0}9'0"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) (Likawunt Yeheyis *et al.,* 2012).

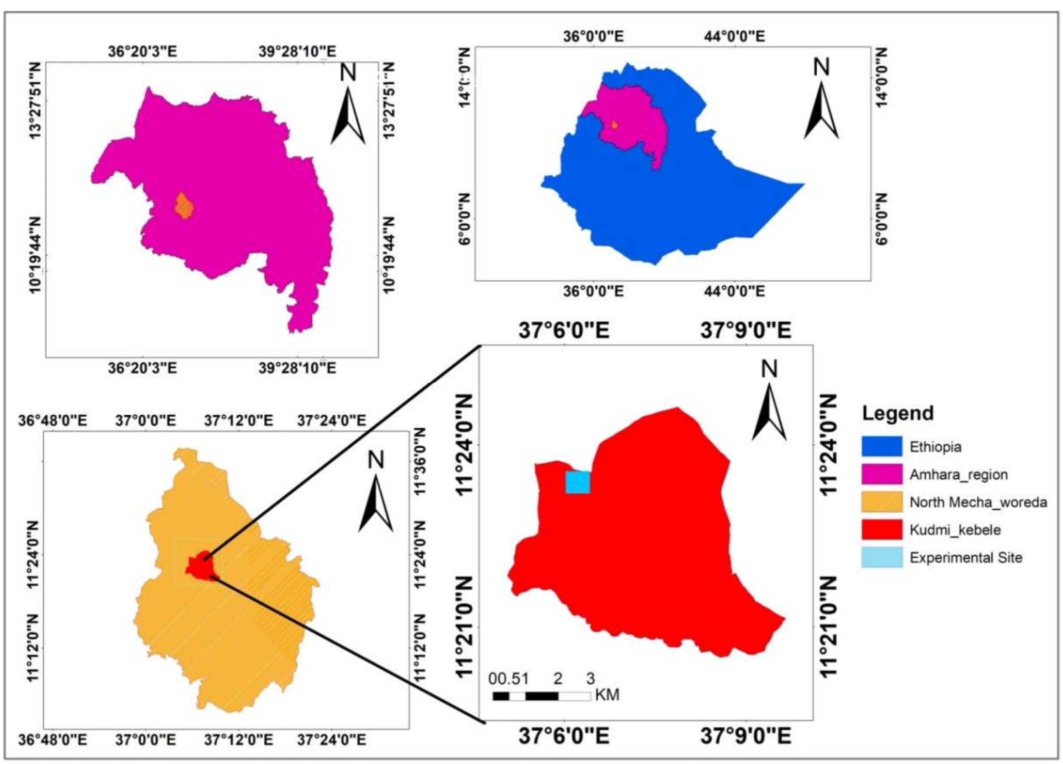


Figure 1. Experimental site

3.2 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 by oxen. The land was leveled out to maintain a well prepared seedbed and laid down experimental plots. 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 plot. The sowing plots were irrigated three times per week (Basaran *et al.,* 2017) and weeding management was held by hand weeding practice. Follow-up activities were held throughout the experimental period (until forages were harvested).

3.3 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 rates with the proportions of (100%, 75%:25%, 50%:50%, 25%:75%, 100%) Sudan grass (Aden-Gode) and vetch species (*Vicia dasycarpa*), respectively and it was intercropped under three (3) replications. The experiment has a total of five (5) treatments with 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 288m^2 (24m*12m) with 12m^2 (4m*3m) individual plot size (Appendix 7.3). The space between plot and block was 1m and 1.5m respectively. 25 kg/ha for *Vicia dasycarpa* of vetch species 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 sowing method was applied through row broadcasting without considering seed spacing. The two varieties of grown forages of Sudan grass (Aden-gode) and vetch species (*Vicia dasycarpa*) were sown at the same time (Iqbal *et al.,* 2015).

Table 2. Treatment setup of the Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) intercropping

Treatments	Intercropping seed rate	sowing seed rate (Sudan grass+vetch) in kg/ha
T1(Sole Sudan grass)	100% S	10kg/ha
T2	75% S:25% V	7.5kg/ha+6.25kg/ha
T3	50%S:50% V	5kg/ha+12.5kg/ha
T4	25%S:75% V	2.5kg/ha+18.75kg/ha
T5 (Sole vetch)	100% V	25kg//ha

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

3.4 Agronomic Parameter Data Collection Methods

3.4.1 Agronomic parameter data collection methods for Sudan grass (Aden-gode)

During the time of data collection, different agronomic parameters were recorded. 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. For agronomic parameters, ten plants (Ahmed *et al.,* 2019) 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.

Plant Height: For Sudan grass forage, the height agronomic parameter was recorded by using tap meter from ten plants randomly selected from the four middle rows of each plot leaving the two edge rows by considering the border effect. Plant heights were measured from above the soil surface to the tips of the tallest leaf (Natural standing height) for Sudan grass (Rayburn *et al.,* 2007). After measuring the height of the plant average mean value was determined.

Number of Leaf per Tiller: Numbers of leaves per tiller were recorded through selected ten plants from the middle rows randomly considering the border effect as other agronomic characteristics. Just before cutting plants for fresh biomass, the number of leaves were counted and average value was recorded.

Leaf Length: Such like to that plant height, and leaf length also was measured by using a tap meter. Leaf length was measured from the peak of the sheath or the base of the leaf blade to the apex parts of the leaf. Ten plants were selected from the middle rows and randomly select the leaf and measurement was preceded and the average value of leaf length was recorded.

Leaf Width: Leaf width was measured by selecting ten plants randomly from selected rows considering border effect and such like leaf length; leaves were selected randomly from selected plants. Leaf width was also measured by using Ruler. Leaf width was measured from three parts of the leaf (Arendonk, & Poorter, 1994) such as; at the base of the leaf blade, at the middle of the leaf, and below the tip parts of the leaf, and the average was recorded.

Number of Tillers per Plant: The number of tillers per plant was also counted by taking ten plants from each experimental plot randomly by leaving edge rows and then the average number of tillers per plant was determined for each plot.

Stem thickness: To measure stem thickness, ten plans were selected from the middle rows randomly considering the border effect like other agronomic parameters. Stem thickness (stem circumference) was measured by using a tap meter after avoiding all leaves and leaf sheath from the steam and the average value was recorded.

Root Number and Root Length: The number and length of roots from each plot were measured by thoroughly digging out. Immediately after the sample is taken and washed with water gently to clean the soil and other debris that enabled to count and measure properly. The numbers of the root of each plot were counted and determined the mean value of the root numbers. The root length was measured from the crown root part to the tip of the longest root and determined the average length.

Leaf to stem ratio: Leaf to stem ratio was determined by taking a fresh subsample weight of about 500g from harvested fresh biomass for each treatment and then leaves and stems were alienated carefully. The fractioned subsample of leaf and stem were brought into air dried in airtight bag and then the leaf to stem ratio was calculated by dividing leaf dry weight to stem dry weight (Nguku *et al.,* 2016).

3.4.2 Agronomic parameter data collection methods for vetch (*Vicia dasycarpa*)

Plant Height: For vetch species, the height agronomic parameter was recorded by using a tap meter from ten plants randomly selected from the four middle rows of each plot leaving edge rows by considering the border effect. Plant height was measured from the soil surface to the end part (tip) of the tallest branch (Rayburn *et al.,* 2007).

Number of Branches: The number of branches of vetch was recorded by separating the individual vetch from each plot carefully. The branch numbers of the vetch were recorded by only considering the first branch rather than the fine branch of the vetch plant.

Root Length and Root Number: length and number of roots from each plot were measured by carefully digging out as soon as immediately after the sample was taken and washing with a droplet of water to clean the soil and other debris that enables to count and measure properly. The numbers of the root of each plot were counted and determined the mean value of the root numbers. The root length was measured from the base of the branch root part to the tip of the largest branch or tap root and was determined by the mean values of the root length from each plot.

Number of Nodules: The number of nodules was recorded from each plot. Ten vetch plants were selected as soon as immediately after the sample is taken and appropriately dug out from the soil and also thoroughly washed the root with clean water to remove the soil and debris for counting nodules effectively.

3.5 Sampling Methods for Fresh Biomass and Dry Matter Yield (ton/ha)

The harvestable plant for fresh biomass and dry forage yield determination was cut down at 5 cm and 2.5 cm for Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) above the ground level respectively. Fresh biomass was collected for vetch species when it reaches the fifty percent flowering stage and the first heading stage for Sudan grass (Enchev, 2021). The plot size of each treatment was $12m^2$ and from each plot, four middle rows (4^{th}, 5^{th}, 6^{th}, and 7^{th}) with a net harvestable area of ($3.6m^2$) per plot and $54m^2$ per total harvestable area from fifteen plots by considering border effects (leaving 50cm lengthwise from each side). A fresh herbage yield of the Sudan grass and vetch was measured immediately after harvesting and weighed soon after harvesting using field balance. Fresh biomass yield was measured for each sole crop as well as for both components in the case of intercropping. The dry matter percentage was determined by taking about 500g (weighted by field sensitive balance) of fresh subsamples from the total fresh biomass from each plot. Subsamples were chopped into short lengths (2-5cm) and then packed with an air-tight bag and subjected to oven drying at 65ºC for 72 hours to estimate dry matter yield (ton/ha). 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. After determining the dry matter percentage, the dry matter yield was calculated. The weighed fresh sub-samples (FWss) were oven dried and reweighted (DWss) to estimate dry matter yield (DMY). The dry matter yield (DMY) of forage grown in the study area was calculated through Tarawali (1995) formula, (10×TFW×DWss /(HA×FWss)).

Where:

TFW = Total fresh biomass weight in kg

DWss = Dry weight of the subsample in grams

FWss = Fresh weight of the subsample in grams

HA = Harvested area in m^2

10 = A constant for conversion of yields in kg/m^2 to ton/ ha

Therefore, to determine crude protein yield (CPY), Dry matter yield (DMY) is determined and then multiplied with the CP content of the feed samples (CPYt/ha = CP% × DMY).

3.6 Biological Compatibility

3.6.1 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

Y_{sI} = yield of Sudan grass in intercropping

Y_{sS} = yield of Sudan grass in sole cropping

Y_{vI} = yield of vetch species in intercropping

Y_{vS} = yield of vetch species in sole cropping

3.6.2 Competitive ratio (CR)

The CR also was determined through the ratio of the forages sown in a mixed stand and represents the proportion of individual LERs of forage in intercropping and multiplying the value by their respective seed rate intercropping proportion. The following formulas can be used to determine the CR (Fuller & Madella, 2001; Petrie & Bates, 2017).

$CR_s = (LER_s/LER_v) \times Z_{vs}/Z_{sv})$

$CR_v = (LER_v/LER_s) \times (Z_{sv}/Z_{vs})$

$CR_S/CR_V = (LER_s/LER_v) \times Z_{vs}/Z_{sv})/ (LER_v/LER_s) \times (Z_{sv}/Z_{vs})$

Where;

CR_s and CR_v = competitive ratio of Sudan grass and Vetch,

LER_s and LER_v = the Land Equivalent Ratio of Sudan grass and Vetch

Z_{sv} = Sown ratio of Sudan grass in the intercropping

Z_{vs} = sown ratio of Vetch in the intercropping

3.6.3 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.

$$A_{sv} = \frac{Y_{sv}}{Y_s * Z_{sv}} - \frac{Y_{vs}}{Y_v * Z_{vs}}$$

Where;

A_{sv} = the Aggressiveness of Sudan grass and vetch

Y_{sv} = dry matter yield of Sudan grass in the intercropping

Y_{vs} = dry matter yield of Vetch in the intercropping

Y_s and Y_v = dry matter yield of Sudan grass and vetch on their sole stand

Z_{sv} and Z_{vs} = Intercropping proportion of Sudan grass with vetch and vetch with Sudan grass, respectively

3.7 Chemical Composition Determination

Chemical composition analysis of forage samples was carried out using representative samples from respected sample plots. From total fresh biomass 500g of Fresh samples were taken and stored in an airtight bag and samples were dried in a forced-air draft oven at 65°C for 72 hours for 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) at Bahir Dar University College of Agriculture and Environmental Sciences in Animal Nutrition Laboratory. Representative grounded samples from each treatment plot have waited in an airtight bag until subjected to chemical analysis. Then after, representative grounded samples were subjected to chemical analysis following the methods (AOAC*,* 1990) to determine the dry matter (DM), ash, organic matter (OM), and nitrogen (N) (Kjeldahl procedure). Forage quality measurements such as determination of acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) were analyzed by using the Van Soest method (Van Soest *et al.,* 1991). Crude protein was determined through determine nitrogen contents of sample forages and multiply by 6.25. Ash content was determined by igniting at 550°C overnight.

3.8 Statistical Analysis

Microsoft excels spreadsheet and SAS version 9.0 (SAS, 2004) software package was used for the data record, data management, and data analysis. After collecting and recording data, the data was checked for its normality. After checking data normality, 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 chemical composition were subjected to Analysis of Variation (ANOVA). With the assumptions attended, the analysis of variance was performed with the application of the F test. 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 plant morphology, dry matter yield, and chemical composition. The model for data analysis was:-

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

Where:

Y_{ijk} = result from the variable of morphological characteristics, forage yield, biological compatibility and chemical composition

μ = overall mean

B_i = block effect

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

e_{ijk} = experimental error effect

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Effects of Seed Rate on Morphological Parameters of Sudan Grass (*Sorghum sudanense* "Aden gode") Intercropping with Vetch (*Vicia dasycarpa*)

All morphological parameters of Sudan grass (Aden gode) *i.e*. plant height, number of leaves per plant, number of tiller per plant, leaf length, leaf width, leaf area, root number, leaf to stem ratio, and dry matter percentage presented in (Table 3) was significantly affected ($P<0.05$) on seed rate of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) intercropping. Whereas, root length and stem thickness of Sudan grass (Aden gode) were not significant different ($P>0.05$). In the current study as shown in (Table 3), the better results of morphological parameters of Sudan grass (Aden gode) such as plant height, number of leaves per tiller, number of tiller per plant, leaf length, leaf width, leaf area, root number, and leaf to stem ratio was recorded in 75%:25% seeding rate intercropping of Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*).

4.1.1 Plant height

A seed rate of vetch (*Vicia dasycarpa*) and Sudan grass (Aden gode) intercropping had a significant ($P<0.05$) effect on plant height. The current result revealed in (Table 3) the overall mean value of plant height (153.13±3.05cm) of Sudan grass (Aden gode) was recorded. The highest plant height (161.17cm) was recorded in 75%:25% of seed rate intercropping. The medium plant height (156.3cm and 151cm) of Sudan grass (Aden gode) was recorded on seed rate treatment combination of 50%:50% and 25%:75%, respectively. The shortest plant height (144.03cm) was recorded from Sudan grass sown alone. This high variation of plant height is due to the intercropping forage seed rate difference.

Plant height in the current study was significantly ($P<0.05$) affected by intercropping seed rate treatments. This significant results of seed rate intercropping on plant height were supported by the authors Guleria & Kumar (2016) they reported that intercropping of Sudan grass with legumes produced significantly taller than a pure stand. 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. These results are also in harmony with the authors Amanullah *et al.* (2016) who stated that intercropping forage cereals with legumes could increasing plant height in intercropping forages. 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.

The mean plant height (153.13±3.05cm) of the current result was highly similar to the finding of Najmaldin & Ali (2019) who conducted a 12kg/ha seed rate of Sudan grass (*Sorghum sudanese*) sown and found a significant effect on plant height (152.6cm). 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 Aklilu 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 intra-specific nutrient competition.

The 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 plant height of Sudan grass (Aden gode) was highest in intercropped than in its alone and this result is supported by Basaran *et al.* (2017) who showed the plant height of Sudan grass (*Sorghum sudanese*) is highest in the mixture than its alone. On the other hand, the results of plant height (151cm) in 25%:75%, intercropping seed rate was greater than the results found by Erkovan (2022) who outlined (52.38cm) plant height was obtained from 25%:75% intercropping of Sudan grass (*Sorghum sudanese*) with common vetch (*Vicia villosa*). This greater result might be due to the genetic variation of Sudan grass and vetch, environmental variation, and also management variation.

The higher ($P<0.05$) plant height in intercropping than Sudan grass (Aden gode) sown alone observed in the current study might be due to fixing nitrogen by the vetch (*Vicia dasycarpa*). It may also possibly due to competition to the light, decreasing of seed rate, and also low plant density could allow for good aeration in intercropping. This result is highly agreed with the finding of Basaran *et al.* (2017) who found the highest plant height of sorghum Sudan grass hybrid intercropped with soybean (Yemsoy) and cowpea (Ulkem) varieties with different seed ratios. It was possibly due to light competition between inter-species. This result is also supported by the authors Adeniyan *et al.* (2014) who conducted research on intercropping of maize (*Zea mays*) and cassava (*Manihot esculenta*) and revealed that intercropping maize (*Zea mays*) was increased in plant height than its sole.

Therefore, the plant height of Sudan grass (Aden gode) was higher in the intercropped than alone. It might be the reason high plant density (100%) Sudan grass prevents the passage of sunlight into the bottom leaves and due to inter-species light competition in intercropping is responsible for plant growth. This was in harmony with Basaran *et al.* (2017) who outlined the intercropping of Sudan grass (Aneto) with cowpea (Ulkem) and soybean (Yemsoy) varieties. Generally, the highest plant height is better agronomical management to achieve more biomass in forage development.

4.1.2 Number of leaves per tiller

The number of leaves per tiller is significantly ($P<0.05$) affected on seed rate of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) intercropping with the overall mean value of (8.84±0.60). In the current result (Table 3) the largest number of leaves per tiller (12.33) was obtained from 75%:25% seed rate intercropping treatment. On the other hand, the lowest value of leaf number per tiller (8.97, 7.13, and 6.93) was obtained from 100%, 50%:50%, and 25%:75% seed rate intercropping treatments, respectively.

Significant ($P<0.05$) difference in leaf per tiller was found as shown in (Table 3) below. The highest leaf number per tiller (12.33) was obtained from 75%:25% seed rate intercropping of Sudan grass (Aden gode) and then leaf number decreased to (8.97) when Sudan grass (Aden gode) sown alone. This result was supported by the finding of Atabayeva *et al.* (2021) who outlined the number of leaves decreases from 7.0 to 5.5 as sowing rate increases. Whereas, present result was also greater than the finding of Kriukova (2020) who revealed the leaf number of Sudanese grass ranges from 6.6-7.9. Significantly higher value of leaf number per tiller (12.33) was obtained from intercropped Sudan grass (Aden gode) than it's alone (8.97) (Table 3). This results were in line with the finding of Ginwal *et al.* (2019) who outlined that a higher value of leaf number per tiller was recorded in forage maize and cowpea intercropping. The greater number of leaf numbers per tiller in the intercropping might be due to the reason intercropping with legumes and hence, better forage canopy and efficient utilization of solar radiation. On the other hand, current results were akin to the finding of

Shahrajabian *et al.* (2021) they showed that the maximum and the minimum values of leaves per tiller were 11.04 and 10.88 and they stated that decreasing of leaf number is associated with increasing seed rate. This might be the reason high density or seed rate would have caused for decreasing leaf number due to nutrient competition. Besides to this, leaf number per tiller (12.33) from 75%:25% intercropping seed rate in the current result was similar to the finding of Keskin *et al.* (2018) who revealed that the number of leaves of sorghum Sudan grass hybrid (Hay day) which had 12.5.

4.1.3 Number of tiller per plant

The number of tillers per plant in the present study was significantly ($P<0.001$) influenced by the Seed rate of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) intercropping as shown in (Table 3). The mean values of the number of tillers per plant (11.58±0.80) were recorded. The greater number of tillers per plant (19.67) was recorded from 75%:25% intercropping of Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) and intermediate tillers number per plant (13.67) was observed from 50%:50% seed rate intercropping treatment. The lowest numbers of tillers per plant (5.67, & 7.33) was obtained from Sudan grass (Aden gode) sown alone and from 25%:75% Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) seed rate intercropping respectively.

Results on Table 3 showed that 75%:25% seed rate intercropping has highest value of numbers of tiller per plant (19.67). This might be 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. Present study of tiller number per plant was also greater than the value obtained by Alemu Tarekegn *et al.* (2020) who noted mean tiller number (6.53) was obtained from the same cultivar (Aden) in two season. Tiller number per plant (19.67) in 75%:25% intercropping treatment was higher than the finding of Shahrajabian *et al.* (2021) whose result revealed that the highest value of number of tillers per plant (2.91) had obtained from forage sorghum (*Sorghum bicolor* L.

Moench) compared with control treatment (2.87). These authors also noted that a higher tiller number per plant (3.28) was recorded when forage sorghum (*Sorghum bicolor* L. Moench) planted at less density than higher plant density treatments. 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.

The current results of seed rate treatments, the number of tillers per plant (19.67, 13.67, & 7.33) was greater than the value of tiller number per plant (6.87, 6.67, 6.93) obtained by Hassan *et al.* (2017) who found that tiller number per plant was significantly affected by intercropping of Sudan grass (*Sorghum sudanense* ((P.) Staph) with cow pea (*Vigna sinensis* L.), guar, and lima bean (*Cyamopsis tetragonoloba* L.), respectively sown with 50%:50% seed rate intercropping that compared from Sudan grass (*Sorghum sudanense* ((P.) Staph) sown as solid. The more tiller number in intercropping forages were observed and it might be due to the favorable microclimate created by legume (*Vicia dasycarpa*) and better availability of nitrogen to Sudan grass (Aden gode) plants. Besides to this, greater results might be due to the reason intercropping legumes, seed rate difference and also might be water use efficiency due to intercropping forage might maintain the soil moisture.

