MADDA WALABU UNIVERSITY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE

DEPARTMENT OF ANIMAL SCIENCE

EFFECT OF SEED PROPORTION AND PLANTING PATTERN ON DRY MATTER YIELD,COMPATIBILITY AND CHEMICAL COMPOSITION OF OAT AND VETCH MIXTURES IN SINANA DISTRICT, ETHIOPIA

MSc. THESIS

BY GEMECHU LUCHA BULCHA

November, 2023

Bale Robe, Ethiopia

EFFECT OF SEED PROPORTION AND PLANTIG PATTERN ON DRY MATTER YIELD, COMPATIBILITY AND CHEMICAL COMPOSITION OF OAT AND VETCH MIXTURE IN SINANA DISTRICT, ETHIOPIA

A Thesis Submitted To The Department Of Animal Science , School Of

Graduate Studies

MADDA WALABU UNIVERSITY

In Partial Fulfillment of The Requirements For The Degree Of Master Of Science In Animal Production

BY

GEMECHU LUCHA BULCHA

November, 2023

Bale-Robe, Ethiopia

Advisors Approval Sheet

This thesis has been submitted for examination with my approval as University advisor

Dr. Girma Defar (Ass. Prof) ____________________ ________________

Major advisor Signature Date

Chairperson Signature Date

_________________________ ____________________ _________________

Internal Examiner Signature Date

_________________________ ____________________ ________________

Internal examiner (Chairperson) signature date

_________________________ ____________________ _________________

External Examiner Signature Date

DEDICATION

This thesis is dedicated to my beloved mother W/ro Gorbe Regasa and my wife Tereku Deresa Lemu who were responsible for laying a great foundation in my life.

STATEMENT OF THE AUTHOR

First, I proclaim that this thesis is my own work and that all sources of materials used for this thesis have been appropriately acknowledged. This thesis has remained submitted in partial fulfillment of the requirement for MSc. degree at the Madda Walabu University and is deposited at the University Library to be made available to debtors under rules of the library. I solemnly declare that this thesis is not given to any other organization anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are permissible without special permission provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies, when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, though, permission must be obtained from the author.

Name: Gemechu Lucha Bulcha

Place: Madda Walabu University, Bale-Robe, Ethiopia
November,2023
Signature: ________

BIOGRAPHY

The author Gemechu Lucha was born in Aira Woreda, West Wollega Zone, Oromia Regional State on Febraury, 1979. He attended his elementary and secondary school education at Chalte Aira Primary School and Lalo Aira Secondary School, respectively. He joined Hawassa University in 2008 and graduated with a BSc. degree in Animal and Range Science on July, 2010 and after graduation, the author was employed by Dawe Serer Woreda Pastoralist Area Development Office in September, 2010 and have been working there until the end of September 2018. He joined School of Graduate Studies at Madda Walabu University to pursue his MSc. in Animal Production in October 2019.

ACKNOWLEDGEMENTS

First and foremost, I would like to praise the Almighty God, for He timely revealed holy hands for guidance, delightful goodness and mercy upon me.

I want to express my sincere thanks to Oromia Public Service and Human Resource Bureau for giving me a chance for pursuing my MSc study and Dawe Serer Environment, Forest and Climate Change Authority and Dawe Serer Pastoral Area Development Office for sponsoring to cover my study expenses.

I sincerely convey my deep thanks to my major advisor Girma Defar (PhD, Asst. prof. in Animal Production) Director of College of Agriculture and Natural Resource, at Madda Walabu University for his limitless guidance and encouragement since the early time of proposal development to thesis work. His support and guidance was not limited to the working days and hour but any time and place. I would like to say him my God sanctify you for this!!!

I am also thankful to Mr. Berhanu Tassew (Assistant Researcher II) who is a team leader in Animal feed and range land improvement at Sinaana Agricultural Research Center (SARC) who helped me from the time of proposal development to the time of finalizing my thesis work. Mr.Berhanu's support and guidance was not limited to this work,' he also found seeds, fertilizer and facilitated all the necessary working materials for the success of my work.

I would like to express my special thanks to my parents and friends who supported me morally for successful accomplishment of this thesis. I am also indebted to say thanks to staff of department of Animal and Range science and college of Agriculture and Natural Resource of Madda Walabu University.

I would like to explain my sincere appreciation to Ato Azmeraw Asires, Jimma University Animal science laboratory technician for his assistance in laboratory analysis of feed samples.

Lastly, I want to express my sincere thanks to Sinana Agricultural Research Center for permitting me to use the trial site, inputs, internet and various work materials to write –up the thesis.