4.1.4 Leaf length and leaf width

Leaf length and width are important parameters to determine green forage yield and quality. Leaf length and leaf width in the current study were statistically significant ($P<0.001$) on intercropping seed rate of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) as shown in (Table 3). In the current study, the longest leaf (45.27cm) and widest leaf (2.79cm) were obtained from 75%:25% intercropping seed rate of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*). The smallest leaf length (29.93cm) was recorded at 25%:75% and the narrow leaf (2.22cm) were obtained from 50%:50% intercropping seed rate treatments. Whereas, the intermediate leaf length (40.43cm, 35.67cm) was recorded from 50%:50% intercropping seed rate and 100% seed rate of Sudan grass (Aden gode) sown as a sole. On the other hand, the medium values of leaf width (2.27, 2.24cm) were obtained from Sudan grass (Aden gode) sown as sole and from 25%:75% intercropping seed rate treatment, respectively. leaf length and leaf width in intercropped Sudan grass (Aden gode) had the best leaf length and width compared to Sudan grass (Aden gode) sown as solid. This might be due to the seed rate effect and intercropping of vetch (*Vicia dasycarpa*). The reason also might be legume intercropping had a complementary effect on Sudan grass (Aden gode) providing nitrogen and having an implication on increasing leaf length and width of Sudan grass (Aden gode).

The present results revealed that the overall mean value of leaf length 37.83±0.82cm was obtained. This result disagreed with the finding of Pahuja *et al.* (2014) who revealed leaf length (95±2.0cm) was found from sugar graze affected by row spacing. The current result of the leaf length ranges (29.93, 45.27cm) was slightly lower than the finding of Singh *et al.* (2014) whose results showed that leaf length (45-70cm) of forage sorghum hybrid. This variation was due to the genetic variation between Sudan grasses and forage sorghum hybrid and also might be due to row spacing having greater variation in leaf length than seed rate factors.

On the other hand, the overall leaf width (2.38±0.05cm) of the current result was statistically significant ($P<0.001$) on intercropping seed rate as shown in (Table 3). The current study revealed in (Table 3), the narrow and widest values of leaf (2.22, 2.79cm) were observed. The widest leaf was obtained from the 75%:25% intercropping seed rate. This greater value was attributed to plants' response to the light competition to the canopy and due to intercropping of vetch legumes can atmospheric biological nitrogen fixation takes place in the root nodules responsible for morphological development. These results were agreed with the finding of (Ginwal *et al.,* 2019). Whereas, it was lower than the finding of Singh *et al.* (2014) whose result showed that the leaf width (4-7cm) of the forage sorghum hybrid was recorded. This greater result might be the genetic variation between Sudan grasses (Aden gode) and forage sorghum. Meanwhile, smaller leaf width (2.79cm) was recorded in the current results than the finding of Pahuja *et al.* (2014) who outlined leaf width (6±0.58cm) was obtained in sugar grass sow spacing variation as a factor.

4.1.5 Stem thickness

Stem thickness is an important morphological parameter of grass forage which is an indicator of the quality of grass forage. It has a direct relationship with the crude fiber of grass forage and may have an inverse relationship with crude protein. If the Stem thickness increases it could be decreasing the protein content of the forage grass. Stem thickness is also an important factor in determining the digestibility and palatability of grass forages. Stem helps plants to support upright on the soil surface and increase forage yield. Even though, having this advantage high Stem thickness is not desirable due to wooden plants containing cellulose, hemicelluloses, and lignin which are difficult to digest, reduced palatability, and affect forage quality. But, Stem thickness in the current results was not significantly (P>0.05) different in seed rate intercropping of Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) as shown in (Table 3).

4.1.6 Root number and root length

Root number and root length of Sudan grass are the most important morphological parameters of Sudan grass having a direct relationship to increasing other plant morphological parameters due to their nutrient uptake from the soil. Therefore, significant (P<0.01) differences in root number and insignificance (P>0.05) in root length were observed in different seed rates of Sudan grass (Aden gode) intercropping with vetch (*Vicia dasycarpa*) in the current results (Table 3).

The root number of Sudan grass (Aden gode) in the current study was significantly (P<0.01) affected by seed rate treatments. The mean value of the root number (26.17±1.42) in the current study was obtained as shown in (Table 3). Therefore, the highest number of roots (35) in the current study was obtained in 75%:25% seed rate treatment. However, no significant differences were observed between 100% and 50%:50% seed rate treatments (Table 3). Meanwhile, the intermediate root numbers (29) per plant were obtained from 25%:75% seed rate treeatment. From the current results, greater root number per plant of Sudan grass (Aden gode) was found in intercropped than in its pure stand. This might be due to intercropping of different seed amounts having differences in root numbers and intercropping legumes fix atmospheric nitrogen could help plants growth and root development.

4.1.7 Leaf to stem ratio

Leaf to steam ratio is the most essential factor which helps determine the digestibility and palatability of any forages. Leaf represents the plant fraction of greatest importance in Animal feeds. Given its impact on diet choice, forage quality, and ruminant consumption, the ratio of leaf to stem biomass fractions for forage grasses is more important.

Leaf to stem ratio of the current result was statistically significant ($P<0.001$) on seed rate intercropping treatment (Table 3). The leaf to steam ratio is an important parameter to indicate better forage biomass production. Therefore, the mean value of the current results of leaf to steam ratio was 1.75±0.07 which means, the dry weight of the leaf was greater than the dry weight of steam of Sudan grass (Aden gode). 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*). Whereas the have no significant difference between 50%:50% and 25%:75% seed rate treatments (Table 3). The highest value of leaf to stem ratio (2.05) was obtained from 75%:25% seed rate intercropping plot compared to sole (100%) treatment. 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. This leads to greater leaf dry weight than stem dry weight and the highest leaf to stem ratio was obtained.

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 highest leaf to stem ratio (2.05) of the present study was in harmony with the finding of Bizelew Gelayenew *et al.* (2020) who showed that leaf to stem ratio (2.04) was found in Elephant grass (*Pennicetum purpureum*) planted with vetch (*Vicia villosa*). Whereas, the current study was in contrast to the finding of Ginwal *et al.* (2019) who stated that intercropping of grass forages with legumes (cow pea and guar) in varying row ratios and their respective sole treatment has no significance difference in the leaf to steam ratio. 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. On the other hand, Simili *et al.* (2013) reported that Sudan grass had 0.5 leaf to stem ratio. This significant value was less than the value obtained in the current study ranged from 1.50-205. When it comes to a plant's ability to absorb light and CO_2, leafy biomass plays a significant role. The greater leaf component suggests its potential for carbon sequestration by absorbing and lowering atmospheric CO_2 levels, and the larger leaf to stem ratio strongly suggests its competitive advantage to light for photosynthesis.

4.1.8 Dry matter percentage

Determination of dry matter percentage in forage is essential to insure that animals are receiving the proper amount of nutrients through their diet. There was a significant effect ($P<0.01$) on dry matter percentage in current results (Table 3). From each treatment plot the mean value of dry matter percentage was 20.89±0.59% and there is no variations between other treatments. This greater result of dry matter percentage (23.87%) in 50%:50% seed rate intercropping treatment was due to the reason forages taken from this treatment was more moisture than other treatments. Whereas the lower dry matter percentage in 25%:75% and 100% was due to the reason having less moisture content of Sudan grass (Aden gode).

Dry matter percentage was significantly ($P<0.01$) affected by intercropping seed rate (Table 3). Better dry matter percentages were obtained from intercropped than Sudan grass (Aden gode) sown alone. These high dry matter percentages were due to direct (increasing leaf number) and indirect (lower stem thickness) effects of morphological development. Present result is akin to the finding of Asem *et al.* (2020) who stated that dry matter percentages were affected by intercropping patterns of Sudan grass (*Sorghum sudanese*) and cow pea (*Vigna unguiculata*). Mean dry matter percentage (21.02%) of Aden in two season found by Alemu Tarekegn *et al.* (2020) was less than the dry matter obtained in present study. The result of Asem *et al.* (2020) dry matter percentage was significantly affected and produced a lower dry matter percentage (18.44%) in Sudan grass (*Sorghum sudanese*) intercropping with cow pea (*Vigna unguiculata*) than the current result of dry matter percentage (22.15%) of Sudan grass (Aden gode) intercropping with vetch (*Vicia dasycarpa*) in the same seed rate (75%:25%).

Therefore, in the current result had better dry matter and forage quality than the result of (Asem *et al.,* 2020). In addition to current results dry matter percentage of Sudan grass (Aden gode) ranged from 17.91%-23.87% was in line with the finding of Lyons *et al.* (2019) dry matter percentage (20%) on optimal harvesting time of Sudan grass. Besides those authors, dry matter percentages (17.91%-23.87%) obtained in the current study were in accordance with dry matter percentage (15.3%- 23.9%) obtained by Beck *et al.* (2014) studied on chemical composition and dry matter percentage of Sorghum-Sudan grass hybrid.

In contrast, the highest value of dry matter percentage was obtained by the scholars Keskin *et al.* (2018) their results showed that Sudan grass hybrid had dry matter percentage ranging from 32.0% up to 38.0%. This greater dry matter percentage might be due to genetic, environmental, and management variation. On the other hand, dry matter percentage obtained by the author Enchev (2021) ranged from 26.8%-34.8% of Sudan grass cultivar and these results were greater than the dry matter percentage obtained in the current study ranged from 17.91% -23.87%. This greater value was due to genetic variation.

Table 3. Morphological parameters of sole and intercropped Sudan grass (Aden-gode)

Treatments	Measured Morphological Parameters									
	PH (cm)	NLPT(count)	NTPP(count)	LL (cm)	LW (cm)	Stt(cm)	RN(count)	RL(cm)	LSR	DM%
T1(Sole Sudan grass)	144.03^{c}	8.97^{b}	5.67^{c}	35.67^{c}	2.27^{b}	3.29^{a}	17.67^{c}	18.00^{ba}	1.87^{b}	19.63^{bc}
T2	161.17^{a}	12.33^{a}	19.67^{a}	45.27^{a}	2.79^{a}	2.10^{ba}	35^{a}	23.33^{ba}	2.05^{a}	22.15^{b}
T3	156.3^{ba}	7.13^{b}	13.67^{b}	40.43^{b}	2.22^{b}	2.85^{ba}	23^{c}	25.80^{a}	1.61^{c}	23.87^{a}
T4	151^{bc}	6.93^{b}	7.33^{c}	29.93^{d}	2.24^{b}	2.95^{ba}	29^{b}	19.36^{ba}	1.50^{c}	17.91^{c}
T5 (Sole vetch)	-	-	-	-	-	-	-	-	-	-
Over all mean	153.13	8.84	11.58	37.83	2.38	2.79	26.17	21.62	1.75	20.89
SEM (±)	3.05	0.60	0.80	0.82	0.05	0.28	1.42	1.14	0.07	0.59
CV%	3.03	17.59	16.34	4.35	2.70	19.81	10.86	16.41	7.35	6.12
R^2	0.84	0.81	0.95	0.96	0.97	0.65	0.91	0.67	0.84	0.87
LSD	9.28*	3.11*	3.78***	3.29***	0.13***	1.11^{NS}	5.68**	7.09^{NS}	0.23**	2.55**

*T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, PH = Plant Height, NLPT = Number of Leaves per Tiller, NTPP = Number of Tiller per Plant, LL = Leaf Length, LW = Leaf Width, LA = Leaf Area, Stt = Stem thickness, RN = Root Number, RL = Root Length, LSR= Leaf to Steam Ratio, DM% = Dry Matter percentage, SEM = Standard Error of Mean, CV% = Coefficient of Variation percent, R^2 = Coefficient of determination, N = Number, cm = centimeter, a, b & c = level of mean difference, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01), *** (p<0.001)*

4.2 Effects of Seed Rate on Morphological Parameters of Vetch *(Vicia dasycarpa)* Intercropping with Sudan Grass (*Sorghum sudanense* "Aden gode")

In the current study all morphological parameters such as plant height, number of branches, root number, nodule number and dry matter percentage production of vetch (*Vicia dasycarpa*) were statistically significant (P<0.05) effects on seed rate intercropping with Sudan grass (Aden gode) (Table 4). While, root length of vetch (*Vicia dasycarpa*) was not statistically significant (P>0.05) on seed rate intercropping with Sudan grass (Aden gode) (Table 4). Therefore, most of the morphological parameters of vetch (*Vicia dasycarpa*) that intercropped with Sudan grass (Aden gode) were higher than the vetch (*Vicia dasycarpa*) that was not intercropped with Sudan grass (Aden gode) in the current study.

4.2.1 Plant height

Plant height is an important morphological parameter for forage production to obtaining high biomass and dry matter production. In the current study, a statistically significant (P<0.001) plant height of vetch (*Vicia dasycarpa*) was obtained on seed rate intercropping (Table 4). 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 (Table 4). Increasing plant height in intercropping treatment is due to inter-species light competition. On the other side, the intermediate plant heights (127.33, 117.33cm) in the current study were obtained from 50%:50% and 25%:75% seed rate intercropping treatments that were compared from Vetch sown as a pure stand (Table 4).

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 4). 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 (117.33 to 136.23cm) in the present study was increased with increasing seed rate proportion (25% to 75%) of Sudan grass and this result was similar to the finding of Erkovan (2022) who noted that plant height of vetch (*Vicia sativa*) increase from 48.38cm to 52.38cm with increasing the Sudan grass ratio from 25% to 50%. Plant height of vetch species noted by the authors Kassahun Desalegn and Wasihun 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). 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.

These result was also in line with the finding of Yihalem Denekew and Habtemariam Asefa (2012) 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 *et al.* (2018) from oats–vetch mixtures at different harvesting stages. On the other hand, the highest plant height (139.2cm) of vetch (*Vicia dasycarpa*) was obtained by the authors Bizelew Gelayenew *et al.* (2020) noted that vetch (*Vicia dasycarpa*) intercropped with Elephant grass (*Pennisetum purpureum*) in Debre Zeit and Holeta. Whereas, the plant height (133.6cm) of vetch (*Vicia dasycarpa*) intercropped with Elephant grass (*Pennisetum purpureum*) in Debre Zeit was comparable with present plant height (136.23cm) of vetch (*Vicia dasycarpa*). Other study conducted by Malede Birhan (2018) noted that the plant height (114.22cm) of vetch (*Vicia villosa*) in 75%:25% seed proportion with triticale was less than the current study plant height of vetch (*Vicia dasycarpa*) in the same seed rate proportion. This less plant height was due to both vetch and the component grass genetic variation, and environmental.

4.2.2 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. The current study (Table 4) revealed that the overall mean number of branch of vetch (*Vicia dasycarpa*) was 17.75±0.82. Besides to this, the 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. Present study showed that numbers of branches were decreased with increasing seed rate in intercropping due to intra-species nutrient competition. Even as seed rate intercropping have advantageous for efficient water used and enough moisture available and leads to increasing branch number of vetch (*Vicia dasycarpa*). On the other hand, intermediate branch numbers (19.00, 15.67) of vetch in the current study were obtained from 75%:25% and 25%:75% seed rate intercropping compared to the vetch (*Vicia dasycarpa*) sown as a pure stand (Table 4). This might be due to the reason increasing seed rate may be decreasing branch number. The highest branch number in 50%:50% seed rate intercropping treatment might be due to the reason less nutrient competition between and within species and also it might be due to Sudan grass gaining its importance for supportive mechanisms for vetch and leads to increasing branch numbers.

The number of branches (17.75±0.82) in the current study was significantly affected by seed rate intercropping and 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. Inconsistency, seed rate was statistically insignificant ($P>0.05$) on number of branches found by Shahrajabian *et al.* (2017) noted that the branch number of common vetch (*Vicia sativa* L.) sown as a pure stand had higher branch number than intercropped with oat (*Avena sativa* L.) under seed rate and row configuration treatments. The current mean value of branch number (17.75±0.82) of vetch (*Vicia dasycarpa*) was greater than the mean value of branch number (11.43) noted by Eshetie Alemu *et al.* (2018) on oats–vetch mixtures at different cutting stage under residual moisture condition in Ethiopia. This greater result was due to environmental factors, soil type, and also might be the component grass variations.

4.2.3 Root number and root length

The root number of vetch (*Vicia dasycarpa*) was affected by seed rate intercropping with Sudan grass (Aden gode). Significant ($P<0.001$) variation was observed on root number of vetch (*Vicia dasycarpa*) in seed rate intercropping with Sudan grass (Aden gode). However, in this study insignificant ($P>0.05$) root length was observed among seed rate intercropping treatment as shown in (Table 4). Significantly root number (38.00) of vetch (*Vicia dasycarpa*) was obtained from 75%:25% seed rate intercropping plots (Table 4). Whereas, significantly lower root number (20.01) was found from 25%:75% vetch (*Vicia dasycarpa*) intercropping seed rate. Greater root number in 75%:25% seed rate intercropping compared to 25%:75% vetch (*Vicia dasycarpa*) intercropping indicated that lower seed rate had factor to increasing root number and leads to increasing forage production. However, the intermediate root numbers (31.07, 26.33) were found from the 50%:50% and 100% seed rate intercropping treatments, respectively (Table 4). The lower value of root number in vetch (*Vicia dasycarpa*) grown in sole compared to 50%:50% seed rate intercropping and this was due to the reason highest seed rate cause for intra-species nutrient competition and it may decrease the forage production.

The significant ($P<0.001$) variation of root number with different seed rate intercropping treatments was similar with the finding of Acikbas *et al.* (2021) they showed that root number was significantly ($P<0.01$) affected by seed rate intercropping of common vetch (*Vicia sativa* L.) and Triticale (*Xtriticosecale Wittmack*) compared from common vetch (*Vicia sativa* L.) sown alone. In the current results, root number (38.00) of vetch in 75%:25% seed rate intercropping significantly higher than vetch sown as alone. This result was inconsistent with the study of Acikbas *et al.* (2021) outlines that the root number (17.95) of common vetch (*Vicia sativa* L.) sown as a pure stand was greater than the value of root number (11.42) in the 80%:20% intercropping of Triticale (*Xtriticosecale Wittmack*) and common vetch (*Vicia sativa* L.). The present study showed that a positive effect of intercropping on root number of vetch (*Vicia dasycarpa*). This was attributed from Sudan grass (Aden gode) has a positive effect on vetch root number and might be intercropping had important in efficient water used and retention of moisture leads to increasing of root number in vetch (*Vicia dasycarpa*). The present study was supported by the finding of Bukovsky-Reyes *et al.* (2019) noted that there have positive significant variation was observed in root number in ray grass (*Secale cereale*) intercropped with hairy vetch (*Vicia villosa*). This significant result was expected, in mixture vetch root number was adapted when inter-species competition.

4.2.4 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. The mean value of root nodules (21.42±0.94) in the recent study were found significantly affected by seed rate intercropping of Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) as revealed in (Table 4). 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) in the current results were 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. Increasing seed rate would be caused for decreasing the number of nodules. However, the medium numbers of nodules (26.09, 17.03) of vetch (*Vicia dasycarpa*) were observed from 50%:50% and 25%:75% seed rate intercropping treatments.

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 (2017) intercropping of common vetch with oat compared to the recent study of seed rate intercropping with Sudan grass. The recent results of the number of nodules in vetch (*Vicia dasycarpa*) were less than the number of nodules (53) noted by the authors Muluneh Minta and Angaw Tsige (2014) on vetch (*Vicia dasycarpa*) that was un-inoculated with *rhizobium* bacteria. Therefore, the highest number of nodules in the seed rate treatment has the ability to increase biological atmospheric nitrogen fixation (Golparvar, 2012) in the intercropping and leads to increasing forage yield in both forages grown under the experiment.

4.2.5 Dry matter percent of vetch

Dry matter percentage production revealed in (Table 4) was statistically significant ($P<0.05$) on seed rate intercropping treatment of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*). Significantly, the highest value of dry matter percentages (19.48, 19.24, and 18.95%) were found in 50%:50%, 100%, and 75%:25% seed rate treatment in the recent study. Whereas, the lowest value of dry matter percentage (17.22%) was obtained from 25%:75% seed rate intercropping plots (Table 4). Therefore, the highest dry matter percentage seed rate intercropping treatments would give better dry matter yield than the lowest dry matter percentage seed rate treatment. On the other hand, the lowest dry matter percentage is vital when forages are stored for a long period due to low moisture content compared to the highest dry matter percentage production. Whereas, the lowest dry matter percentage would have better nutritional value than the greater dry matter percentage production.

Dry matter percentages of the current results were significantly (P<0.05) different in seed rate intercropping of Sudan grass and Vetch. This significant effect of dry matter were comparable with the finding of Song *et al.* (2021) showed that statistically significant of dry matter percentages was found on Sorghum-Sudan grass (*Sorghum bicolor*) intercropped with cow pea (*Vigna unguiculata* L.Walp) and lablab (*Lablab purpureus* (L.) Sweet). Hence, the mean value of dry matter percentage (18.72%) in the present study was significantly (P<0.05) greater than the mean value of dry matter percentage production (9.40%) of Cow pea (*Vigna unguiculata* L.Walp) intercropped with Sorghum-Sudan grass hybrid (*Sorghum bicolor*) noted by the author Song *et al.* (2021). Meanwhile, the mean value of dry matter percentage (13.82%) of lablab (*Lablab purpureus* (L.) Sweet) intercropped with sorghum-Sudan grass (*Sorghum bicolor*) outlined by Song *et al.* (2021) was less than the mean value of dry matter percentage (18.72%) of vetch (*Vicia dasycarpa*) intercropped with Sudan grass (Aden gode) in the present study.

Inconsistency to the recent study, the dry matter percentage production revealed by Demissie Negash *et al.* (2017) had no statistically significant (P>0.05) on seed rate intercropping of oat (*Avena sativa*) and vetch (*Vicia villosa*). However, comparable result of dry matter percentage (19.48%) production was found from 50%:50% seed rate intercropping with the finding of Demissie Negash *et al.* (2017) noted that dry matter percentage (19.43%) production from 75%:25% seed rate intercropping treatment of oat (*Avena sativa*) and vetch (*Vicia villosa*). contradictory, the lower value of dry matter percentage (18.05%) production was found by Demissie Negash *et al.* (2017) from 100% vetch sown alone compared to the recent study of dry matter percentage production obtained from 100% vetch sown as pure stand. But, the dry matter percentage (19.29%) obtained by the authors Demissie Negash *et al.* (2017) from 25%:75% intercropping oat and vetch was greater than the value of dry matter percentage (17.22%) production found from 25%:75% Sudan grass intercropped with vetch in the present study. These variations of dry matter percentage productions were due to genetic and environmental variations.

Table 4. Morphological parameters of sole and intercropped vetch (*Vicia dasycarpa*)

Treatments	Measured Parameters					
	PH (cm)	NBr (count)	RN (count)	RL(cm)	NN (count)	DM%
T1(Sole Sudan grass)	-	-	-	-	-	-
T2	136.23^{a}	19.00^{b}	38.00^{a}	22.00^{ba}	31.67^{a}	18.95^{a}
T3	127.33^{b}	27.00^{a}	31.07^{b}	24.32^{a}	26.09^{b}	19.48^{a}
T4	117.33^{c}	15.67^{b}	20.01^{d}	21.34^{b}	17.03^{c}	17.22^{b}
T5 (Sole vetch)	109.85^{d}	9.33^{c}	26.33^{c}	23.33^{ba}	11.01^{d}	19.24^{a}
Over all mean	122.69	17.75	28.83	22.75	21.42	18.72
SEM (±)	1.16	0.82	1.02	0.67	0.94	0.92
CV%	1.85	9.98	4.13	5.81	7.26	3.86
R^2	0.97	0.96	0.98	0.65	0.98	0.90
LSD	4.55***	3.54***	2.38***	2.64^{NS}	3.11***	1.44*

*T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, PH = Plant Height, NBr = Number of Branch, RN = Root Number, RL= Root Length, NN = Nodule Number, DM% = Dry Matter percentage, SEM = Standard Error of Mean, CV% = Coefficient of Variation percent, R^2 = Coefficient of determination, N = Number, cm = centimeter, a, b & c = level of mean difference, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01), *** (p<0.001)*

4.3 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 5). 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 5).

4.3.1 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 5). 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 (Table 5). 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 (Table 5). 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 shown 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 a pure stand cultivation might be decreasing dry matter yield.

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 5). 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 Mergia 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.

The mean value (5.75±0.37t/ha) of DMY obtained in present study was similar with the finding of Alemu Tarekegn *et al.* (2020) who showed that 5.78 t/ha of mean dry matter found from the Sudan grass (Aden gode) in two season. 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 5. 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 as reported by Alla *et al.* (2015).

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 5). 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.

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 Mergia 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). Similar to the present study, the scholars Ghanbari *et al.* (2010); Basaran *et al.* (2017) stated that forage qualities and quantities were highly achieved in intercropping. This could be crude protein yield per unit area is mostly dependent on dry matter production (Abuneram, 2013). 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 (Singh *et al.,* 2008; Seran & Brintha, 2010; Alla *et al.,* 2015).

4.3.2 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 5). 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.

On the other hand, yield of intercropping had certain changes under different intercropping seed rates. 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 Yihalem Denekew and Habtemariam 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. The recent dry matter yield (6.19t/ha) obtained from 25%:75% treatment was higher than the result of Muluneh Minta and Angaw Tsige (2014) who showed that 5.45t/ha of dry matter yield was found from un inoculated vetch (*Vicia dasycarpa*) in Ethiopia.

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 Mergia 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.

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 (Geleti Driba, 2014). 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.

Present mean CP yield (1.18±0.07t/ha) was greater than the mean CP yield (0.75t/ha) obtained by Eshetie Alemu *et al.* (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 Malede Birhan (2013).

4.3.3 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 5). 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 5). 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 5). 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.

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 Mergia 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 (Sani *et al.,* 2011; 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 addition to this, highest dry matter yields in the intercropped were observed in the recent study due to the beneficial effects of intercropping on nutrient uptake for both forages grown as confirmed by the authors Sharma & Chander (2006) who conducted a research on Sudan grass (*Sorghum sudanense*) with cow pea (*Vigna unguiculata*) intercropping. 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.

Total crude protein of the forage grown was significantly (P<0.001) affected by seed rate treatments (Table 5) 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 (Table 5). 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 characterstics of both forages grown under irrigation and laso might be due to legumes could be enhance CP content of grass in the intercropping. The present results were supported by the previous scholars Malede Birhan (2013); Hassan *et al.* (2017); Eshetie Alemu *et al.* (2018); and Mergia Abera *et al.* (2022).

Table 5. 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)*

4.4 Biological Compatibility of Sudan Grass and Vetch Species in Intercropping

4.4.1 Land equivalent ratio

Land equivalent ratio (LER) was used to evaluate the output efficiency of intercropping. Significantly (P<0.01) land equivalent ratios were higher LER of Sudan grass (Aden gode) than intercropped vetch (*Vicia dasycarpa*) as shown in (Table 6). However, no significant (P>0.05) effect of LER_V was observed in all intercropping treatments. LER_T in the recent study was statistically significant (P<0.01) affected by each seed rate intercropping treatments. Statistically highest LER_T (2.21) was obtained from 75%:25% seed rate intercropping (Table 6). This was due to highest dry matter yield recorded and yield advantage was observed from this intercropped seed rate treatment. Whereas, the lowest LER_T (1.55) was found from 25%:75% seed rate intercropped treatment. This lower LER_T indicates that there is less intercropping yield advantage than 75%:25% and 50%:50% seed rate intercropping.

Hence, results in (Table 6) showed that seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) had effects on LER_T. 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. Awad & Ahmed (2012) and Asem *et al.* (2020) who were found that intercropping of Sudan grass (*Sorghum sudanense*) and cow pea (*Vinga unguiculata*) had significantly ($P<0.05$) increased forage productivity and land equivalent ratio.

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. Hence, more dry matter production and yield advantages were found from this seed rate intercropping of Sudan (Aden gode) grass and vetch (*Vicia dasycarpa*). Whereas, the lowest LER_T (1.55) was obtained from 25%:75% seed rate intercropping and which means that 55% of more land would be required for planting the sole forages to produce the same dry matter yield per hectare. Therefore, similar LER_T results were observed when maize (*Zea mays* L.) intercropped with cow pea (*Vigna unguiculata* L.) in 100:100, 75:25, 50:50, and 25:75 seed rate noted by Dahmardeh *et al.* (2010) and it indicated that intercropping had yield advantage compared to monoculture. Generally, the current results were in agreement with those reported by many investigators including Shri *et al.* (2014); Dwivedi *et al.* (2015) they noted that yield occurs when the intercropped forages due to less compete for the same ecological niches and the intra-specific competition.

4.4.2 Competitive ratio

The competitive ability of the constituent species in intercropping system is indicated by the competitive ratio (CR). 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.

Hence, the results shown in (Table 6) CR_S and CR_V were significantly ($P<0.05$, $P<0.01$) affected by seed rate intercropped of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*), respectively rather than CR_S/CR_V (P>0.05). In all other seed rate intercropping, the values of CR_S were mostly greater than the value of CR_V in the recent study (Table 6) 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, result (Table 6) indicated that 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 (Al-Bakri *et al.,* 2003; Singh & Tarawali, 2007; Abuneran, 2013).

4.4.3 Dominance of aggressiveness

Aggressiveness (A) is a simple way to assess how much the relative yield increases in forage species over other intercropping forage species. Aggressiveness (A) zero means, neither of the forages is thought to be aggressive or both forages are equally capable of competing. Hence, in current 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. Even though, Sudan grass (Aden gode) aggressiveness in the recent study was less in 75%:25% seed rate intercropping treatment than others and leads to increasing yield advantage. Whereas, A_T in a recent study (Table 6), revealed the aggressiveness of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) was less at 75%:25% intercropping and increased at 50%:50% seed rate intercropping and then decreased at 25%:75% seed rate 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.

Similar results were observed by the authors Verma *et al.* (2005) showed that intercropping space of forage sorghum (*Sorghum bicolor*) with pigeon pea (*Cajanus cajan*) had significantly effect on aggressiveness (0.53). Ahmad *et al.,* (2006) also noted that forage sorghum-legume intercropping had positive aggressivity due to forage sorghum appearing dominant forage over legumes. 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.

Table 6. 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)*

4.5 Effect of Seed Rate Intercropping of Sudan Grass and Vetch on Chemical Composition

4.5.1 Chemical composition of Sudan grass (*Sorghum sudanense* “Aden gode”)

4.5.1.1 Dry matter (DM %)

Dry matter content of Sudan grass (Aden gode) in present study was significantly (P<0.001) affected by seed rate intercropping treatments as shown in (Table 7). There was a significant effect (P<0.001) on dry matter percentage in current results (Table 7). From each treatment plot the mean value of dry matter percentage was 19.14±0.24%. The highest value of DM (22.18%) was recorded from 50%:50% seed rate intercropping while, lowest DM (16.12%) was found from 25%:75% seed rate intercropping treatment. The lowest value of DM content (16.12%) obtained from 25%:75% seed rate treatment might be due to deacreasing sudan grass seed in the proportion. The highest DM contents are most important due to most nutritional values of feed are drived from the drymatter contents of the feed. The DM variations between treatments were due to the seed rate proportions in the intercropping. Better dry matter percentages were obtained from intercropped treatments than Sudan grass (Aden gode) sown alone. These better dry matters were due to direct (increasing leaf number, tiller number, and others) effects of morphological development.

Therefore, the present result is akin to the finding of Asem *et al.* (2020) who stated that dry matters were affected by intercropping of Sudan grass (*Sorghum sudanese*) with cow pea (*Vigna unguiculata*). The current result of DM (22.18%) of Sudan grass (Aden gode) intercropping with vetch (*Vicia dasycarpa*) in the 50%:50% seed rate treatment was greater than the authors Asem *et al.* (2020) dry matter was significantly affected and produced a lower DM (18.44%) in Sudan grass (*Sorghum sudanese*) intercropping with cow pea (*Vigna unguiculata*). Therefore, in the current result had better dry matter and forage quality than the result of Asem *et al.* (2020). In addition to current results dry matter percentage of Sudan grass (Aden gode) ranged from 16.12%-22.18% was in line with the finding of Lyons *et al.* (2019) dry matter (20%) on optimal harvesting time of Sudan grass. The variations of the present result to the previous was due to the seed rate intercropping treatment variations.

4.5.1.2 Ash content

Ash content of Sudan grass (Aden gode) in the present results were statistically significant ($P<0.05$) on seed rate intercropping with vetch (*Vicia dasycarpa*) (Table 7). The lowest value of total ash (5.79%) content was found from 25%:75% seed rate intercropping followed by 75%:25% seed rate intercropping (6.52%). Whereas, the intermediate value of ash (7.43%) content was found from 50%:50% seed rate intercropping and the higher ash (9.13%) content was recorded from Sudan grass (Aden gode) sown as a pure stand with the mean (7.22±0.49%) value of ash contents of Sudan grass (Aden gode) in the present study. Seed rate in the intercropping was factored for increasing or decreasing the ash content of Sudan grass (Aden gode). When the seed rate decreases in intercropping, decreasing ash contents were observed as shown in (Table 7). These lowest values of ash contents in the intercropped Sudan grass were due to the fact that Sudan grass (Aden gode) in the intercropping had better crude protein content and better leaf to stem ratios. It might be due to Sudan grass (Aden gode) in the intercropping having less fiber fraction than its pure stand.

According to Linn & Martin (1999), the majority of forage has an ash level that ranges from 3 percent to 12 percent. Hence, present studies of ash content ranges (5.79-9.13%) were similar to the finding of Mahmood *et al.* (2013) who noted that ash contents of sorghum ranged from (6.1-9.7%) obtained in their trial of nutritional quality of forage sorghum. Less ash contents (5.79-9.13%) were found in present study compared from the mean Ash (10.02%) value obtained by Alemu Tarekegn *et al.* (2020) in two season with the same Sudan grass (Aden gode) cultivar. This might be due to intercropping helps to decrease cell wall accumulations of Sudan grass in present study. In agreement with the finding of Mergia Abera *et al.* (2022) who showed that when compared to intercropped desho (*Pennisetum pedicellatum*) with *Vicia* species, the pure stand of desho grass (*Pennisetum pedicellatum*) produced a greater ash content. Besides, the present study was in harmony with the finding of Malede Birhan, (2018) who noted that ash content of Triticale (*Xtriticosecale wittmack*) had significant affected by seed rate intercropping with vetch (*Vicia villosa* R.).

But, disagreement to the finding of Malede Birhan (2018), the ash contents of Sudan grass (Aden gode) was lower in intercropped than its pure stand. Ash contents were significantly affected by seed rate intercropping and Sudan grass (Aden gode) ash contents were lower than the finding of Aysheshim Bantihun, *et al.* (2022) who noted that ash content of grass species such as Brachiaria (*Brachiaria mutica*), Desho (*Pennisetum pedicellatum*), and Napier grass (*Pennisetum purpureum*) ranged in (14.7-18.7%) factored with harvesting age in Ethiopia. This difference was attributed in forage grasses changes from species to species and might be due to differences in morphological fractions, climatic conditions, and soil properties (Beyadglign Hunegnaw, 2019). The lower ash content might be due to soil nutrient uptake competition among inter-species. Whereas, the higher ash content of Sudan grass (Aden gode) in sole indicated that higher concentration of mineral. This study was in agreement with the finding of Aychew Zewdu (2021) who noted that The highest ash contents were recorded in both sole desho (*Pennisetum pedicellatum*) and Phalaris (*Phalaris aquatica* (*acc6583*)).

4.5.1.3 Organic matter

Organic matter content of Sudan grass (Aden gode) in the present study was significantly ($P<0.05$) affected by seed rate intercropping similar to ash content due to organic matter obtained through the difference of ash content from 100 percent. When treatments applied in the present study had a lower value of ash contents, they would have higher value of organic matter. Hence, higher organic matter (94.21%) was found from 25%:75% intercropping followed by 75%:255% (93.48%) and 50%:50% (92.57%) seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) with the mean value of organic matter (92.78%). The variation of organic matter in the current study might be due to the variation of seed rate in the intercropping and due to the significant difference in Sudan grass (Aden gode) ash content with regard to seed rate.

A significant difference was obtained in the organic matter of Sudan grass (Aden gode) in present study similar to Jiao *et al.* (2022) who shown that Sudan grass (*Sorghum sudanense* (Piper) Stapf.) organic matter content was significantly affected by fertilizer application. The same to present study Aychew Zewdu (2021) who showed that organic matter of Desho (*Pennisetum pedicellatum*), phalaris (*Phalaris aquatica* (*acc6583*)), and oat (*Avena sativa*), had a significant difference on their sole and intercropped. Besides to this, Aysheshim Bantihun *et al.* (2022) who showed that organic matter (81.3%-86.5%) contents of grass species such as Desho (*Pennisetum pedicellatum*), Brachiaria (*Brachiaria mutica*), and Napier grasses (*Pennisetum purpureum*) were significantly affected by the harvesting stage and lower than the organic matter in the present study. This was due to OM differed significantly among species, and this might be attributed from grass genetic variation, environmental factors, soil types, soil healthiness, and also seed rate factors.

4.5.1.4 Crude protein

Crude protein is the most important chemical composition parameter in forage production. The crude protein content of grass is lower than the crude protein content of legumes. Therefore, intercropping grass with legumes is crucial to increasing the crude protein content of grass. In the current study, increasing crude protein was observed in seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*). Significant ($P<0.01$) differences in Sudan grass (Aden gode) crude protein were observed in the current results. Significantly highest value of CP (12.19%) was found from 75%:25% seed rate intercropping treatment and followed by 50%:50% seed rate treatment which has 11.02% CP compared from CP (8.97%) obtained from Sudan grass (Aden gode) grown alone as shown (Table 7). This might be due to intercropping of grass with legumes having the ability to increase the CP contents of intercropped forages. The greater CP in this seed rate treatment might also be due to a good morphological performance of Sudan grass (Aden gode) leading to increasing in crude protein.

Current results of CP (12.19%) in 75%:25% intercropping were greater than CP (10.90%) obtained by Basaran *et al.* (2017) who revealed that Sudan grass hybrid (Aneto) intercropping with soybean (Yesilsoy) from a 100%:100% seed rate. Results of CP (8.97%) from sole Sudan grass (Aden gode) in the present study was similar to Asem *et al.* (2020) who outlined that CP (8.90 to 8.74%) obtained from sole Sudan grass (*Sorghum sudanense*) for two seasons. This greater value of crude protein could be the high availability of Nitrogen in intercropping and also due to less nutrient competition among inter-species due to decreasing seed rate intercropping. Besides to this, current results of crude protein were higher than the finding of Asem *et al.* (2020) noted that CP (9.18%) of Sudan grass (*Sorghum sudanense*) had higher in intercropped with cow pea (*Vinga unguiculata*) in 75%:25% seed rate intercropped compared to its alone. In addition higher CP (12.19%) was obtained compared from CP (10.58%) obtained by Alemu Tarekegn *et al.* (2020) for the same Sudan grass (Aden gode) cultivars. This lower value might be attributed from seed rate intercropping with legumes to increasing protein content of component grass.

Current results of increasing CP of Sudan grass in intercropping were in line with the previous study by Erkovan (2022) who reported that seed rate intercropped of Sudan grass (*Sorghum sudanense* (piper.) (16.73%) with common vetch (*Vicia sativa* L.) had significant differences in CP contents of sole Sudan grass (14.66%). Legumes could improve the crude protein content of grasses due to legumes provide nitrogen content to the intercropping grass as shown by Iqbal *et al.* (2019). The present study was in agreement with the study of Uher *et al.* (2019) crude protein of maize (*Zea mays* L.) intercropped significantly higher than its sown sole. This could be due to the higher availability of nitrogen in the intercropping treatment. Current results also comparable with the finding of Guleria & Kumar (2016) who were noted that intercropped Maize (*Zea mays* L.) with cow pea (*Vigna unguiculata*) had higher crude protein than sole sown. Meanwhile, the current study was similar to the finding of Khan *et al.* (2005) who stated that seed rate proportion in cereal-legume intercropping had significant effects on forage quality. Therefore, in agreement with the previous studies by Hassan *et al.* (2017); Javanmard *et al.* (2017); Salem *et al.* (2019) who noted that crude protein was higher in intercropping than forages sown as a pure stand.

4.5.1.5 Neutral detergent fiber

Neutral Detergent Fiber (NDF) content is one of the determinations of forage nutritional value. When Neutral Detergent Fiber (NDF) component of forages is high, intake is affected due to that of increasing the structural carbohydrates in the forage (Lopes *et al.,* 2020). The decreasing of neutral Detergent Fiber (NDF) ratio indicates forages had higher quality (Kir & Dursun, 2018). Although, NDF does not assess how digestible the fiber in forages is, and it is a useful predictor of "bulk" and hence feed consumption (Oh *et al.,* 2016).

Neutral detergent fiber percentage with respect to seed rate intercropping with vetch (*Vicia dasycarpa*) was significantly (P<0.01) affected in the current study as shown in (Table 7). In decreasing seed rate of Sudan grass (Aden gode) results in decreasing NDF% content and also decreased NDF% content of Sudan grass (Aden gode) in intercropped with vetch (*Vicia dasycarpa*) compared to its pure stand. The lower value of NDF (61.30%) was recorded from 75%:25% seed rate intercropping followed by 25%:75% intercropped which had 64.18% of NDF relative to its pure stand (69.99%) revealed in (Table 7). It could be due to better morphological development of Sudan grass due to its intercropping effect.

Similar results of NDF% contents of Sudan grass (Aden gode) in the present study were found by Mergia Abera *et al.* (2022) who noted that the NDF% of Desho (*Pennisetum pedicellatum*) grass in sole sown was higher than the intercropped with vetch species. Current results of NDF% content of Sudan grass ranged from (61.30%-69.99%) which were lower than the finding of Lopes *et al.* (2020) who outlined that (73.82 to 78.19%) NDF contents of forage sorghum were observed. Intercropping Sudan grass (Aden gode) with vetch (*Vicia dasycarpa*) significantly increased forage qualities through decreasing NDF% contents and increasing the digestibility with respect to its alone. This result was akin to the finding of Awad & Ahmed (2012) who outlined that the mixing Sudan grass (*Sorghum sudanense*) with cow pea (*Vigna unguiculata* L.Walp) significantly improved forage qualities with respect to Sudan grass grown as a pure stand. This is also in line with the finding of Asem *et al.* (2020) who noted that intercropping of Sudan grass (*Sorghum sudanense*) with cow pea (*Vinga unguiculata*) significantly enhanced forage quality through decreasing CF% of Sudan grass compared to its sown alone. Besides this, the present NDF% results were in line with Erkovan (2022) who stated that NDF% content of Sudan grass (*Sorghum sudanense* (piper.) stapf.) was altered by seed ratio and seeding row arrangement in the intercropping with forage legumes.