LIST OF ABBREVIATIONS AND ACRONOMY

ADF …………………………………………………..Acid Detergent Fiber

cm……………………………………………… …Centimeter

CP…………………………………………………..Crude protein

CSA………………………………………………..Central Statistical Agency

DM…………………………………………………Dry

matterFAO…………………………………………………..Food and Agriculture Organization

GDP………………………………………………..Gross Domestic Product

Ha…………………………………………………..Hectare

ILRI………………………………………………..International Livestock Research Institute

PH…………………………………………………Plant height

SOMSC……………………………………………South Oromia Meteorological Service

Center

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN THE APPENDIX

Appendix Table Page

LIST OF FIGURES IN THE APPENDIX

Figures **Page**

EFFECT OF SEED PROPORTION AND PLANTING PATTERN ON DRY MATTER YIELD, COMPATIBILITY AND CHEMICAL COMPOSITION OF OAT AND VETCH MIXTURES AT SINANA DISTRICT, ETHIOPIA

ABSTRACT

Oat (Bonsa) and Vetch (Gebisa) mixture pasture experimental trial was conducted to evaluate the effect of seed proportion and planting pattern treatment) on Dry Matter Yield (DMY), compatibility and chemical composition of the mixed stand. Seeds of oat and vetch were mixed as A1B1(50%oat+50%vetch), A2B3(75%oat+25%vetch), A3B3(25% oat+75%vetch), A4B1(100% oat), A5B2 (100% vetch), A4B2 (100 % oat), A5B1 (100 % vetch), A4B3(100% oat) and A5B3(100% vetch) and were sown in the same row (B2), alternate (B3) and broadcasting pattern (B1). Randomized complete block design in factorial arrangement having two factors (five levels of oat-vetch mixture with three planting pattern and two Locations) with three replications were used to layout the experiment. The longest plant height (88 .3 and 115.83 cm) was recorded for A3B3 and A2B3 in vetch followed by oat in mixture in both alternate row pattern whereas the shortest (41.9 and 55.7cm) recorded for A2B2 (75%oat+25%vetch) and A3B2 (25% vetch +75% oat) for vetch and oat seed proportion in both same row planting pattern, respectively. Similarly, the highest FBY (21.7 and 3.95 t/ha) followed by (53.5 and 12.95 t/ha) was recorded in vetch followed by oat for A3B3 and A2B3(25% vetch+75%oat) and (75%oat+25%vetch) in both alternate row planting pattern respectively.The A2B3 and A3B3 (75%oat+25%vetch) and A3B3 (25%oat+75% vetch) seed proportion resulted in significantly higher ($P<0.001$) DMY for oat and vetch ($P<0.001$) in the mixture. For oat and vetch, total herbage yield, an alternate row planting pattern gave significantly the highest ($p<0.0001$) DMY, followed by broadcasting. The maximum RY in oat(1.79)and vetch (0.77) was observed with RYT of 3.2 forA2B3 and A3B3 in plots planted with alternate row pattern. Yet, the minimum (0.1) and (0.17)was observed at A3B2 and A2B2 in oat and vetch in plots treated with same row pattern. Similarly, the maximum CR in oat (9) and vetch (1.2) and total LER (5.94) was observed at A2B3 and A3B3 in plots treated with alternate row pattern .Yet, the minimum CR 2.13, 0.29 and 0.57 was observed in oat, vetch and total LER at A1B3, A2B1 and A3B2 in the treatment. The maximum (22.23%) and minimum (12.1%) CP content was observed for A5B1 and A4B2 in sole vetch and oat in the treatment. Similarly, the maximum DM content was 92.6 observed for A3B1 whereas the minimum 88.2 % was observed A3B2 in plots treated with broadcasting and same row pattern. The maximum Ash (12.72 %) recorded for A2B2 in plot treated with same row pattern whereas the minimum 8.37 % was recorded for A5B1 in plot treated with broadcasting. Similarly, the maximum NDF (59.6%), ADF (33.39%) and ADL (7.65%) was recorded in plots treated with same and broadcasting row pattern. Whereas, the minimum NDF (35.41 %) , ADF (24.03 %) and ADL(3.23 %) was recorded for A5B1, A3B3 and A5B2 in plots treated with broadcasting, alternate and same row planting pattern respectively. Therefore, to get the maximum DM yield A2B3 was appropriate for oat and vetch seed proportion whereas to get maximum CP A5B1 in sole stand vetch was suitable among the treatments.

***Key words:** Dry matter yield, Relative yield, chemical composition,Oat and Vetch Mixture*

1.INTRODUCTION

The livestock production is one of the huge sectors that play a significant role in food security in Ethiopia (Girma *et al.,* 2017). The sub-sector supports about 16.5% of the national Gross Domestic Product (GDP) and 35.6% of the agricultural GDP. It likewise supports 15% of export earnings and 30% of agricultural employment (Samson and Frehiwot, 2014).

Ethiopia has huge livestock population in Africa comprising of 40 million sheep, 65 million cattle, 51 million goats, 49 million chickens and 8 million camels in 2020 (Central Statistics Agency, CSA, 2020a). Also the country has 6.19 and 8.44 million bee hives and donkeys respectively (CSA, 2017/2018). It is eminent that livestock sector products and by-products of the meat, milk, honey, egg, cheese and butter which provide portentous nutrients to human being which contribute to the improvement of the nutritional status of the people, as well as supporting and sustaining the livelihoods of an estimated 80% of the rural population (Negash e*t al.*, 2017; CSA, 2017/18) .