Osman *et al.* (2010) also noted that row seeding configuration is thought to reduce NDF% of forages in the intercropping. This reduction of NDF% in the intercropping might be due to the seed ratio in the intercropping is thought to be reduced nutrient competition and heat stress in the intercropped than sole sown forages. In comparison to the current results of NDF%, the authors Erkovan (2022) who showed that seed rate intercropping of common vetch (*Vicia sativa* L.) with Sudan grass (*Sorghum sudanense* (piper.) stapf.) had a significant effect on NDF% and had the ability to decrease NDF% content compared to its pure stand. Therefore, decreasing seed rate in intercropping had the ability to decrease NDF% compared to Sudan grass (Aden gode) sown alone and this was in line with the finding of Erkovan (2022) who stated that, less seed ratio in the intercropping had lower NDF% compared to sole sown. This might be due to fewer competition conditions and affect NDF% due to nutrients availability and decreasing cellulosic content. The present study was In contrast with Aklilu Mekasha *et al.* (2020) who noted that increasing seed rate had an effect on decreasing the NDF% content of forage sorghum varieties studied on their nutritive values in Ethiopia. Therefore, NDF% value in 75%:25% seed rate intercropping treatment had better nutritional value than others due to low NDF%. This might be due to less stem thickness and also it might be due to better morphological development in this treatment.

4.5.1.6 Acid detergent fiber

Acid Detergent Fiber was not significantly ($P>0.05$) affected by Seed rate intercropping of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) in the current results as shown in (Table 7). The overall mean value of ADF (43.34±1.59%) but not significantly affected by seed rate. Current results were comparable with Erkovan (2022) who revealed that the ADF% contents of Sudan grass (*Sorghum sudanense* (piper.) stapf.) was not significantly differenced among seed rate intercropping with common vetch (*Vicia sativa* L.) in Turkish.

4.5.1.7 Acid detergent lignin

Acid detergent Lignin contents of forages are one of the indicators of forage nutritional value. Acid Detergent Lignin lowers the consumption and digestion of hay or feed, which lowers the quality of those products. Therefore, acid detergent lignin contents of Sudan grass (Aden gode) in the present study were significantly ($P<0.01$) affected by seed rate intercropping with vetch (*Vicia dasycarpa*) (Table 7). The higher ADL (14.05%) was obtained from 100% seed rate of Sudan grass (Aden gode) and followed by 50%:50% (13.18%), 25%:75% (11.61%) of ADL contents, and less ADL value from 75%:25% (9.41%) seed rate intercropping with the mean value of ADL (12.06±0.46%). Less ADL value from 75%:25% (9.41%) seed rate intercropping means Sudan grass (Aden gode) in this intercropping has better nutritional value due to less structural carbohydrate and also due to higher leaf steam ratio. The variation in ADL% might be due to seed rate and could be a factor in increasing and decreasing the lignin content. Whereas, it could be the availability of nitrogen in intercropping due to vetch can fix atmospheric nitrogen through their nodules and reduce fiber synthesis.

In agreement with the present study, Malede Birhan (2018) showed that seed proportion had a significant difference in ADL% of Triticale mixture with vetch in Ethiopia. Meanwhile, 9.70% of ADL 75%:25% Triticale (*Xtriticosecale wittmack*) with vetch (*Vicia villosa* R.) mixture and agreed with the present study of Sudan grass (Aden gode) ADL% content. The higher ADL (14.05%) was obtained from 100% seed rate of Sudan grass (Aden gode) and is comparable with the finding of Malede Birhan (2018) who noted that higher value of ADL (15.30%) was found from 100% of seed rate of forage Triticale (*Xtriticosecale wittmack*) in Ethiopia.

Table 7. Chemical composition of the sole and intercropping of Sudan grass (Aden-gode)

	Chemical composition Parameters						
Treatments	DM%	Ash%	OM %	CP%	NDF%	ADF%	ADL%
T1(Sole Sudan grass)	17.37^{c}	9.13^{a}	90.87^{b}	8.97^{c}	69.99^{a}	45.48^{a}	14.05^{a}
T2	20.90^{b}	6.52^{b}	93.48^{a}	12.19^{a}	61.30^{c}	41.29^{a}	9.41^{c}
T3	22.18^{a}	7.43^{ba}	92.57^{ba}	11.02^{ba}	65.88^{b}	44.38^{a}	13.18^{ba}
T4	16.12^{d}	5.79^{b}	94.21^{a}	9.81b^{c}	64.18^{cb}	42.19^{a}	11.61^{b}
T5(Sole vetch)	-	-	-	-	-	-	-
Overall mean	19.14	7.22	92.78	10.50	65.34	43.34	12.06
SEM (±)	0.24	0.49	0.49	0.34	0.96	1.59	0.46
CV%	4.79	11.83	0.92	6.59	2.77	8.41	6.65
R^2	0.94	0.83	0.83	0.86	0.86	0.38	0.91
LSD	1.83***	1.71*	1.71*	1.38**	3.62**	7.28^{NS}	1.61**

*T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, ADL = Acid Detergent Lignin, SEM = Standard Error of Mean, CV% = Coefficient of Variation percent, R^2 = Coefficient of determination, N = Number, cm = centimeter, a, b, c& d = level of mean difference, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01), *** (p<0.001)*

4.5.2 Chemical composition of vetch (*Vicia dasycarpa*)

4.5.2.1 Dry matter (DM %)

The dry matter contents revealed in Table 8 was statistically significant (P<0.05) on seed rate intercropping treatment. The highest value of DM (18.02%) was found from 25%:75% seed rate treatment. Whereas, the lowest value of DM (16.08%) was obtained from 50%:50% seed rate intercropping plots. Therefore, the highest dry matter seed rate intercropping treatments would give better nutritional value than the lowest dry matter seed rate treatment. On the other hand, the lowest dry matter is vital when forages are stored for a long period due to low moisture content compared to the highest dry matter percentage production.

DM of the current results were significantly (P<0.05) different in seed rate intercropping of Sudan grass and Vetch. This significant effect of dry matter were comparable with the finding of Song *et al.* (2021) showed that statistically significant of dry matter contents was found on Sorghum-Sudan grass (*Sorghum bicolor*) intercropped with cow pea (*Vigna unguiculata* L.Walp) and lablab (*Lablab purpureus* (L.) Sweet). Hence, the mean value of dry matter percentage (17.18±0.12%) in the present study was significantly (P<0.05) greater than the mean value of dry matter content (9.40%) of Cow pea (*Vigna unguiculata* L.Walp) intercropped with Sudan grass hybrid (*Sorghum bicolor*) noted by the author Song *et al.* (2021). Comparable result of dry matter content (18.02%) was found from 25%:75% seed rate intercropping with the finding of Demissie Negash *et al.* (2017) noted that dry matter percentage (19.43%) production from 75%:25% seed rate intercropping treatment of oat (*Avena sativa*) and vetch (*Vicia villosa*). These variations of dry matter percentage productions were due to genetic and environmental variations.

4.5.2.2 Ash content

On its DM% contents of Vetch, ash content of vetch in the present study was slightly statistical significantly (P<0.05) affected by the seed rate intercropping treatment as shown in (Table 8). Therefore, highest value of ash (10.12%) content was recorded from vetch (*Vicia dasycarpa*) sown as a sole (100%) seed rate followed by 25%:75% (8.46%), 50%:50% (7.45%) and the lowest ash (6.15%) was obtained from 75%:25% seed rate intercropping and 8.04±0.59 mean value of ash content was found. These variations in ash content of vetch

(*Vicia dasycarpa*) in sole and in intercropped were due to seed rate intercropping, and morphological development differences. When the seed rate of vetch (*Vicia dasycarpa*) increases, the ash content becomes increases while, decreasing the seed rate, increasing organic matter observed in the present study.

In harmony with the present results, the highest value of ash (13.71%) content was obtained from sole vetch (*Vicia dasycarpa*) and the lowest ash (10.67%) from 75%:25% seed rate treatment. However, relatively similar Ash (8.1%, 12%, & 11.2%) content was recorded from *Vicia sativa*, *Vicia villosa,* and *Vicia dasycarpa* (Kassahun Desalegn & Wasihun Hassen, 2015). Whereas, similar results of ash contents were found in the present study ranged from (6.15-10.21%) with a mean (8.04±0.59%) to the results of Usman Semmana *et al.* (2019) who outline that, ash contents of vetch species ranged from (6.45-9.18%) with a mean value of 8.22%.

Inconsistently, lower ash contents range from 6.15-10.12% were recorded in present study compared to the study of Muluneh Minta and Angaw Tsige (2014) who noted that the ash content of *Vicia dasycarpa* ranged from 12.31-12.41%. Whereas, Eshetie Alemu *et al.* (2018) revealed that, vetch (*Vicia dasycarpa*) intercropped with oat (*Avena sativa*) had no significant difference and the ash contents ranged from 10.23-11.90 in different harvesting ages. These results of ash content obtained by Eshetie Alemu *et al.* (2018) were greater than the ash content of Vetch (*Vicia dasycarpa*) in the present study. Besides to this, the mean (8.04%) value of ash content in present study was less than the value obtained by Malede Birhan (2018) who revealed that the mean (11.21%) value of ash obtained in different harvesting stages of vetch (*Vicia villosa* R.) mixture with Triticale (*Xtriticosecale wittmack*) in Ethiopia. Inconsistently, lower ash content (6.15-10.21%) was obtained compared to the results of Demissie Negash *et al.* (2017) ranging from 12.41-12.94% in different seed rate mixture of vetch (*Vicia villosa*) and oat (*Avena sativa*). These variations were due to seed rate, species variation, management difference, agro-ecology difference, and soil fertility.

4.5.2.3 Organic matter

Organic matter content of vetch (*Vicia dasycarpa*) in this study was statistical significantly ($P<0.05$) affected by the seed rate intercropping treatment as shown in (Table 8). Hence, 75%:25% seed rate treatment had the highest value of OM (93.85%) followed by 50%:50%

(92.55%), and 25%:75% (91.53%) while, the lowest OM was recorded from sole vetch (89.88%) with the mean (91.96±0.59%) value of organic matter (Table 8). When the seed rate of vetch (*Vicia dasycarpa*) decreasing the seed rate, increasing organic matter observed in the present study. These variations in OM content of vetch (*Vicia dasycarpa*) in sole and in intercropped were due to seed rate intercropping, and morphological development differences.

The lower organic matter contents of Vetch species ranging from 73.1-76.6% obtained by the authors Teshale Jabessa *et al.* (2020) compared to the present results of *Vicia dasycarpa* ranged from 89.88-93.85% of DM basis. Similar results of organic matter (92.55%) were obtained from 50%:50% treatment with the finding of Kassahun Desalegn & Wasihun Hassen (2015) who noted that, 92.1% of organic matter of vetch (*Vicia dasycarpa*). Whereas, the present results of organic matter (89.88-93.85%) on seed rate intercropping treatment were significantly similar to the finding of Kassahun Desalegn & Wasihun Hassen (2015) who noted that organic matter ranged from 90.4-92.1% of different vetch species. However, the higher values of organic matter (89.88-93.85%) with the mean value (91.96%) of vetch (*Vicia dasycarpa*) in the present study were obtained compared to the study revealed by Usman Semmana *et al.* (2019) who outlined that organic matter of vetch species ranged from (84.21-84.51%) with a mean value of (84.37%) study conducted on the performance evaluation of vetch species on the highland area of Ethiopia. The variations obtained in the current results from previous studies were attributed from seed rate treatments, variation in agro-ecologies, management difference, and also due to edaphic factors.

4.5.2.4 Crude protein

Crude protein content in livestock feeding is the most important to increase the Animal products such as egg, meat, milk, and milk products. Plant source protein is cheap than Animal source protein and hence the development of forage is advisable to increase the protein content of forages for Animals.

Hence, crude protein contents of the present result as shown in (Table 8) were statistically significant ($P<0.01$) affected by seed rate intercropping of Vetch (*Vicia dasycarpa*) and Sudan grass (Aden gode). Results revealed in (Table 8) showed that crude protein content in seed rate intercropping of 50%:50% (24.06%), 25%:75% (21.80%), 75%:25% (20.98%), and 100% (17.63%) with a mean value (21.12±0.76%) were obtained in the present study.

Therefore, the highest crude protein was found from 50%:50% (24.06%) and the lowest (17.63%) was from vetch sown as a pure stand. The higher CP (24.06%) from 50%:50% seed rate treatment was attributed from hhaving greater number of branch and root length, have able to capture nutrient from the soil. This intercropping has a significant effect on increasing crude protein contents of forages. In addition, increasing seed rate in intercropping of vetch showed that decreasing the crude protein value as revealed in the current results.

All seed rate intercropped vetch had CP contents that were higher than the typical diet's 10.6 % CP value but lower than the 32.6% CP value for feed with protein supplements. The outcome is greater than what Van Soest (1982) suggested, young herbage had a CP content of up to 14% to 16%. The present results of crude protein shown in (Table 8) significantly higher than the study of Kassahun Desalegn & Wasihun Hassen (2015) who outlined that the crud protein (CP) concentration of *Vicia dasycarpa* was the most promising one (18.9%) compared to 12%, 9.2%, and 9.1% of *Vicia atropurpurea*, *Vicia villosa, and Vicia sativa* were obtained, respectively.

However, in agreement with the authors Eshetie Alemu *et al.* (2018) higher crude protein ranged from (17.63-24.06%) in the present study obtained compared to the crude protein ranged from (13.97-21.38%) in vetch (*Vicia dasycarpa*) mixtures with oat (*Avena sativa*) in Ethiopia. Increase crude protein in the present study was due to the higher morphological parameters recorded and intercropping could enhance forages to soil nutrient uptake and water use efficiency. Whereas, The high CP value found in the current study, intercropped forages is corroborated by Berhanu Alemu *et al.* (2007) who found that mixed forages containing up to 25–50% legume generated higher-quality forage and yields than exclusively planted forages. On the other hand, crude protein (21.80%) obtained from a 25%:75% seed rate in the present study was similar to the finding of Usman Semmana *et al.* (2019) who noted that crude proteins ranging from (22.01-22.18%) found from vetch (*Vicia dasycarpa*) accessions. Inconsistency to the present study, the finding of Dura *et al.* (2012) who were noted that crude protein in the intercropped legumes was lower than in the pure stand legumes. Therefore, the variations of the present study might be due to the reason seed rate intercropping, agro-ecological variation, edaphic factors, and experimental management.

4.5.2.5 Neutral detergent fiber

The neutral detergent fiber in the present study was statistically significant ($P<0.001$) on the effect of seed rate intercropping of vetch (*Vicia dasycarpa*) and Sudan grass (Aden gode) as shown in (Table 8) below. Results showed in (Table 8), lowest NDF% were 41.14%, 43.01%, 45.73%, 48.48% obtained from 75%:25%, 25%:75%, 50%:50% and 100% of seed rate intercropping treatments. Seed rate had a significant effect on NDF% in the present study. A result revealed that an increased seed rate in the treatment indicates that increasing the NDF% except in 50%:50% treatment indicates a slightly decreased NDF% as shown in (Table 8). Increase in NDF content has been associated with the decrease in crude protein content and leaf to stem ratios. These difference results of NDF% observed between treatments might be due to variation in seed rate in the intercropping.

Hence, the current results of neutral detergent fiber (NDF) content of vetch ranged from 41.14%-48.48% with a mean value of 44.59±0.65%. This NDF value was below 45-55% of NDF which indicates that vetch (*Vicia dasycarpa*) in the present study was high quality in nutritional value (Singh & Oosting, 1992). Relatively greater NDF (49.81%-50.38%) of *Vicia dasycarpa* had been reported by the Scholars Eshetie Alemu *et al.* (2018) compared from the present study. NDF% of vetch (*Vicia dasycarpa*) in present study were significant ($P<0.001$) and similar NDF% results of cow pea (*Vigna unguiculata* L.Walp) is and lablab (*Lablab purpureus* (L.) Sweet) intercropped with Sudan grass hybrid (*Sorghum bicolor*) obtained by Song *et al.* (2021). The finding of Lithourgidis *et al.* (2006) revealed that sole vetch (*Vicia sativa*) had higher NDF content similar to the present study. On the other side, significant results of NDF% were found by Muluneh Minta & Angaw Tsige (2014) who noted that NDF% contents of vetch species ranged from 40.25%-50.17%, and similar results were observed in the present study ranging from 41.14%-48.48% of NDF contents of vetch (*Vicia dasycarpa*). The value of NDF (48.48%) obtained from a 100% seed rate agreed with the finding of Kassahun Desalegn & Wasihun Hassen (2015) who found that 47.1% NDF from *Vicia dasycarpa* on the evaluation of vetch species in Ethiopia.

However, significantly similar mean (46.15%) value of NDF content of vetch species was obtained by Gezahegn Kebede *et al.,* (2013) compared to the present mean (44.59%) value of NDF%. Inconsistency to present study, the higher NDF (87.5%) content of *Vicia dasycarpa* was found by the authors Teshale Jabessa *et al.,* (2020). The decreasing of neutral detergent fiber has been associated with the digestibility of the forage. Therefore, highly digestible *Vicia dasycarpa* was found in the present study on the effect of seed rate intercropping. This difference in NDF contents of vetch in different seed rate intercropping from the previous studies might be due to the vetch species difference, seed rate variation, edaphic factors, agro-ecological variations, and also management differences.

4.5.2.6 Acid detergent fiber

Seed rate had significant ($P<0.01$) effect on acid detergent fiber (ADF) in the present study as shown in (Table 8). Lowest ADF (26.12%) content was recorded from 75%:25% seed rate treatment followed by 28.15% of ADF from 50%:50% seed rate. Intermediate ADF (31.30%) content of vetch was recorded from 25%:75% seed rate treatment. Whereas, higher ADF (34.31%) content was found from sole vetch (*Vicia dasycarpa*). These variations of ADF% contents of vetch in the present study were due to seed rate variation. Therefore, increasing in ADF% contents of vetch (*Vicia dasycarpa*) was observed with an increasing seed rate in the intercropping (Table 8).

Present ADF (26.12-34.31%) contents of vetch (*Vicia dasycarpa*) were less than the ADF contents found by Song *et al.* (2021) noted that 38.66-46.30% of Lablab (*Lablab purpureus* (L.) Sweet) and cow pea (*Vigna unguiculata* L.Walp) intercropped with Sudan grass hybrid (*Sorghum bicolor*). Besides these scholars, Muluneh Minta & Angaw Tsige (2014) who outlined that the ADF of vetch species had 36.47-41.80% but they found that higher ADF (41.80%) content of *Vicia dasycarpa* compared to the present results of *Vicia dasycarpa*. Whereas, scholars Kassahun Desalegn & Wasihun Hassen (2015) found that higher ADF (35.1-37.3%) values of vetch species with the higher value of *Vicia dasycarpa* ADF (37.3%) contents compared to the present study. In addition to these scholars, the lowest ADF contents of *Vicia dasycarpa* were recorded compared by the authors Getu Kitaw *et al.* (2010) who reported that ADF (77.7%) was recorded from *Vicia dasycarpa* at Holleta agricultural research center

However, the lowest ADF (20.8%) content was found from alfalfa (*Medicago sativa*) intercrop with oat (*Avena sativa*) (Befekadu chemere & Yunus Abdu, 2015) compared to the present study. The lowest value of ADF% contents of *Vicia dasycarpa* in the present study might be due to the reason seed rate variation in intercropping, better morphological development, and better crude protein content variation among the treatments. Whereas, the difference observed in ADF% from the previous study might be due to the treatment variation, environmental, edaphic, and species variation factors.

4.5.2.7 Acid detergent lignin

Acid Detergent Lignin (ADL) in dry matter basis was not significantly (P>0.05) affected by seed rate intercropping of vetch (*Vicia dasycarpa*) with Sudan grass (Aden gode) in the present study as shown in (Table 8). There is no significant difference was observed between the seed rate treatments. A similar result was found by Eshetie Alemu *et al.* (2018) who noted that ADL content was not significantly affected in the mixtures of vetch and oat. In addition to this, the authors Demissie Negash *et al.* (2017) also showed that ADL contents of vetch (*Vicia villosa*) were insignificant with the seed rate proportion that has sown with oat.

Table 8. Chemical composition of the sole and intercropping of vetch (*Vicia dasycarpa*)

	Chemical composition of vetch (on DM %)						
Treatments	DM%	Ash%	OM%	CP%	NDF%	ADF%	ADL%
T1(Sole Sudan grass)	-	-	-	-	-	-	-
T2	17.56^{b}	6.15^{c}	93.85^{a}	20.98^{b}	41.14^{c}	26.12^{c}	5.67^{b}
T3	16.08^{c}	7.45^{bc}	92.55^{ba}	24.06^{a}	45.73^{b}	28.15^{c}	6.40^{ba}
T4	17.09^{b}	8.46^{ba}	91.53^{bc}	21.80^{ba}	43.01^{c}	31.30^{b}	7.02^{ba}
T5(Sole vetch)	18.02^{a}	10.12^{a}	89.88^{c}	17.63^{c}	48.48^{a}	34.31^{a}	8.47^{a}
Overall mean	17.18	8.04	91.96	21.12	44.59	29.97	6.89
SEM (±)	0.12	0.59	0.59	0.76	0.65	0.68	0.48
CV%	3.83	13.61	1.19	6.22	2.49	4.55	15.36
R^2	0.89	0.79	0.79	0.87	0.93	0.91	0.66
LSD	1.31^{*}	2.19^{*}	2.19^{*}	2.63^{**}	2.22^{***}	2.72^{**}	2.12^{NS}

*T1=Treatment one, T2=Treatment two, T3=Treatment three, T4=Treatment four, T5=Treatment five, DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, ADL = Acid Detergent Lignin, SEM = Standard Error of Mean, CV% = Coefficient of Variation percent, R^2 = Coefficient of determination, N = Number, cm = centimeter, a, b & c = level of mean difference, LSD = Least Significant Difference, NS = Non Significant level, * (p<0.05), ** (p<0.01), *** (p<0.001)*

4.6 Correlations Between Morphological Characteristics, Forage Yield, and Chemical Composition of Sudan grass (*Sorghum sudanense*) Intercropped with Vetch (*Vicia dasycarpa*)

The relationship between morphological characteristics, forage yield, and chemical composition was studied and revealed in (Table 9) below. Hence, plant height in the present result showed that high positively significant correlated to the number of tillers per plant and dry matter content, and has moderate positive correlation to crude protein and crude protein yield. On the other hand, it has negatively correlated with stem thickness, Ash, NDF, ADF, and ADL. These results were in agreement with the finding of Tiruset Tesfaye (2019) who noted that the plant height of Desho grass (*Pennisetum pedicellatum*) was moderately correlated with crude protein and crude protein yield. Plant height has also positively correlated with LSR in line with the authors Bimrew Asmare *et al.* (2017) but, disagreed with the authors Tiruset Tesfaye (2019); Aychew Zewdu *et al.* (2021) who noted that Desho grass (*Pennisetum pedicellatum*) intercropped with vetch species. This might be attributed from seed rate proportion in the intercropping and grass species variations.

The number of Leaves per Tiller (NLPT) was positively correlated with all morphological parameters (except stem thickness), CP, and CPY. These results were in line with the finding of Aychew Zewdu (2021) who noted that NLPP had positive correlation with all morphological parameters of Desho (*Pennisetum pedicellatum*), Oat (*Avena sativa*), and Phalaris (*Phalaris aquatica* (*acc6583*)) intercropping with vetch (*Vicia dasycarpa*). Positive correlation of NLPT with plant height was in line with Bimrew Asmare *et al.* (2017); Genet Tilahun *et al.* (2017). In addition, Tiruset Tesfaye (2019); Aychew Zewdu (2021) who were reported that NLPP was positively correlated with all NTPP, LLPP, DMY, and CPY of Desho grass (*Pennisetum pedicellatum*) intercropped with vetch species. NLPT was significantly positively correlated with LSR and this was similar to the finding of Aychew Zewdu (2021) who stated that NLPP was correlated with LSR. while, Tiruset Tesfaye (2019) noted that NLPP was not correlated with LSR. The present result of NLPT was similar to the finding of Beyadglign Hunegnaw (2019) who reported that NLPP has negatively correlated with ADF in the case of brachiaria cultivars. This might come from efficient soil nutrient utilization and nitrogen availability in the intercropping leads to increasing leaf number per plant and decreasing Ash, ADF, NDF, and ADL contents of Sudan grass in the present study.

NTPP in the present study was highly positively correlated with LL and DM, DMY, CP, and CPY and negatively correlated with stem thickness (Stt), NDF, ADL, Ash and ADF. This was supported by Aychew Zewdu (2021); Beyadglign Hunegnaw, (2019) in the case of Desho (*Pennisetum pedicellatum*), oat (*Avena sativa*), phalaris (*Phalaris aquatica* (*acc6583*)), and brachiaria cultivars, respectively. Besides to these authors, Tesfaye Belayneh *et al.* (2020) also showed that NTPP had negatively correlated with ADF and ADL of vetch in intercropping and a pure stand. This was due to NLPT correlated to NTPP and leafy plants have better protein contents and which might be reduced the fiber fractions of the forage.

LL was highly positively correlated with (NTPP, DM, DMY, CP, and CPY) whereas, medium positive correlated with NLPT and LSR. This could be leaf have responsible for capturing sunlight for photosynthesis and leads to increasing crude protein. However, LL has negatively less correlated with stem thickness, NDF, ADF, and ADL contents. Therefore, LL might have responsible for increasing the NTPP, DM, DMY, CP, And CPY while it might have decreasing fiber fractions. Present results were similar to the results of Bimrew Asmare *et al.* (2017) who defined that LL has positive relationship with plant height, DM, and DMY. Whereas, Tiruset Tesfaye (2019) showed that LL has a positive relationship with PH, NTPP, NLPP, LSR, DMY, CP, and CPY but is inversely related to DM and ash.

In agreement with the results of Bimrew Asmare *et al.* (2017) LSR have negative relationship with NDF, ADF and ADF, and ADL (Tiruset Tesfaye, 2019) but disagreed to DM, DMY, and CPY (Bimrew Asmare *et al.,* 2017). DMY in present result has significantly strong positive correlated with CP and CPY (Tiruset Tesfaye, 2019), moderately with DM (Aychew Zewdu, 2021), weakly correlated with ash and ADF. In present study significant strong positive correlations were observed between CP with CPY, NDF with ADL and moderately insignificant with ADF similar with the previous studies Bimrew Asmare *et al.* (2017) but contradict with the results of Yihalem Denekew *et al.* (2005); Bayble Taye *et al.* (2007); Genet Tilahun *et al.* (2017).

Table 9. Correlation of morphological and chemical composition parameters on effect of seed rate on Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) intercropping

	PH	NLPT	NTPP	LL	Stt	LSR	DMY	DM	ASH	CP	CPY	NDF	ADF	ADL
PH	**1.00**	**0.20**	**0.73****	**0.54**	**-0.54**	**0.26**	**0.68***	**0.75****	**-0.50**	**0.61***	**0.69***	**-0.61***	**-0.35**	**-0.56**
NLPT		**1.00**	**0.52**	**0.64***	**-0.61***	**0.78****	**0.58***	**0.43 NS**	**-0.02**	**0.52**	**0.60***	**-0.29**	**-0.39**	**-0.42**
NTPP			**1.00**	**0.84*****	**-0.70***	**0.46**	**0.75****	**0.89*****	**-0.31**	**0.85*****	**0.81***	**-0.73***	**-0.41**	**-0.66***
LL				**1.00**	**-0.49**	**0.69***	**0.91*****	**0.70***	**0.07**	**0.78****	**0.90*****	**-0.34**	**-0.09**	**-0.39**
Stt					**1.00**	**-0.44**	**-0.37**	**-0.72****	**0.52**	**-0.53**	**-0.43**	**0.56**	**0.80****	**0.42**
LSR						**1.00**	**0.62***	**0.36**	**0.13**	**0.29**	**0.56**	**-0.10**	**-0.14**	**-0.30**
DMY							**1.00**	**0.58***	**0.03**	**0.78****	**0.97*****	**-0.32**	**0.00**	**-0.44**
DM								**1.00**	**-0.43**	**0.69***	**0.64***	**-0.63***	**-0.51**	**-0.50**
ASH									**1.00**	**-0.35**	**-0.11**	**0.59***	**0.39**	**0.52**
CP										**1.00**	**0.89*****	**-0.64***	**-0.21**	**-0.64***
CPY											**1.00**	**-0.46**	**-0.07**	**-0.56**
NDF												**1.00**	**0.55**	**0.92*****
ADF													**1.00**	**0.35**
ADL														**1.00**

*PH= Plant Height, NLPT = Number of Leaves per Tiller, NTPP= Number of Tiller per Plant, LL= Leaf Length, Stt = stem thickness, LSR = Leaf to Stem Ratio, DM = Dry Matter, DMY = Dry Matter Yield, CP = Crude Protein, CPY = Crude protein Yield, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, ADL =Acid Detergent Lignin, * (p<0.05), ** (p<0.01), *** (p<0.001)*

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, Sudan grass (Aden gode) 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 of vetch intercropping had significant effect on morphological parameters of Sudan grass (Aden gode). Whereas, significantly higher PH, RN, and NN of vetch (*Vicia dasycarpa*) were observed in 75%:25% seed rate intercropping treatment. 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) and CPY (2.07t/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 agressivity in 75%:25% seed rate intercropping than others and had higher dry matter yield compared to other intercropped treatments.

Whereas, chemical compositions of Sudan grass (Aden gode) was affected by seed rate and higher 12.19 CP% and 0.96 CPYt/ha were found from 75%:25% seed rate treatment while, lower NDF% and ADL% were obtained. On the other side, higher CP% (24.06) and CPYt/ha (1.39t/ha) of Vetch (*Vicia dasycarpa*) were obtained from 50%:50% and sole (100%) seed rate treatment respectively. Whereas, lower NDF% and ADF% contents were found from 75%:25% seed rate intercropping treatment. Correlations of morphological and chemical composition of the forage grown was revealed in present study and plant height have positive correlations with number of tillers per plant, dry matter, dry matter yield, crude protein and crude protein yield. Most morphological parameters were negative insignificant correlated to NDF, ADF, and ADL content of forages grown in intercropping and in their sole.

5.2 Recommendations

Based on the above provided conclusions, the following recommendations are forwarded to the next research, extension activities.

- Better morphological parameters, dry matter and dry matter yield, chemical compositions in terms of crude protein and crude protein yield, land equivalent ratios, and low agressivity and competivity was found from seed rate intercropping treatment compared from sole. Hence, to increasing the forage yield, seed rate intercropping should be considered.

- From the employed seed rate intercropping treatment, 75%:25% of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) was recommended for increasing morphological, forage yield and quality.
- Further studies should be conducted for evaluating appropriate agronomic and management practices to increase productivities of Sudan grass (Aden gode) and vetch (*Vicia dasycarpa*) and also future studies should be conducted research on Sudan grass (Aden-gode) and vetch (*Vicia dasycarpa*) in different intercropping system with animal trial in the same study area with similar agro-ecologies.

CHAPTER SIX: REFERENCES

Abebe Mekoya, Oosting, S.J., Fernandez-Rivera, S., and Van der Zijpp, A.J. (2008). Farmers'perceptions about exoti multi-purpose fodder trees and constraints to their adoption. *Agrofor.Syst*, 73(2), 141–153.

Abera Mergia, Adugna Tolera, Ajebu Nurfeta, and Diriba Geleti. (2022). Herbage accumulation and nutritive value of mixtures of desho grass and Vicia spp. in southern Ethiopia. *Journal of Agronomy, 114*(1), 165–172. https://doi.org/10.1002/agj2.20891

Abuneran, M. A. (2013). Evaluation of forage yield of yellow pearl millet as sole and intercrop with exotic cowpea genotypes under agro-ecological zone of sudan. *Afr. Crop Sci. Conf. Proc*, *11*, 29–37.

Açikbaş, S., Özyazici, M., & Bektaş. (2021). Root System Interactions of Common Vetch (Vicia Sativa L.) and Triticale (Xtriticosecale Wittmack) Under Intercropping Conditions. *Turkish Journal of Agricultural and Natural Science*, *8*(3), 857–865.

Addisu Jimma, Fitsum Tessema, Deribe Gemiyo, and Zekarias Bassa. (2016). Assessment of Available Feed Resources, Feed Management and Utilization Systems in SNNPRS of Ethiopia. *Journal of Fisheries and Livestock Production* 4(3), 183. Doi: 10.4172/2332-2608.1000183

Adeniyan, O., Aluko, O., Olanipekun, S., Olasoji, J., & Aduramigba, V. (2014). Growth and Yield Performance of Cassava/Maize Intercrop Under Different Plant Population Density of Maize. *Journal of Agricultural Science*, *6*(8). https://doi.org/10.5539/jas.v6n8p35

Adugna Tolera, Alemu Yami, and Dawit Alemu. (2012). Livestock feed resources in Ethiopia, challenges, opportunities and the need for transformation. Ethiopian animal feed industry Association, Addis Ababa, 132.

Adugna Tolera. (2007). Feed resources for producing export quality meat and livestock in Ethiopia (Examples from selected Woredas in Oromia and SNNP regional states). *Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM) Ftxas Agricultural Experiment Station (TAES)/Texas A&M University System Feed*, 88.

Adugna Tolera. (2007). Feed Resources for Producing Export Quality Meat and Livestok in Ethiopia. Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM) managed by Texas Agricultural Experiment Station (TAES) of Texas A & M University System.

Ahmad, A., Ahmad, H., Ahmad, R., Mahmood, N., & Nazir, M. (2006). Performance of forage sorghum intercropped with forage sorghum legumes under different planting patterns. *Pak. J. Agric. Sci*, *43*, 25–31.

Ahmed Nagwa R., A. M. Sheha and W. A. Hamd-Alla. (2019). Effect of Intercropping of some Legume Forage Crops with Maize Under Levels of Mineral Npk and Nano Npk

Fertilizer. *Journal of Plant Production Journal*, *10*(10), 833-842. Doi: 10.21608/jpp.2019.62861

Ajebu Nurfeta. (2010). Feed intake, digestibility, nitrogen utilization and body weight change of sheep consuming wheat straw supplemented with local agricultural and agro-industrial byproducts. *Trop Anim Health Prod, 42*, 815–824.

Aklilu Mekasha, Doohong Min, Nathnael Bascom, and Jessie Vipham.. (2020). *Seeding rate effects on forge productivity and nutritive value of sorghum (Sorghum bicolor L.)*. 1–38. https://doi.org/10.1002/agj2.20856

Al-Bakri, A. M., Ibrahim, A. E., & Gangi, A. (2003). Forage yield potential of Sudan grass-cowpea irrigated mixtures in central Sudan. *Gezira Journal of Agricultural Science*, *1*(2), 94–110.

Alemayehu Mengistu and Sissay Amare. (2003). Integrated Livestock Development Project (ILDP). Livestock Feed Source Survey. North Gondar, Ethiopia, 75.

Alemayehu Mengistu, Gezahagn Kebede, Fekede Feyissa, &Getnet Assefa. (2017). Overview of improved forage and forage seed production in Ethiopia: Lessons from fourth livestock development project. *International Journal of Agriculture and Biosciences*, *6*(4), 217–226.

Alemayehu Mengistu, Gezahagn Kebede, Fekede Feyissa, & Getnet Assefa. (2017). *Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities Farming System Dynamism in Ethiopia View project*. 176-185. https://doi.org/10.14662/ARJASR2017.013

Alemayehu Mengistu. (2002). Forage Production in Ethiopia: A case study with implications for livestock production. Ethiopian Society of animal production, Addis Ababa, Ethiopia.

Alemayehu Mengistu. (2005). Feed source base of Ethiopia*: Status, limitations and opportunities for integrated development*. Proceedings of the 12th annual Conference of the *Ethiopian Society of Animal Production (ESAP),* Addis Ababa, Ethiopia, 12–14 August, 410

Alemayehu Mengistu. (2006). “Country pasture/forage resource profiles, Ethiopia”. *http://www. fao. org/ag/AGP*.

Alemayehu Mengistu . (2004). *Pasture and forage resource profiles of Ethiopia*. 58. https://agris.fao.org/agris-search/search.do?recordID=ET20060000

Alemu Tarekegn, Dessalegn Amsalu, and Kifetew Adane. (2020). *Effects of variety and cutting frequency on biological performance and quality of Sudan grass cultivars in central Gondar zone, Ethiopia. Gondar Agricultural Research Center P.O.Box 1337*. unpublished document.

Alemu Tarekegn. (2014). Adaptability of vetch (*Vicia spp.*) for potential feed production in

Gumara-Maksegnit watershed, North Gondar, Ethiopia. *Livestock Research for Rural Development*, *26*(7), 1-5.

Alla, H., Shalaby, E., Dawood, R., & Zohry, A. (2014). Effect of Cowpea (*Vigna sinensis* L.) with Maize (*Zea mays* L.) Intercropping on Yield and Its Components. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, *8*(11), 1227–1233.

Alla, H., Shalaby, E., Dawood, R., & Zohry, A. (2015). Effect of cowpea (Vigna sinensis L.) with maize (Zea mays L.) intercropping on yield and its components. *International Journal of Agricultural and Biosystems Engineering*, *8*(11), 1258–1264.

Alves, A., Pascoal, L., Cambuí, G., da Silva Trajano, J., da Silva, C., & Gois, G. (2016). Fibra para ruminantes: Aspecto nutricional, metodológico e funcional. *Pubvet*, *10*, 513–579.

Amanullah, F. K., Muhammad, H., Jan, A. U., & Ali, G. (2016). Land equivalent ratio, growth, yield and yield components response of mono-cropped vs. inter-cropped common bean and maize with and without compost application. *Agric. Biol. JN Am*, *7*(2), 40–49.

Andualem Tonamo. (2016). A review on cattle husbandry practices in Ethiopia. *International Journal of Livestock Production*, *7*(2), 5–11. https://doi.org/10.5897/ijlp2015.0276

Ararsa Derara and Amanuel Bekuma. (2020). Study on Livestock Feed Resources, Biomass Production, Feeding System and Constraints of Livestock Production in Relation to Feeds in Weliso District, South. *Biogeneric Science and Research*, *ISSN 2692-1081*, 1–14. https://doi.org/10.46718/JBGSR.2020.05.000113

Arendonk, J. J. C. M. Van & H. Poorter. (1994). The chemical composition and anatomical structure of leaves of grass species differing in relative growth rate. *Plant, Cell and Environment, 17*, 963-970.

Armah-Agyeman, G., Loiland, J., Karow, R., Bean, B., & Karow, R. S. (2002). Sudangrass. *Em*, *8793*. www.agry.purdue.edu/ext/forages/publications/grasses/sudan.htm

Asci, O. O., Acar, Z., & Arici, Y. K. (2015). Hay yield, quality traits and interspecies competition of forage pea – Triticale mixtures harvested at different stages. *Turkish Journal of Field Crops*, *20*(2), 166–173. https://doi.org/10.17557/tjfc.83484

Asem, M., Zen El-Dein, A., & Ahmed, N. (2020). Forge yield and its quality of sudangrass and cowpea under different intercropping patterns. *Al-Azhar Journal of Agricultural Research*, *45*(1), 77–88. https://doi.org/10.21608/ajar.2020.126660

Ashenafi Mengistu, Getnet Assefa, & Fekede Feyissa. (2019). Feed Resources Availability and Feeding Practices of Smallholder Farmers in Selected Districts of West Shewa Zone , Ethiopia Feed Resources Availability and Feeding Practices of Smallholder. *World Journal of Agricultural Sciences*, *15*, 21–30.

Atabayeva, K., Mirsharipova, G., & Mustafakulov, D. (2021). Influence of planting norms and harvest term on Sudan grass (Sorghum×drummondii) yield. *E3S Web of Conferences 284*, *03021*, 284. https://doi.org/10.1051/e3sconf/202128403021

Ates, E., & Tenikecier, H. S. (2019). Hydrocyanic acid content, forage yield and some quality features of two sorghum-Sudan grass hybrid cultivars under different nitrogen doses in Thrace, Turkey. *Current Trends in Natural Sciences*, *8*(16), 55–62.

Awad O. Abusuwar and Ahmed A. Bakshawain. (2012). Effect of chemical fertilizers on yield and nutritive value of intercropped Sudan grass (Sorghum Sudanense) and cowpea (Vigna unguiculata L. Walp) forages grown in an adverse environment of western Saudi Arabia. *African Journal of Microbiology Research,* 6(14), 3485–3491. Doi: 10.5897/AJMR12.007

Ayan, I. O., Mut, H., Basaran, U., Acar, Z., & Asci, O. O. (2012). Forage potential of cowpea (Vigna unguiculata L. Walp). *Turkish Journal of Field Crops*, *17*(2), 135-138. https://doi .org/10.17557/tjfc.58599

Aychew Zewdu. (2021). Farmers' Participatory Evaluation And Performance Testing Of Sele cted Forage Varieties In Selected Districts Of Eastern Amhara Region, Ethiopia. *Msc. Thesis, Bahir Dar University College Of Agriculture And Environmental Science*.

Aynalem Haile, Workneh Ayalew, Noah Kebede, Tadelle Dessie and Azage Tegegne. (2011). *Breeding strategy to improve Ethiopian Boran cattle for meat and milk production*. *26*, 46. http://mahider.ilri.org/handle/10568/3141

Aysheshim Bantihun, Bimrew Asmare, and Yeshambel Mekuriaw. (2022). Comparative Eval uation of Selected Grass Species for Agronomic Performance, Forage Yield, and Chemical Composition in the Highlands of Ethiopia. *Advances in Agriculture*, *2022*, 13 . https://doi.org/10.1155/2022/6974681

Azage Tegegne, Zewdu Ayele and Dirk Hoekstra. (2011). Farmer innovations in livestock feeding and management in semi-arid areas of Ethiopia. Tropentag, October 5–7, Bonn "Development on the margin".

Azraf Ahmad, Riaz Ahmad, Naeem Mahmood and M.S. Nazir. (2006). Competitive Performance of Associated Forage Crops Grown in Different Forage Sorghum-Legume Intercropping Systems. *Pakistan Journal of Agricultural Science,1*(2), 43.

Balehegn Mulubrhan, Adugna Tolera, A., Ayantunde, S., Karimou, M., Zampaligré, N., André, K., Gnanda, I., Varijakshapanicker, P., Kebreab, E., Dubeux, K., Fekede Feyissa, & Adesogan, A. T. (2020). Improving adoption of technologies and interventions for increasing supply of quality livestock feed in low- and middle income countries. *Global Food Security*, *26*, 100372. https://doi.org/10.1016/j.gfs.2020.100372

Barre, P., Turner, L. B., & Escobar-Gutiérrez, A. J. (2015). Leaf Length Variation in Perennial Forage Grasses. *Agriculture (Switzerland)*, *5*(3), 682-696. https://doi.org/10.33 90/agriculture5030682

Basaran, U., Copur Dogrusoz, M., Gulumser, E., & Mut, H. (2017). Hay yield and quality of intercropped sorghum-sudan grass hybrid and legumes with different seed ratio. *Turkish Journal of Field Crops*, *22*(1), 47–53. https://doi.org/10.17557/tjfc.301834

Bayble Taye, Solomon Melaku, and N. K. Prasad. (2007). Effects of cutting dates on nutritive value of Napier (Pennisetum purpureum) grass planted sole and in association with Desmodium (Desmodium intortum) or Lablab (Lablab purpureus). *Livestock Research for Rural Development*, *19*(1), 1–11

Beck, P. A., Hutchison, S., Gunter, S. A., Losi, T. C., Stewart, C. B., Capps, P. K., & Phillips, J.M. (2014). Chemical composition and in situ dry matter and fiber disappearance of sor ghum × Sudangrass hybrids. *Journal of Animal Science*, *85*(2), 545-555. https://doi.org/1 0.2527/jas.2006-292

Befekadu Chemere, and Yunus Abdu. (2015). *Evaluation of biomass yield and growth perfor mance of alfalfa and oat cultivars in the High Land of Arsi , Ethiopia*. *27*(6), 1–8.

Belay Duguma, Azage Tegegne, and B. Hegde. (2012). Smallholder livestock production system in Dandi district, Oromia Regional State, central Ethiopia. *Global Veterinaria*, *8*(5), 472–479.

Belel M., R. Halim, M. Rafii & H. Saud. (2014). Intercropping of Corn With Some Selected Legumes for Improved Forage Production: A Review. *Journal of Agricultural Science*, *6*(3), 48. Doi:10.5539/jas.v6n3p48x

Berhanu Alemu, Solomon Melaku , and N K Prasad. (2007). Effects of varying seed proportions and harvesting stages on biological compatibility and forage yield of oats (Avena sativa L.) and vetch (Vicia villosa R.) mixtures. *Livestock Research for Rural Development*, *19*(1), 12.

Berhanu Gebremedhin, Adane Hirpa, and Kahsay Berhe. (2009). Feed marketing in Ethiopia: Results of rapid market appraisal. *Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya*, *15*, 1–64.

Beyadglign Hunegnaw. (2019). *"*Effects of fertilizer and soil types on different cultivars of *Brachiaria* species biomass yield and quality and farmers' perception in west Gojam zone, Ethiopia," *M. Sc. thesis*, *Bahir Dar University, Bahir Dar, Ethiopia.*

Beyene Teklu, Tegene Negesse, and Ayana Angassa. (2011). Effect of farming systems on livestock feed resources and feeding systems in Benishangul-Gumuz region, western Ethiopia. *International Research Journal of Agricultural Science*, *1*(1), 20-28.

Bimrew Asmare, Solomon Demeke, Taye Tolemariam, Firew Tegegne, Aynalem Haile, and Jane Wamatu. (2017). Effects of altitude and harvesting dates on morphological characteristics, yield and nutritive value of desho grass (Pennisetum pedicellatum Trin.)i nEthiopia. *Agriculture and Natural Resources*, *51*(3), 148-153. https://doi.org/10.1016/j. anres.2016.11.001

Bizelew Gelayenew, Berhan Tamir, Getnet Assefa. and Fekede Feyissa. (2020). Effects of Spacing of Elephant Grass and Vetch Intercropping on Agronomic Performance and Herbage Yield of Elephant Grass. *J. Agric. Sci*, *30*(2), 13–30.

Boufennara, S. Lopez1, H. Bousseboua, R. Bodas, and L. Bouazza. (2012).Chemical composition and digestibility of some browse plant species collected from Algerian arid rangelands. *Spanish Journal of Agricultural Research*, 10(1), 88-98. Doi.org/10.5424/sjar/2012101-134-11

Bukovsky-Reyes, S., Isaac, M. E., & Blesh, J. (2019). Effects of intercropping and soil properties on root functional traits of cover crops. *Agriculture, Ecosystems and Environment*, *285*(106614). https://doi.org/10.1016/j.agee.2019.106614

CSA (Centeral Statistical Agency). (2018). Agricultural sample survey Volume II report on livestock and livestock characteristics, Federal Democratic Republic of Ethiopia, Central Statistical Agency; Statistical bulletin number 587.

CSA (Centeral Statistical Agency). (2021). Agricultural Sample Survey. Report on Livestock and Livestock Characteristics (Private Peasant Holdings). *Federal Democratic Republic of Ethiopia*, *II*(587), 104.

CSA (Centeral Statistical Agency). (2017). Agricultural sample survey. Report on livestock and livestock characteristics (private peasant holdings). Central Statistical Agency (CSA): Addis Ababa, Ethiopia, 194.

CSA (Centeral Statistical Agency). (2021). *Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey 2020/21 [2013 E. C.] report on livestock and livestock characteristics*. *II*(February).

Choi, G. J., Lee, S.-H., Lee, K., Ji, H. C., Hwang, T.-Y., & Kim, K.-Y. (2017). Comparison of Growth Characteristics, Productivity and Feed Values between Varieties of Sudangrass and Sorghum-Sudangrass Hybrids. *Journal of The Korean Society of Grassland and Forage Science*, *37*(1), 92–99. https://doi.org/10.5333/kgfs.2017.37.1.92

Coleman, S. W., & Moore, J. E. (2003). Feed quality and animal performance. *Field Crops Research*, *84*(1–2), 17–29. https://doi.org/10.1016/S0378-4290(03)00138-2

Dahmardeh, M., Ghanbari, A., Syahsar, B. A., & Ramrodi, M. (2010). The role of intercropping maize (*zea mays l.*) and cowpea (*vigna unguiculata l.*) on yield and soil chemical properties. *African Journal of Agricultural Research*, *5*(8), 631-636. https://doi.org/10.5897/AJAR09.607

Dariush, M., Ahad, M., & Meysam, O. (2006). Assessing the land equivalent ratio (LER) of two corn [*Zea mays L.*] varieties intercropping at various nitrogen levels in Karaj, Iran. *Journal of Central European Agriculture*, *7*(2), 359–364.

Demİrhan, F., Orak, A., & Tenİkecİer, H. S. (2018). Effect of different ratio and intercropping systems on forage yield and some components of Hungarian vetch (*Vicia* *pannonica Crantz.*) and grass combination under arid climate conditions. *Bulgarian Journal of Crop Science*, *55*(1), 44–52.

Demissie Negash, Getachew Animut, Mengistu Urgie, and Solomon Mengistu. (2017). Chemical Composition and Nutritive Value of Oats (*Avena sativa*) Grown in Mixture with Vetch (*Vicia villosa*) with or Without Phosphorus Fertilization in East shoa Zone, Ethiopia. *Journal of Nutrition & Food Sciences*, *07*(04), 471-479. https://doi.org/10.4172 /2155-9600.1000609

Desalegn Kassahun, and Wasihun Hassen. (2015). Evaluation of Biomass Yield and Nutritional Value of Different Species of Vetch (*Vicia spp.*). *Academic Journal of Nutrition*, *4*(3), 99–105. https://doi.org/10.5829/idosi.ajn.2015.4.3.96130

Dhima, K. V., Lithourgidis, A. S., Vasilakoglou, I. B., & Dordas, C. A. (2007). Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Research*, *100*(2–3), 249–256. https://doi.org/10.1016/j.fcr.2006.07.008

Dinesh Kumar, R.B. Ardeshna, Magan Singh, Govind Makarana, R.K. Meena, Sanjeev Kumar, Rakesh Kumar and B.S. Prajapat. (2021). Sustainable Production of Sesamum through Legume Intercropping: A Review. *Indian Journal of Ecology, 48*(5), 1403–1413.

Dura, K., Aleksandar, M., Branko, M., Sanja, V., & Nenad, D. (2012). Common vetch-wheat intercropping: Haylage yield and quality depending on sowing rates. *African Journal of Biotechnology*, *11*(30), 7637–7642.

Dwivedi, A., Dev, I., Kumar, V., Yadav, R., Yadav, M., Gupta, D., Singh, A., & Tomar, S. (2015). Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. *International Journal of Life Sciences Biotechnology and Pharma Research*, *4*(3), 145.

Emana Megersa, Ashenafi Mengistu and Getahun Asebe. (2017). Nutritional Characterization of Selected Fodder Species in Abol and Lare Districts of Gambella Region, Ethiopia. *Journal of Nutrition & Food Sciences, 7*(2), 2–6. Doi: 10.4172/2155-9600.1000581

Enchev, S. (2021). Productivity and feed quality of Sudan grass (*Sorghum sudanense* (Piper) Stapf.) and sweet sorghum forms. *Agricultural Science and Technology*, *13*(1), 57–62. https://doi.org/10.15547/ast.2021.01.011

Endale Yadessa, Abule Ebro, Lemma Fita and Getnet Asefa. (2016). Livestock feed production and feed balance in meta- Robi District, West Shewa Zone, and Oromiya Regional State, Ethiopia. *Acad. Res. J. of Agri. Sci. and Res*, *4*(2), 45–54.

Endale Yadessa. (2015). Assesment of Feed Resources And Determination Of Mineral Status Of Livestock Feed In Meta Robi District,West Shewa Zone, Oromia Regional State, Ethiopia. *MSc. Thesis, Ambo University College of Agriculture And Veterinary Sciences, Department of Animal Sciences.*

Erkovan, S. (2022). Row Seeding Configuration Regulates Yield, Quality And Competition In Common Vetch (*Vicia Sativa* L.)-Sudangrass (*Sorghum Sudanense* (Piper.) Stapf.) Mixture. *Turkish Journal Of Field Crops*, *27*(1), 87–94.

Eshetie Alemu Molla, Berhanu Alemu Wondimagegn and Yeshambel Mekuriaw Chekol. (2018). Evaluation of biomass yield and nutritional quality of oats-vetch mixtures at different harvesting stage under residual moisture in Fogera District, Ethiopia. *Agriculture and Food Security*, *7*(1), 1–10. Doi.org/10.1186/s40066-018-0240-y

Eskandari, H., Ghanbari, A. & Javanmard, A. (2009). Intercropping of Cereals and Legumes for Forage Production. *Notulae Scientia Biologicae*, *1*(1), 07-13. Doi.org/10.15835/nsb1 13479

Eyasu Elias. (2016). *Soils of the Ethiopian Highlands: Geomorphology and Properties. CASCAPE Project, ALTERA, Wageningen University and Research Centre (Wageningen UR). The Netherlands.*

Fantahun Dereje, Solomon Dugasa, Diriba Diba, Hasan Yusuf, Busunesh Tesfaye and Ayantu Mekonnen. (2020). The Status of Improved Forage Production and Utilization in Horro Guduru Wollega Zone, Western Oromiya Regional State, Ethiopia. *World Journal of Agricultural Sciences*, *16*(4), 238–246. https://doi.org/10.5829/idosi.wjas.2020.238.246

Fantahun Dereje. (2016). The Effect of Variety and Seed Proportions on Yield, Nutritional Quality and Compatibility of Oat and Vetch Mixtures. *Msc. Thesis, Addis Ababa University, College of Veterinary Medicine and Agriculture, Department Of Animal Production Studies.*

FAO (Food and Agriculture Organization of the United Nations). (2017). Africa sustainable livestock 2050-technical meeting and regional launch, Addis Ababa, Ethiopia, 21-23 February 2017. *FAO Animal Production and Health Report. Rome, Italy*, (12), 36.

FAO (Food and Agriculture Organization of the United Nations). (2018). Grassland Index. A searchable catalogue of grass and forage legumes Food and Agriculture Organization of the United Nations. *11th FAO Joint Meeting on Pesticide Management 9–12 October 2018 Rome, Italy*.

FAO (Food and Agriculture Organization of the United Nations). (2019). Availability and utilization of agro industrial by-products as animal feed in Ethiopia.

Fekede Feyissa, Agaje Tesfaye and Angaw Tsigie. (2011). Producing and using alternative feeds to crop residues efficient use of crop residues: Animal Feed Vs Conservation Agriculture Research Project. *Ethiopian Institute of Agricultural Research (EIAR)*. Addis Ababa, Ethiopia.

Fitsum Reda, Verkleij, J. A. C., & Ernst. (2005). Relay cropping of sorghum and legume shrubs for crop yield improvement and Striga control in the subsistence agriculture region of Tigray (northern Ethiopia). *Journal of Agronomy and Crop Science*, *191*(1), 20–26. https://doi.org/10.1111/j.1439-037X.2004.00126.x

Francis, C. A. (1989). Biological Efficiencies in Multiple Cropping Systems. *Advances in Agronomy*, *42*, 1–42. https://doi.org/10.1016/S0065-2113(08)60522-2

Fuller, D. Q., & Madella, M. (2001). Issues in Harappan archaeobotany: retrospect and prospect. *Indian Archaeology in Retrospect*, *2*, 317–390.

Geleti Diriba. (2014). Agronomic and nutritional evaluation of selected forage legumes and locally available feedstuff, and characterization of forage and dairy innovation systems in Bako and Nekemte Peri-Urban Areas, Oromia, Ethiopia. 87–103.

Genet Tilahun, Bimrew Asmare, And Yeshambel Mekuriaw. (2017). Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of desho grass (*Pennisetum pedicellatum Trin*.) in the highlands of Ethiopia. *Tropical Grasslands-Forrajes Tropicales,* 5(2), 77–84. Doi: 10.17138/TGFT(5)77-84

Geren, H., Avcioglu, R., Soya, H., & Kir, B. (2008). Intercropping of corn with cowpea and bean: Biomass yield and silage quality. *African Journal of Biotechnology*, *7*(22).

Getachew Assefa. (2021). Efforts, Successes And Challenges Of Green Feed Production In Ethiopia. *Journal of Animal and Feed Research*, *11*(1), 13-17. Doi.org/10.51227/ojafr. 2021.3

Getnet Assefa, Melkamu Bezabih, Kindu Mekonnen, Aberra Adie, and Million Gebreyes. (2022). Crop Residues Management and Nutritional Improvement Techniques. *Climate Smart Feed and Forage Innovations Training Workshop, May 16-18, Bahir Dar, Ethiopia*.

Getnet Assefa, Mesfin Dejene, Jean Hanson, Getachew Anemut, Solomon Mengistu, and Alemayehu Mengistu. (2012). "Forage seed research and development in Ethiopia." *Ethiopian Institute of Agricultural Research. Addis Ababa, Ethiopia*, 3-5.

Getnet Assefa, Tekleyohanes Berhanu, Lemma Gizachew, Mesfin Dejenie, and Diriba Geleti. (2003). Major Herbaceous Forage Legumes: Some Achievements in Species and Varietal Evaluation in Ethiopia. *Food and Forage Legumes of Ethiopia: Progress and Prospects: Proceedings o f the Workshop on Food and Forage Legumes 22-26 September2003, Addis Ababa, Ethiopia*, 129.

Getu Kitaw, Solomon Melaku, Eyasu Seifu, and Mesfin Dejene. (2010). Supplementary value of vetch (*Vicia dasycarpa*) hay as a replacement to concentrate mix in the diet of lactating crossbred cows. *SINET: Ethiopian Journal of Science*, *33*(1), 31–40.

Gezahagn Kebede, Getnet Assefa, Alemayehu Mengistu, and Hussein Mohammed. (2013). Evaluation of Vetch Species and their Accessions for Agronomic Performance and Nutritive Value in the Central Highlands of Ethiopia. *Ethiop. J. Agric. Sci.*, *24*, 99–121.

Gezahagn Kebedea, Fekede Feyissa, Hussein Mohammed, Getnet Assefa, Mengistu Alemayehu, Alemayehu Mengistu, and Mamaru Tesfaye. (2019). Yield Performance and Nutritive Value of Vetch Species Grown on Nitosol and Vertisol Conditions in the

Central Highlands of Ethiopia. *International Journal of Sciences. 2(1), 60-81*.

Gezahegn Kebede,Fekede Feyissa, Getnet Assefa, Alemayehu Mengistu, & Mengistu Alemayehu. (2020). Evaluation of accessions of vetch species for agronomic performance under nitosol and vertisol conditions in the central highlands of Ethiopia. *Journal of Crop Science and Biotechnology*, *23*(3), 215–228.

Gezahegn Kebede. (2018). Morpho-agronomic performance of vetch species and their accessions grown under nitosol and vertisol conditions in the central highlands of Ethiopia. *Agriculture and Food Security*, *7*(1), 1–14. https://doi.org/10.1186/s40066-018-0243-8

Ghanbari, A., Dahmardeh, M., Siahsar, B. A., & Ramroudi, M. (2010). Effect of maize (*Zea mays* L.)-cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. *Journal of Food, Agriculture & Environment*, *8*(1), 102–108.

Ginwal, D. S., Kumar, R., Ram, H., Dutta, S., Arjun, M., & Hindoriya, P. S. (2019). Fodder productivity and profitability of different maize and legume intercropping systems. *Indian Journal of Agricultural Sciences*, *89*(9), 1451–1455.

Gnanagobal, H., & Sinniah, J. (2018). Evaluation of growth parameters and forage yield of Sugar Graze and Jumbo Plus sorghum hybrids under three different spacings during the maha season in the dry zone of Sri Lanka. *Tropical Grasslands-Forrajes Tropicales*, *6*(1), 34–41. https://doi.org/10.17138/TGFT(6)34–4.

Golparvar, R. A. (2012). Multivariate analysis and determination of the best indirect selection criteria to genetic improvement the biological nitrogen fixation ability in common bean genotypes (Phaseolus vulgaris L.). *Genetika*, *44*(2), 279–284.

Guleria, G., & Kumar, N. (2016). Sowing methods and varying seed rates of cowpea on production potentialof sorghum, sudan grass hybrid and cowpea: A review. *Agricultural Research Communication Centre journals*, *37*(4), 290-299. Doi.org/10.18805/ag.v37i4.6 45

Hailu Gebru. (2015). A Review on the Comparative Advantages of Intercropping to Mono-Cropping System. *Journal of Biology, Agriculture and Healthcare, 5*(9), 1–14.

Harper, K. J., & McNeill, D. M. (2015). The role NDF in the regulation of feed intake and the importance of its assessment in subtropical ruminant systems (the role of NDF in the regulation of forage intake). *Agriculture*, *5*(3), 778–790.

Hassan, H. H. M., Sayed, M. R. I., & Mousa, W. M. E. (2017). Effect of Intercropping Patterns on Forage Yield and Land Use Efficiency of Some Summer Fodder Crops. *Zagazig Journal of Agricultural Research*, *44*(6), 2007-2020. https://doi.org/10.21608/zj ar.2017.51226

IGAD (Intergovernmental Authority on Development). (2011). The Contribution of Livestock to the Ethiopian Economy – Part II. *IGAD Livestock Policy Initiative Working Paper No. 02 – 11*.

Iqbal, M A, Asif, I., Kashif, A., Haider, A., Khan, R. D., Bilal, A., Faisal, N., & Ali, R. (2015). Integration of forage sorghum and by-products of sugarcane and sugar beet industries for ruminant nutrition: a review. *Global Veterinaria*, *14*(5), 752-760. https://doi.org/10.5829/idosi.gv.2015.14.05.93223

Iqbal, Muhammad Aamir, Bethune, B. J., Iqbal, A., Abbas, R. N., Aslam, Z., Khan, H. Z., & Ahmad, B. (2017). Agro-botanical response of forage sorghum-soybean intercropping systems under atypical spatio-temporal pattern. *Pakistan Journal of Botany*, *49*(3), 987–994.

Iqbal, Muhammad Aamir, Hamid, A., Ahmad, T., Siddiqui, M. H., Hussain, I., Ali, S., Ali, A., & Ahmad, Z. (2019). Forage sorghum-legumes intercropping: Effect on growth, yields, nutritional quality and economic returns. *Bragantia*, *78*(1), 82-95. https://doi.org/10.1590/1678-4499.2017363

Iqbal, Muhammad Aamir, Hamid, A., Hussain, I., Siddiqui, M. H., Ahmad, T., Khaliq, A., & Ahmad, Z. (2019). Competitive indices in cereal and legume mixtures in a south Asian environment. *Agronomy Journal*, *111*(1), 242–249. Doi.org/10.2134/agronj2017.11.0658

Javanmard, A., Majdi, M., Hamzepour, N., & Nasiri, Y. (2017). Evaluation of forage production using maize-legume intercropping and biofertilizer under low-input conditions. *Philippine Agricultural Scientist*, *100*(1).

Jiao, A., Gao, B., Gao, M., Liu, X., Zhang, X., Wang, C., Fan, D., Han, Z., & Hu, Z. (2022). Effect of nitrilotriacetic acid and tea saponin on the phytoremediation of Ni by Sudan grass (Sorghum sudanense (Piper) Stapf.) in Ni-pyrene contaminated soil. *Chemosphere*, *294*, 133-654.

Keskİn, B., Akdenİz, H., Temel, S., & Eren, B. (2018). *Determination of Agricultural Characteristics of Some Silage Sorghum and Sudan Grass Varieties Grown as Second Product*. *28*(4), 412–418. https://doi.org/10.29133/yyutbd.358318

Khan, Z., Ahmad, K., Danish, M., & Mirzaei, F. (2012). Minerals Profile of Forages for Grazing Ruminants in Pakistan. *International Journal of Livestock Research*, *2*(2), 74. https://doi.org/10.5455/ijlr.20120407060608

Kindu Mekonnen, Melkamu Bezabih, Thorne, P., Million Gebreyes, Getnet Hammond, J., & Abera Adie. (2022). Feed and forage development in mixed crop–livestock systems of the Ethiopian highlands: Africa RISING project research experience. *Agronomy Journal*, *114*(1), 46–62.

Kingwell-Banham, E. J. (2015). *Early rice agriculture in South Asia. Identifying cultivation systems using archaeobotany*. UCL (University College London).

Kir, H., & Dursun, B. (2018). The Yield and Agronomic Characteristics of Silage Sorghum and Sorghum - Sudangrass Hybrid Cultivars Under Kirsehir Ecological Conditions. *International Journal of Agricultural and Natural Sciences, 1*(3), 173–176.

Kosev, V., & Vasileva, V. (2018). Comparative Biological Characteristics Of Winter Vetch Varieties. *Forage Research*, *44*(2), 67–73.

Kriukova, T. I. (2020). Sowing qualities and yield properties of Sudanese grass depending on fractionation. *IOP Conference Series: Earth and Environmental Science*, *422*(1). https://doi.org/10.1088/1755-1315/422/1/012027

Kumar, R., Kumar, D., Datt, C., Makarana, G., & Yadav, M. R. (2018). Forage yield and nutritional characteristics of cultivated fodders as affected by agronomic interventions: A Review. *Indian Journal of Animal Nutrition*, *35*(4), 373–385.

Kumar, R., Kumar, S., Singh, M., Meena, B. S., Tomar, S. K., Datt, C., Ram, H., & Rathore, D. K. (2016). Performance of quality protein maize under different planting windows. *Indian Journal of Animal Nutrition*, *33*(2), 154–159.

Lang, B. (2001). *Sudan/Sorghum Forage Management, Iowa State University Extension, Fact Sheet BL-50, June 2001*.

Li, L., Sun, J., Zhang, F., Li, X., Yang, S., & Rengel, Z. (2001). Wheat/maize or wheat/soybean strip intercropping I. Yield advantage and interspecific interactions on nutrients. *Field Crops Research*, *71*(2), 123–137. https://doi.org/10.1016/S0378-4290(01)00156-3

Likawnt Yeheyis, Kijora C., van Santen E. and Peters K. J. (2012). Sweet annual lupins (Lupinus spp.); their adaptability and productivity in different agro-ecological zones of Ethiopia. *Journal of Animal Science Advances*, *2*(2), 20–215.

Lima, E., Pires, A., Moura, M., Costa, F., Rodrigues, S., & Alves, K. (2017). Nutritional characteristics of Sorghum hybrids hay (*Sorghum sudanense sudanense vs. Sorghum bic olor*). *Acta Scientiarum-Animal Sciences*, *39*(3), 229-234. https://doi.org/10.4025/v39i3.32524

Linn, J. G., & Martin, N. P. (1999). *Forage quality tests and interpretations. University of Minnesota Extension service, Food and Environmental science*.

Lithourgidis, A.S. Vasilakoglou, I.B. Dhima, K.V. Dordas C.A. (2006). Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Research*, *99*, 106–113. https://doi.org/10.1016/j.fcr.2006.03.008

Lopes, A., Edvan, R. L., Bezerra, L. R., Araújo, J. De, Hamilton, J., Neves, J., Amorim, D. S., & Rodrigues, R. (2020). Agronomic characterization and chemical composition of sorghum hybrids for silage making in rainfed conditions.n *Semina: Ciências Agrárias,* 407–420. https://doi.org/10.5433/1679-0359.2020v41n2p407

Lukuyu. B, Gachuiri CK, Lukuyu MN, Lusweti C and Mwendia.S. (2012). Feeding dairy cattle in East Africa. *East Africa Dairy Development Project, Nairobi, Kenya*.

Lyons, S. E., Ketterings, Q. M., Godwin, G. S., Cherney, D. J., Cherney, J. H., Van Amburgh, M. E., Meisinger, J. J., & Kilcer, T. F. (2019). Optimal harvest timing for brown midrib forage sorghum yield, nutritive value, and ration performance. *Journal of Dairy Science*, *102*(8), 7134–7149. https://doi.org/10.3168/jds.2019-16516

Mahmood, A., Ullah, H., Ijaz, M., Javaid, M. M., Shahzad, A. N., & Honermeier, B. (2013). Evaluation of sorghum hybrids for biomass and biogas production. *Australian Journal of Crop Science*, *7*(10), 1456–1462.

Makoi, J. H., & Ndakidemi, P. A. (2010). Effect of plant densities and cropping systems on yield components of cowpea (*Vigna unguiculata L. Walp*.) genotypes and sorghum (*Sorghum bicolor L. Moench*.). *Journal of Tropical Agriculture*, *48*(2), 28–33.

Malede Birhan, & Adugna Tolera. (2014). Livestock Feed Resources Assessment, Constraints and Improvement Strategies in Ethiopia. *Middle-East Jornal of Scientific Research*, *21*(4), 616–622. https://doi.org/10.5829/idosi.mejsr.2014.21.04.82406

Malede Birhan. (2013). Evaluation of Barley Green Forage as Animal Feed Intercropping with Vetch in North Gondar Zone , Ethiopia . *European Journal of Biological Sciences*, *5*(2), 50–54. https://doi.org/10.5829/idosi.ejbs.2013.5.2.7320

Malede Birhan. (2014). Assessment of Agro-Industrial by-Products for Animal Feed Supply in North Gondar Zone, Ethiopia Assessment of Agro-Industrial by-Products for Animal Feed Supply in North Gondar Zone, Ethiopia. *Journal of Animal Production Advances, 4*(1), 342–347.

Malede Birhan. (2018). Effect of seed proportions on morphological characteristics of forage mixture in North Gondar. *Scienceline Online Journal of Animal and Feed Research*, *8*(1), 5–11.

Mesay Yami, Begna Bedada, and Teklewold Teklemedihin. (2013). Enhancing the productivity of livestock production in highland of Ethiopia: Implication for improved on-farm feeding strategies and utilization. Ethiopian Institute of Agricultural Research (EIAR), Kulumsa Agricultural Research Center, Socio-Economics, Ex. *International Journal of Livestock Production*, *4*(8), 113–127. https://doi.org/10.5897/ijlp2012.0145

Mesfin Dejene, Seyoum Bediye, Dawit Alemu, Getu Kitaw, Aemiro Kehaliw. (2014). Livestock feed marketing in Ethiopia Challenges and opportunities for livestock develop ment. *Journal of Agricultural Science and Technology*, *4*, 155–168.

Millner, J. P., Silungwe, D., & Mcgill, C. R. (2011). Forage quality of sorghum, Sudan-grass sorghum×sudan-grass and pearl millet cultivars in Manawatu. *Agronomy NZ Journal*, *41*, 13-22.

Mohammed, J.B., Olufajo, O.O., Singh, B.B., Miko, S. and Mohammad, S.G. (2008). Evaluation of yield of components of sorghum/cowpea intercrops in the Sudan savanna ecological zone. *ARPN Journal of Agricultural and Biological Science*, *3*(3), 30–37.

Monteiro, J. S. T., Havrland, B., & Ivanova, T. (2012). Sweet sorghum (*Sorghum bicolor* (L. Moench) bioenergy value–importance for Portugal. *Agricultura Tropica et Subtropica*, *45*(1), 12–19.

Moosavi, S. G. (2012). Effect of density plant and planting pattern on yield, yield components and morphological traits of forage sorghum in the second cultivation. *International Journal of Agriculture and Crop Sciences (IJACS)*, *4*(1), 28–32.

Mousavi, S. R., & Eskandari, H. (2011). A General Overview on Intercropping and Its Advant ages in Sustainable Agriculture. *Journal of Applied Environmental and Biological Sciences*, *1*(11), 482–486.

Moyer, J. L., Fritz, J. O., & Higgins, J. J. (2004). Trends in forage yield and nutritive value of hay type Sorghum spp. *Agronomy Journal*, *96*(5), 1453-1458. Doi.org/10.2134/agronj20 04.1453

Muluken Shiferaw, Bimrew Asmare, Firew Tegegne, and Dessalegn Molla. (2018). Farmers perception and utilization status of improved forages grown in the natural resource areas of northwestern Ethiopia. *Biodiversitas*, *19*(4), 1568-1578. https://doi.org/10.13057/biodi v/d190450

Muluneh Minta and Angaw Tsige. (2014). Effect of Rhizobium Inoculation on Herbage Yield, Quality and Nitrogen Fixation of Annual Forage Legumes on Nitisols in Central Highlands of Ethiopia. *Advances in Applied Agricultural Sciences*, *02*(10), 29–48.

Muluye Fekade (2019). Improved Forage Production in Ethiopia: Utilization, Challenges and Prospects for Adoption: A Review. *Journal of Biology, Agriculture and Healthcare*, *9*(21), 5–11. https://doi.org/10.7176/JBAH/9-21-02

Mut, H. (2017). Hay yield and quality of intercropped sorghum-Sudan grass hybrid and legumes with different seed ratio. *Turkish Journal of Field Crops*, *22*(1), 47-53.

Naim, A.M.E., Kilali, B.A., Hassan, A.E., Ahmed, M.F. (2013). Agronomic evaluation of sorghum and cowpea intercropped at different spatial arrangements. *Journal of Renewable Agriculture*, *1*(2), 11–16. Doi: 10.12966/jra.05.01.2013

Najmaldin, S. S. Y., & Ali, G. S. (2019). Effect Of Seed Rate And Nitrogen Fertilizer On Forage Yield Of Sudangrass (*Sorghum Sudanense* " Piper " Stapf) In Central Sudan. *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, *6*(4), 4–9.

Nathani, N. M., Patel, A. K., Mootapally, C. S., Reddy, B., Shah, S. V., Lunagaria, P. M., Kothari, R. K., & Joshi, C. G. (2015). Effect of roughage on rumen microbiota composition in the efficient feed converter and sturdy Indian Jaffrabadi buffalo (Bubalus bubalis). *BMC Genomics*, *16*(1), 1–15. https://doi.org/10.1186/s12864-015-2340-4

Nebere Habtamu, Degefa Tolossa, and Amare Bantider. (2021). Analyzing factors affecting the sustainability of land management practices in mecha woreda, northwestern Ethiopia. *Sustainability (Switzerland)*, *13*(13). https://doi.org/10.3390/su13137007

Nguku, S. A., Njarui, D. N., Musimba, N. K. R., Amwata, D., & Kaindi, E. M. (2016). Primary production variables of brachiaria grass cultivars in Kenya drylands. *Tropical and Subtropical Agroecosystems*, *19*(1), 29–39.

Oh, M. R., Hong, H., Li, H. L., Jeon, B. T., Choi, C. H., Ding, Y. L., Tang, Y. J., Kim, E. K., Jang, S. Y., & Seong, H. J. (2016). Effects of physically effective neutral detergent fiber content on intake, digestibility, and chewing activity in fattening heifer fed total mixed ration. *Asian-Australasian Journal of Animal Sciences*, *29*(12), 1719.

Oseni, T. O., & Aliyu, I. G. (2010). Effect of row arrangements on sorghum-cowpea intercrops in the semi-arid savannah of Nigeria. *International Journal of Agriculture and Biology*, *12*(1), 137–140.

Osman, M. E. H., El-Sheekh, M. M., El-Naggar, A. H., & Gheda, S. F. (2010). Effect of two species of cyanobacteria as biofertilizers on some metabolic activities, growth, and yield of pea plant. *Biology and Fertility of Soils*, *46*(8), 861–875.

Pahuja, S. K., Arya, S., Kumari, P., & Panchta, R. (2014). Evaluation of Forage Sorghum Hybrids [*Sorghum Bicolor* (L.) Moench]. *Forage Research*, *40*(3), 159–162.

Petrie, C. A., & Bates, J. (2017). ‘Multi-cropping’, intercropping and adaptation to variable environments in Indus South Asia. *Journal of World Prehistory*, *30*(2), 81–130.

Prusty, S., Mohini, M., Kundu, S. S., Kumar, A., & Datt, C. (2014). Erratum to Methane emissions from river buffaloes fed on green fodders in relation to the nutrient intake and digestibility. *Tropical Animal Health and Production*, *46*(1), 71. https://doi.org/10.1007/s11250-013-0456-6

Rathor, B. M. (2015). Growth and fodder yields of sorghum and cowpea in sole and intercropping Systems. *Bioinfolet-A Quarterly Journal of Life Sciences*, *12*(3b), 777–779.

Rayburn, E. B., Lozier, J. D., Sanderson, M. A., Smith, B. D., Shockey, W. L., Seymore, D. A., & Fultz, S. W. (2007). Alternative Methods of Estimating Forage Height and Sward Capacitance in Pastures Can Be Cross Calibrated. *Forage & Grazinglands*, *5*(1), 1–6. https://doi.org/10.1094/fg-2007-0614-01-rs

Reza, Z. O., Allahdadi, I., Mazaheri, D., Akbari, G. A., Jahanzad, E., & Mirshekari, M. (2013). Effect of different planting proportions and nitrogen fertilizer in intercropping forage sorghum and lima bean. *African Journal of Agricultural Research*, *8*(49), 6488–6498. https://doi.org/10.5897/AJAR11.994

Rusdy, M. (2021). Grass-legume intercropping for sustainability animal production in the tropics. *CAB Reviews, 16*(021). https://doi.org/10.1079/PAVSNNR202116021

Salem, A., Sultan, F. M., & El-Douby, K. A. (2019). Effect of Intercropping Cowpea (*Vigna unguiculata* L.) with Teosinte (*Zea mexicana Schrad*) on Forage Yield Productivity and Its Quality. *Egyptian Journal of Agronomy*, *41*(2), 183–196.

Sani, B. M., Danmowa, N. M., Sani, Y. A., & Jaliya, M. M. (2011). Growth, Yield and Water Use Efficiency of Maize Sorghum Intercrop at Samaru, Northern Guinea Savannah, Nige ria. *Nigerian Journal of Basic and Applied Science*, *19*(2), 253–259.

SAS (Statistical Analysis System). (2004). *SAS/STAT package*. SAS Inst. Inc., Cary, NC, USA.

Schroeder, J. (2012). *Interpreting Forage Analysis*. North Dakota: NDSU Extension Service.

Sefa Salo. (2017). Estimation of Feeds and Fodders for Livestock Population of Ethiopia and Mitigation of Feed Shortage. *Journal of Natural Sciences Research, 7*(11), 45–51.

Semmana, U., Dinkalea, T., & Ebab, B. (2019). Performance evaluation of improved vetch varieties/accessions at the highland of guji zone, bore, Ethiopia. *Agricultural research and technology. Open access journal*, *20*(5), 221- 225. https://doi.org/10.19080/ARTOA J.2019.20.556141

Shahrajabian, M. H., Khoshkharam, M., Sun, W., & Cheng, Q. (2021). The influence of increased plant densities and nitrogen fertilizer levels on forage yield, seed yield and qualitative characteristics of forage sorghum (*Sorghum bicolor* L. Moench). *Thai Journal of Agricultural Science*, *53*(4), 201–217.

Sharma, K. C., & Chander, S. (2006). Response of sweet sudan grass (*Sorghum sudanensis*) to cowpea (*Vigna unguiculata*) intercropping and nitrogen levels in arid region of Rajasthan. *Range Management and Agroforestry*, *27*(1), 31–34.

Shimelis Mengistu and Temesgen Alene. (2016). Training report on forage production, feed management and utilization for Africa RISING project farmers in Basona Worena, Ethiopia. March, 1–11. www.africa-rising.net

Shimelis Mengistu , Ajebu Nurfeta, Adugna Tolera, Melkamu Bezabih, Abera Adie, Endalkac hw Wolde-meskel, and Mesfin Zenebe. (2021). Livestock Production Challenges and Improved Forage Production Efforts in the Damot Gale District of Wolaita Zone, Ethiopia. *Hindawi Advances in Agriculture*, 1–10. https://doi.org/10.1155/2021/5553659

Shri, S., Jha, A. K., & Shirvastava, A. (2014). Evaluation of different intercropping systems for productivity and economics in maize (Zea mays L.).

Simili, F. F., Lima, M. L. P., Medeiros, M. I. M. de, Paz, C. C. P. de, Ruggieri, A. C., & Reis, R. A. (2013). Hydrocyanic acid content and growth rate of sorghum x sudangrass hybrid during fall. *Ciência e Agrotecnologia*, *37*, 299–305.

Singh, B. B., & Tarawali, S. A. (2007). Cowpea and improvements key to sustainable mixed crop/livestock farming system in West Africa. www. Lri Org/Info Serve/Web Pub/Fuldo.

Singh, B., Singh, K. and Dhukia, R.S. (2008). Assessment of yield advantage of different fodder crops in intercropping system. *Annals of Biology*, *24*, 149–152.

Singh, G. P., & Oosting, S. J. (1992). *A model for describing the energy value of straws. Indian Dairyman.*

Singh, P. K., Gautam, R. K., Roy, S. D., Singh, A. K., & Ahmed, S. K. Z. (2014). Performance of sorghum varieties for fodder yield during Rabi season in Andaman & Nicobar Islands. *Jornal of the Andaman Science Association*, 19(2), 174–176.

Singh, U. (2020). Production potential maize based cropping system. *IJAS, 78*(12), 23–27.

Singh, U., Saad, A. A., & Singh, S. R. (2008). Production potential, biological feasibility and economic viability of maize (Zea mays)-based intercropping systems under rainfed conditions of Kashmir valley. *Indian Journal of Agricultural Sciences*, *78*(12), 10–23.

Solomon Bogale, Solomon Melaku, and Alemu Yami. (2008). Potential use of crop residues as livestock feed resources under smallholder farmers conditions in bale highlands of ethiopia. *Tropical and Subtropical Agroecosystems*, *8*(1), 107–114.

Solomon Tefera, Bimrew Asmare, and Firew Tegegne. (2019). Farmers' utilization practice, yield and chemical composition of selected improved forages grown in natural resource management areas of Farta Farmers' utilization practice, yield and chemical composition of selected improved forages grown in natural. *Cogent Food & Agriculture*, *5*(1), 1686961. https://doi.org/10.1080/23311932.2019.1686961

Solomon Zewdu, Binyam Kassa, Bilatu Agza, Ferede Alemu, & Gadisa Muleta. (2014). Smallholder cattle production systems in Metekel zone, northwest Ethiopia. *Research Journal of Agriculture and Environmental Management*, *3*(2), 151–157.

Song, Y., Lee, S., Rahman, A., & Lee, K. (2021). Evaluation of Intercropping Sorghum × Sudangrass Hybrid (Sorghum bicolor) with Legume Crops Based on Growth Characteristics, Forage Productivity, and Feed Values at a Summer Paddy Field. *Journal of the Korean Society of Grassland and Forage Science*, *41*(3), 198-204.

Sturludóttir, E., Brophy, C., Bélanger, G., Gustavsson, A. M., Jørgensen, M., Lunnan, T., & Helgadóttir, Á. (2014). Benefits of mixing grasses and legumes for herbage yield and nutritive value in Northern Europe and Canada. *Grass and Forage Science*, *69*(2), 229–240. https://doi.org/10.1111/gfs.12037

Sun, B., Peng, Y., Yang, H., Li, Z., Gao, Y., Wang, C., Yan, Y., & Liu, Y. (2014). Alfalfa (Medicago sativa L.)/maize (Zea mays L.) intercropping provides a feasible way to improve yield and economic incomes in farming and pastoral areas of Northeast China. *PLoS One*, *9*(10).

Tadesse Amsalu and solomon Addisu. (2014). Assessment of Grazing Land and Livestock Feed Balance in Gummara-Rib Watershed, Ethiopia. *Current Agriculture Research Journal*, *2*(2), 114–122. http://dx.doi.org/10.12944/CARJ.2.2.08

Tarawali S. A., G. Tarawali, A. L. and J. H. (1995). *Methods for the Evaluation of Forage Legumes, Grasses and Fodder Trees for Use as Livestock Feed*. International Livestock Research Institute)| Nairobi, Kenya, 103–111.

Teferi Aregawi, Solomon Melaku, and Lisanework Nigatu. (2008). Management and utilization of browse species as livestock feed in semi-arid district of North Ethiopia. *Livestock Research for Rural Development*, *20*(6), 86.

Tesfaye Agajie, & Chairatanayuth, P. (2007). Management and feeding systems of crop residues: the experience of East Shoa Zone, Ethiopia. *Livestock Research for Rural Deve lopment*, *19*(3), 6–12.

Tesfaye Belayneh, Abdo Mohammed, Amsalu Nebiyu, and Teshale Tigistu. (2020). Evaluation of biomass yield, seed yield and chemical composition of vetch and oats grown in pure stand and in mixture at Mareka district southern, Ethiopia. http://dx.doi.or g/10.2139/ssrn.3907910

Teshale Jabessa, Zinash Amare, and Genet Dejene (2020). Performance Evaluation of Vetch Varieties/Genotypes for Their Agronomic Performance and Nutritive Value in Selected Midland of East Guji Zone, Adola, Southern Oromia and Ethiopia. *Asian Journal of Advanced Research and Reports*, *9*(2), 54–59. https://doi.org/10.9734/ajarr/2020/v9i2

Thorne, Peter Coordinator, P. (2015). *Africa Research in Sustainable Intensification for the Next Generation Ethiopian Highlands Project Technical report, 1 April 2015–30 September 2015*.

Tilahun Amede, Solomon Mengistu, and Roothaert, R. (2005). Intensification of livestock feed production in Ethiopian highlands: potential and experiences of the African highlands initiative. *19th EVA Annual Conference*. https://www.researchgate.net/profile/

Tiruset Tesfay. (2019). Effect Of Intercropping Vetch Species And Harvesting Age On Morphological Characteristics , Forage Yield And Chemical Composition Of Desho Grass (Pennisetum Pedicellatum) And Vetch Species In North Mecha. *Msc. Thesis. Bahir Dar University, College Of Agriculture And Environmental Sciences*.

Uher, D., Svečnjak, Z., Dujmović-Purgar, D., Jareš, D., & Horvatić, I. (2019). Influence of Intercropping Maize With Climbing Bean on Forage Yield and Quality. *Agrofor*, *4*(3), 77–80. https://doi.org/10.7251/agreng1903060u

Unathi, G., Nobulungisa, M., & Solomon, T. B. (2018). Benefits of grass-legume intercropping in livestock systems. *African Journal of Agricultural Research*, *13*(26), 1311–1319. https://doi.org/10.5897/ajar2018.13172

Usman Semman, Getachew Animut, Mengistu Urge. (2017). Effect of different spacing of Napier grass (Pennisetum purpureum) intercropped with or without Lablab (Lablab purpureus) on digestibility of Napier grass. *Egyptian Academic Journal of Biological Sciences*, *9*(2), 31–54. https://doi.org/10.14196/sjpas.v5i9.2246

Usman Semmana, Tamirat Dinkalea and Bedasa Ebab. (2019). Performance evaluation of improved vetch varieties/accessions at the highland of guji zone, bore, Ethiopia. *Agricult ural research and technology*, *20*(5), 556141. Doi: 10.19080/ARTOAJ.2019.20.556141

Uzun, F. Ugur, S., & Sulak, M. (2009). Yield , Nutritional and Chemical Properties of Some Sorghum x Sudan Grass Hybrids (*Sorghum bicolour* (L.) Moench x *Sorghum sudanense* Stapf.). *Journal of Animal and Veterinary Advances*, *8*(8), 1602–1608.

Van Soest, P. J. (1982). *Nutritional ecology of the ruminant.* Corvallis, Oregon: O & B Books. Inc.

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition. *Journal of Dairy Science*, *74*(10), 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551

Verma, S.S., Joshi, Y.P. and Saxena, S.C. (2005). Effect of row ratio of fodder sorghum (*Sorghum bicolor*) in pigeon pea (*Cajanus cajan*) intercropping system on productivity, competition functions and economics under rain fed conditions of north India. *Indian Journal of Agronomy*, *50*(2), 123–125.

Webb, Erin G., Anthony F. Turhollow, Mark E. Downing. (2010). *Review of Sorghum Produc tion Practices: Applications for Bioenergy.*Oak Ridgenational Laboratory.

Weria Weisany, Yaghoub Raei, K. H. A. (2013). Role of Some of Mineral Nutrients in Biological Nitrogen Fixation. *Bulletin of Environment, Pharmacology and Life Sciences*, *2*(4), 77–84. http://www.bepls.com/march_2013.html

Willey, & W. R. (1979). Intercropping Its Importance and Research Needs: Part1. Competitio n and Yield Advantages. *Field Crop Abstracts*, *32*,1-10. http://ci.nii.ac.jp/naid/10024068 486

Yahuza I. (2011). Review of some methods of calculating intercrop efficiencies with particular reference to the estimates of intercrop benefits in wheat/faba bean system. *International Journal of Biosciences*, *1*(5), 18–30.

Yang Yong, M. H. (2017). Effects of Intercropping and Rotation on Forage Yield and Quality of Oat and Common Vetch in Jilin Province, China. *Research on Crop Ecophysiology*, *12*(1), 9–23.

Yihalem Denekew and Habtemariam Asefa. (2012). "On-farm verification of under sowing of cowpea (Vigna unguiculata) and vetch (*Vicia villosa*) on maize crop for forage dry matter yield production in Northwest Ethiopia." *Agricultural Research and Reviews*, *1*(1), 53–57.

Yihalem Denekew, Berhan Tamir, and Solomon Melaku. (2005). Effect of stage of harvesting on composition and yield of natural pasture in northwestern Ethiopia. *Tropical Science, 45*(1), 19–22.

Yosef Mekasha, Azage Tegegne, Alemu Yami., Umunna N. N., and Nsahlai IV. (2003). Effects of supplementation of grass hay with non-conventional agro-industrial byproducts on rumen fermentation characteristics and microbial nitrogen supply in rams. *Small Ruminant Research*, *50*(1-2), 141–151.

Zafaranieh, M. (2015). Effect of various combinations of safflower and chickpea intercropping on yield and yield components of safflower. *Agriculture Science Developments*, *4*, 31–34.

Zaklouta, M., Hilali, M. E., Nefzaoui, A., & Haylani, M. (2011). *Animal Nutrition and Product Quality Laboratory Manual*.

Zhang, G., Yang, Z., & Dong, S. (2011). Interspecific competitiveness affects the total biomass yield in an alfalfa and corn intercropping system. *Field Crops Research*, *124*(1), 66–73.

CHAPTER 7. APPENDIX

Appendix 7.1. ANOVA Tables

ANOVA for Sudan grass plant height

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	663.6091667	132.7218333	6.16	0.0234
Error	6	129.3133333	21.5522222		
Corrected Total	11	792.9225000			
R-Square	Coeff Var	Root MSE	PH Mean		
0.836916	3.031796	4.642437	153.1250		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	485.7691667	161.9230556	7.51	0.0187

ANOVA for Sudan grass NLPT

Source	DF	sum of Squares	Mean Square	F Value	Pr > F
Model	5	61.52916667	12.30583333	5.09	0.0363
Error	6	14.52000000	2.42000000		
Corrected Total	11	76.04916667			
R-Square	Coeff Var	Root MSE	Nlpt Mean		
0.809071	17.59436	1.555635	8.841667		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	56.30250000	18.76750000	7.76	0.0173

ANOVA for Sudan grass NTPP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	371.4166667	74.2833333	20.73	0.0010
Error	6	21.5000000	3.5833333		
Corrected Total	11	392.9166667			
R-Square	Coeff Var	Root MSE	NTPP Mean		
0.945281	16.34218	1.892969	11.58333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	368.2500000	122.7500000	34.26	0.0004

ANOVA for Sudan grass LL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	387.8408333	77.5681667	28.62	0.0004
Error	6	16.2616667	2.7102778		
Corrected Total	11	404.1025000			
R-Square	Coeff Var	Root MSE	LL Mean		
0.959759	4.352392	1.646292	37.82500		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	387.3558333	129.1186111	47.64	0.0001

ANOVA for Sudan grass LW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.69497583	0.13899517	33.57	0.0003
Error	6	0.02484483	0.00414081		
Corrected Total	11	0.71982067			
R-Square	Coeff Var	Root MSE	LW Mean		
0.965485	2.701851	0.064349	2.381667		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	0.66007067	0.22002356	53.14	0.0001

ANOVA for Sudan grass Stem thickness

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	3.36597500	0.67319500	2.19	0.1835
Error	6	1.84211667	0.30701944		
Corrected Total	11	5.20809167			
R-Square	Coeff Var	Root MSE	Stemthick Mean		
0.646297	19.81854	0.554093	2.795833		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	2.26115833	0.75371944	2.45	0.1609

ANOVA for Sudan grass RN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	507.1666667	101.4333333	12.55	0.0039
Error	6	48.5000000	8.0833333		
Corrected Total	11	555.6666667			
R-Square	Coeff Var	Root MSE	RN Mean		
0.912717	10.86543	2.843120	26.16667		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	505.0000000	168.3333333	20.82	0.0014

ANOVA for Sudan grass RL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	158.8041667	31.7608333	2.52	0.1458
Error	6	75.6383333	12.6063889		
Corrected Total	11	234.4425000			
R-Square	Coeff Var	Root MSE	Mean		
0.677369	16.41872	3.550548	21.62500		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	115.7691667	38.5897222	3.06	0.1131

ANOVA for Sudan grass DM%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	63.49514167	12.69902833	7.77	0.0134
Error	6	9.81015000	1.63502500		
Corrected Total	11	73.30529167			
R-Square	Coeff Var	Root MSE	DMp Mean		
0.866174	6.124195	1.278681	20.87917		

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	62.42242500	20.80747500	12.73	0.0052

ANOVA for Sudan grass DMYt/ha

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	23.93229167	4.78645833	6.06	0.0243
Error	6	4.74080000	0.79013333		
Corrected Total	11	28.67309167			
R-Square	Coeff Var	Root MSE	DMYtha Mean		
0.836660	14.46376	0.888894	5.745833		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	23.68542500	7.89514167	9.99	0.0095

ANOVA for TCPYt/ha

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	4.62812000	0.77135333	26.62	<.0001
Error	8	0.23177333	0.02897167		
Corrected Total	14	4.85989333			
R-Square	Coeff Var	Root MSE	Tcpytha Mean		
0.952309	11.52148	0.1440211	1.4427333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
trmt	4	4.57542667	1.14385667	39.48	<.0001

ANOVA for Sudan grass LSR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.92735000	0.18547000	14.01	0.0029
Error	6	0.07941667	0.01323611		
Corrected Total	11	1.00676667			
R-Square	Coeff Var	Root MSE	LSR Mean		
0.921117	6.814312	0.115048	1.688333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	0.87103333	0.29034444	21.94	0.0012

ANOVA for Vetch Plant Height

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1206.424167	241.284833	46.62	0.0001
Error	6	31.053800	5.175633		
Corrected Total	11	1237.477967			
R-Square	Coeff Var	Root MSE	PH Mean		
0.974906	1.854294	2.275002	122.6883		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	1195.368900	398.456300	76.99	0.0001

ANOVA for Vetch Nbranch

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	487.4166667	97.4833333	31.06	0.0003

Error	6	18.8333333	3.1388889		
Corrected Total	11	506.2500000			
R-Square	Coeff Var	Root MSE	nbr Mean		
0.962798	9.981358	1.771691	17.75000		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	486.9166667	162.3055556	51.71	0.0001

ANOVA for Vetch Plant RN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	541.1666667	108.2333333	76.40	0.0001
Error	6	8.5000000	1.4166667		
Corrected Total	11	549.6666667			
R-Square	Coeff Var	Root MSE	rn Mean		
0.984536	4.127993	1.190238	28.83333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	519.0000000	173.0000000	122.12	<.0001

ANOVA for Vetch RL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	19.75000000	3.95000000	2.26	0.1751
Error	6	10.50000000	1.75000000		
Corrected Total	11	30.25000000			
R-Square	Coeff Var	Root MSE	rl Mean		
0.652893	5.814838	1.322876	22.75000		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	16.25000000	5.41666667	3.10	0.1110

ANOVA for Vetch Nodule Number

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	770.4166667	154.0833333	63.76	<.0001
Error	6	14.5000000	2.4166667		
Corrected Total	11	784.9166667			
R-Square	Coeff Var	Root MSE	nn Mean		
0.981527	7.258661	1.554563	21.41667		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	762.2500000	254.0833333	105.14	0.0001

ANOVA for Vetch DM percentage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	27.10887500	5.42177500	10.37	0.0065
Error	6	3.13761667	0.52293611		
Corrected Total	11	30.24649167			
R-Square	Coeff Var	Root MSE	DMp Mean		
0.896265	3.862085	0.723143	18.72417		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	9.42715833	3.14238611	6.01	0.0307

ANOVA for Vetch DMYt/ha

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	26.83428333	5.36685667	5.44	0.0312
Error	6	5.92298333	0.98716389		
Corrected Total	11	32.75726667			
R-Square	Coeff Var	Root MSE	dmytha Mean		
0.839186	16.23608	0.993561	5.767333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	25.97466667	8.65822222	8.77	0.0130

ANOVA for LER Total

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.84797178	0.21199294	3.05	0.1531
Error	4	0.27837911	0.06959478		
Corrected Total	8	1.12635089			
R-Square	Coeff Var	Root MSE	LERtot Mean		
0.752849	14.50381	0.263808	1.818889		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	2	0.69190489	0.34595244	4.97	0.00823

ANOVA for Competition Ratio of Sudan grass

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	9.98717778	2.49679444	4.47	0.0880
Error	4	2.23324444	0.55831111		
Corrected Total	8	12.22042222			
R-Square	Coeff Var	Root MSE	CRS Mean		
0.817253	34.98866	0.747202	2.135556		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	2	9.32968889	4.66484444	8.36	0.0373

ANOVA for Competition Ratio of Vetch

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.99706667	0.49926667	20.06	0.0065
Error	4	0.09953333	0.02488333		
Corrected Total	8	2.09660000			
R-Square	Coeff Var	Root MSE	CRV Mean		
0.952526	22.42813	0.157745	0.703333		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	2	1.96686667	0.98343333	39.52	0.0023

ANOVA for CRs/CRv

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	174.6079111	43.6519778	2.16	0.2365
Error	4	80.6877778	20.1719444		
Corrected Total	8	255.2956889			
R-Square	Coeff Var	Root MSE	CRS/CRV Mean		
0.683944	75.37175	4.491319	5.958889		

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	2	152.2105556	76.1052778	3.77	0.1200

ANOVA for Total Aggressiveness of Sudan grass and Vetch

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	30.02497778	7.50624444	9.04	0.0278
Error	4	3.32197778	0.83049444		
Corrected Total	8	33.34695556			
R-Square	Coeff Var	Root MSE	ASVt Mean		
0.900381	54.49722	0.911315	1.672222		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	2	29.47402222	14.73701111	17.74	0.0103

ANOVA for Sudan grass DM%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	80.05820833	16.01164167	8.87	0.0097
Error	6	10.83208333	1.80534722		
Corrected Total	11	90.89029167			
R-Square	Coeff Var	Root MSE	DM Mean		
0.880822	1.467555	1.343632	91.55583		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatment	3	70.46469167	23.48823056	13.01	0.0049

ANOVA for Sudan grass Ash%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	21.73907500	4.34781500	5.96	0.0252
Error	6	4.37381667	0.72896944		
Corrected Total	11	26.11289167			
R-Square	Coeff Var	Root MSE	ASH Mean		
0.832504	11.82681	0.853797	7.219167		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	18.67155833	6.22385278	8.54	0.0138

ANOVA for Sudan grass CP%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	18.31650833	3.66330167	7.65	0.0139
Error	6	2.87258333	0.47876389		
Corrected Total	11	21.18909167			
R-Square	Coeff Var	Root MSE	CP Mean		
0.864431	6.589264	0.691928	10.50083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	17.78949167	5.92983056	12.39	0.0056

ANOVA for Sudan grass NDF%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	5	121.9594083	24.3918817	7.43	0.0150
Error	6	19.6984833	3.2830806		
Corrected Total	11	141.6578917			
R-Square	Coeff Var	Root MSE	NDF Mean		
0.860943	2.773111	1.811927	65.33917		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	118.6986917	39.5662306	12.05	0.0060

ANOVA for Sudan grass ADF%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	49.4802417	9.8960483	0.74	0.6180
Error	6	79.7038500	13.2839750		
Corrected Total	11	129.1840917			
R-Square	Coeff Var	Root MSE	ADF Mean		
0.383021	8.409434	3.644719	43.34083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	33.59922500	11.19974167	0.84	0.5183

ANOVA for Sudan grass ADL%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	38.70320833	7.74064167	12.02	0.0044
Error	6	3.86501667	0.64416944		
Corrected Total	11	42.56822500			
R-Square	Coeff Var	Root MSE	ADL Mean		
0.909204	6.653693	0.802602	12.06250		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	37.25715833	12.41905278	19.28	0.0018

ANOVA for Sudan grass OM%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	21.73907500	4.34781500	5.96	0.0252
Error	6	4.37381667	0.72896944		
Corrected Total	11	26.11289167			
R-Square	Coeff Var	Root MSE	OM Mean		
0.832504	0.920230	0.853797	92.78083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	18.67155833	6.22385278	8.54	0.0138

ANOVA Table for Vetch DM%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	78.9880417	15.7976083	3.00	0.1067
Error	6	31.5843833	5.2640639		
Corrected Total	11	110.5724250			
R-Square	Coeff Var	Root MSE	DM Mean		
0.714356	2.552758	2.294355	89.87750		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	78.82209167	26.27403056	4.99	0.0454

ANOVA Table for Vetch Ash%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	27.28950833	5.45790167	4.55	0.0462
Error	6	7.19358333	1.19893056		
Corrected Total	11	34.48309167			
R-Square	Coeff Var	Root MSE	ASH Mean		
0.791388	13.61181	1.094957	8.044167		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	25.27349167	8.42449722	7.03	0.0217

ANOVA Table for Vetch CP%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	68.73700833	13.74740167	7.96	0.0126
Error	6	10.35868333	1.72644722		
Corrected Total	11	79.09569167			
R-Square	Coeff Var	Root MSE	CP Mean		
0.869036	6.221077	1.313943	21.12083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	63.78849167	21.26283056	12.32	0.0056

ANOVA Table for Vetch NDF%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	97.4172917	19.4834583	15.71	0.0022
Error	6	7.4400000	1.2400000		
Corrected Total	11	104.8572917			
R-Square	Coeff Var	Root MSE	NDF Mean		
0.929046	2.497269	1.113553	44.59083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	92.58742500	30.86247500	24.89	0.0009

ANOVA Table for Vetch ADF%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	119.0331083	23.8066217	12.81	0.0037
Error	6	11.1537833	1.8589639		
Corrected Total	11	130.1868917			
R-Square	Coeff Var	Root MSE	ADF Mean		
0.914325	4.549217	1.363438	29.97083		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	116.0180917	38.6726972	20.80	0.0014

ANOVA Table for Vetch ADL%

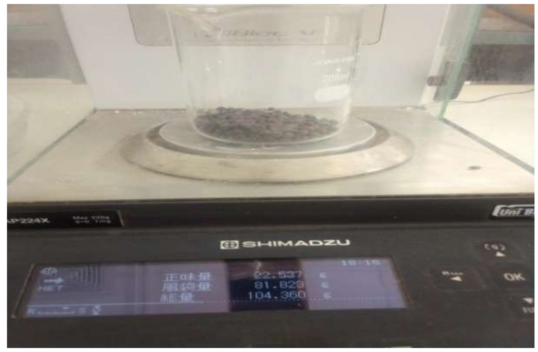
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	12.92678333	2.58535667	2.31	0.1692
Error	6	6.72871667	1.12145278		
Corrected Total	11	19.65550000			

R-Square	Coeff Var	Root MSE	ADL Mean		
0.657667	15.35876	1.058987	6.895000		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	12.74723333	4.24907778	3.79	0.0776

ANOVA Table for Vetch OM%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	27.28950833	5.45790167	4.55	0.0462
Error	6	7.19358333	1.19893056		
Corrected Total	11	34.48309167			
R-Square	Coeff Var	Root MSE	OM Mean		
0.791388	1.190742	1.094957	91.95583		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	3	25.27349167	8.42449722	7.03	0.0217

Appendix 7.2. Field Photo with activities throughout the Experiment



Packed seed of Sudan grass

Vetch seed rate measurment 75% (18.75kg/ha)

Land preparation and Plot layout

Harrowing practis

Sole (100% seed rate) Sudan grass

Sudan grass one month growth stage (a) and one month and half growth stage (b)



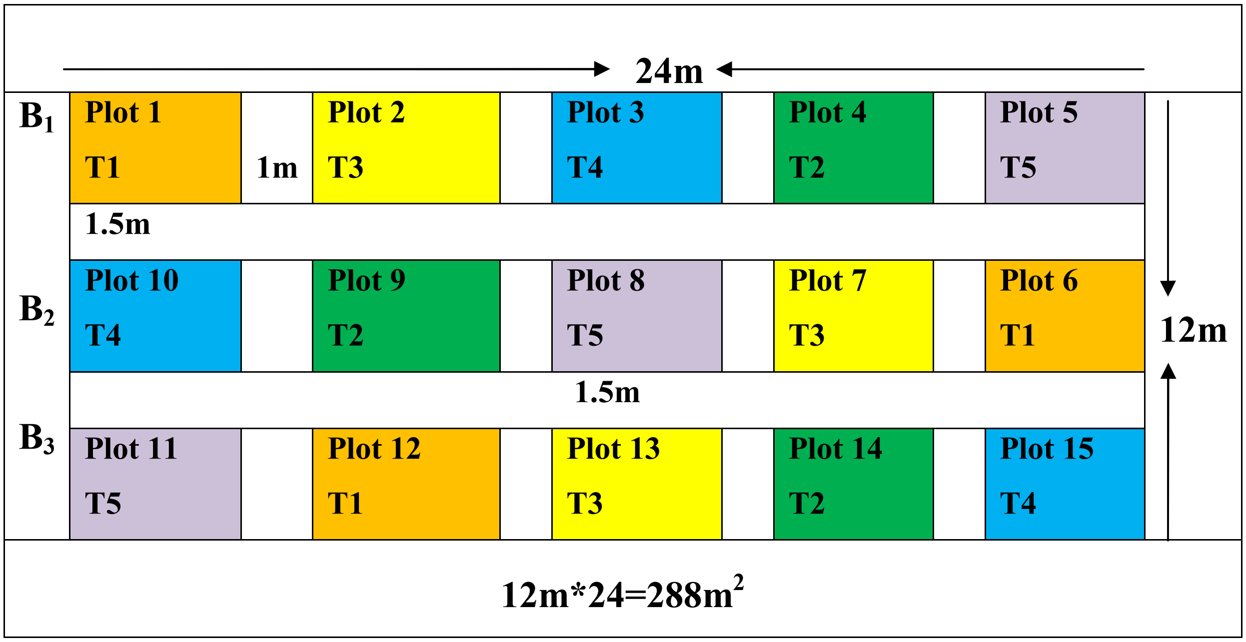
Sudan grass two month and 10 days of growth stage



Three month stage, Sudan grass at (1^{st} heading) & Vetch at (50% flowering) and fresh biomass and leaf length measurement

Ash determination at experimental laboratory

Appendix 7.3 Figure of Plot and Block arrangement (Layout)



Where,

Treatments	Intercropping seed rate	sowing seed rate (Sudan grass+vetch) in kg/ha
T1(Sole Sudan grass)	100% S	10kg/ha
T2	75% S:25% V	7.5kg/ha+6.25kg/ha
T3	50%S: 50% V	5kg/ha+12.5kg/ha
T4	25%S: 75% V	2.5kg/ha+18.75kg/ha
T5(Sole vetch)	100% V	25kg//ha

Experimental periods

Sowing date: January/19/2022

Harvesting date: April/23/2022

Biographical sketch

The author was born on August 1996 G.C in Bibugn District, East Gojjam Zone, Amhara National Regional State of Ethiopia. He attended his primary education at Genamemcha primary school from 2004 to 2012. Then he moved to Liyew Assres Zewdie secondary school from 2013-2016. After successfully passing the Ethiopian Higher Education Entrance Examination, he joined Assosa University, College of Agriculture and Natural Resources in 2016 and graduated with a BSc Degree in Animal Science in Jun 2018 with a CGPA 3.88. Upon graduation, he worked at Assosa University for two years. After serving for about two years, he joined the regular Postgraduate program at Bahir Dar University, College of Agriculture and Environmental Sciences on October 2020 to pursue his MSc degree in the field of Feeds and Animal Nutrition and completed in December 2022 with CGPA 3.78.