Livestock has many advantages such as draught power , manure for crop production , sources of food , cash income , job opportunity creation , fuel , security and investment in the high land and the low land as well as the national economy at large (Kebede *et al*., 2016 ;Yihun*et al.,*2022). However, the productivity level of the livestock resources was shown to be very low (Asfaw *et al*., 2011; Anteneh and Moges, 2017). This is because of the reasons attributed to the scarcity of feed in quality and quantity (Malede, 2013). Animal feed deficiency is one of the primary limitations that hamper productivity of the sector (ILRI, 2014; Salo *et al*., 2017).Climatic change and seasonal variations highly affecting the availability of quantity and qualities of feed resources that have been a common phenomenon inflecting serious challenges in livestock production and productivity (Alemayehu, 2005).
The use of enhanced feed is restricted to 0.3% in non-urban areas of Ethiopia (CSA , 2015) and used crop residues are poor in quality and known with high fiber content which causes low livestock return /output due to malnutrition and exposed easily to disease with high prevalence ‘s rate (Malede and Takele, 2014). Mainly , the overall feed resources available for livestock

productivity for crude protein content is poor and crop residues which used for feeding is below the critical CP level required for effective rumen microbial function (Solomon *et al.,* 2008).

As well, grazing lands which are the principal feed source used as natural pasture are being declined due to various reasons such as population rise, soil erosion and conversion of grazing lands into cultivation (Wakgari *e t al.,* 2022). As a consequence, crop residues have emerged as the main components of livestock diet to sustain and boost their production via cropping intensification however, their nutritive value and digestibility is too low to support animals' extra productivity (Melkamu *et al*., 2016). In addition, crop residues are usually poor in their nutritive value with low crude protein content (4%) and digestible organic matter(<50%)(Melkamu *et al*., 2016) while use of agro industrial by products is little and limited to some urban and peri-urban area (Alemayehu *et al*., 2017). As to other Ethiopian highlands, the highlands of Bale are known by crop livestock mixed farming systems. Because of steady alteration of grazing lands into crop lands, and lack of access for sufficient range land was the most a significant cause of feed shortage (Belay and Geert, 2016). As a result, scarcity of feed in quantity and quality is becoming the principal challenge to enhance livestock production and productivity (Solomon, 2004). Therefore, production of enhanced and more protein source fodder production to use in feeding and feed quality improvement strategies is mandatory to satisfy feed and nutrient demand of livestock if better production and productivity is needed (Shimelis and Temesgen, 2016).

One of the potential and strategic methods to enhance livestock feed availability in terms of quality and quantity is the use of improved forages crops (Alemu *et al.,* 2007). Among the most economically as well as future improvement of agricultural activities in maintaining soil fertility , easily fulfilling the livestock feed quality was oat-vetch mixture which is a good source of protein and energy to satisfy the nutrient requirement of growing and young productive animals (Shimalis, 2018). Hence, mixing of legumes and grasses help as the most forage supplementary alternative since sole grasses deliver low quality fodder due to their inherent lower crude protein content (Unathi *et al*., 2018).

The biomass yield of grass and legume in mixture stands significantly increase the DM and nutritive value that have been superior to sole legume plots (Assefa and Ledin, 2001; Shanker, 2018). Furthermore, the role of such integrated mechanism of forage production is important to ensure the quality and quantity of fodder for convenience use (Geleti, 2000; Tessema and Baars, 2004). The mixture of legume and grass was also recommended method in agricultural activities to help for control of pests, weeds and diseases (Erla, 2011). Efficiency of oat and vetch combinations are known to be superior to pure stands in yield and quality (Assefa and Ledin, 2001; Erol *et al*., 2009). Oat-vetch mixed fodder is a high source of protein and energy nutrient in comparisons which can satisfy the nutritional requirements of growing animals if supplemented with slight amount of concentrate feeds (Shimelis, 2018). Besides, Oat in combination with vetch could be a potential model of intercropping to attain the healthier forage dry matter yield that could address the condition of justifying DM scarcity (Swotantra, 2020).

Animal feed resources in the highlands of Bale zone is predominantly based on natural pasture grazing and crop residues, which are low in quality and quantity (Bogale *et al*.,2008) and which can be categorized as poor quality and enhanced forage crop restricted area in Ethiopia (Bediye *et al*.,2007; Solomon *et al*.,2008; Yami *et al*.,2013). Tremendous, yield and quality improvement of grass were obtained though optimal proportion of seeds and planting pattern of oat-vetch mixture (Melkamu *et al*., 2016), which provides cheap home grown quality protein source for livestock (Ayub *et al*., 2013). Natural pasture and crop left overs, which make up a large portion of livestock feed, are of poor in quality and must be supplemented with forages of higher quality. It's crucial to cultivate enhanced forages with a high biomass production and sensible quality that can mature quickly (Amanuel *et al*., 2019). This is important area of intervention that can help farmers by improving the quantity and quality of the feeds (Getnet, 1999).As a result, designing of agronomic measures that aid in controlling interspecies interactions and ensuring balanced contributions from the component species to the overall herbage mass and quality (Diriba and Adugna, 2013).

1.1. General Objective

The general objective of the study was to evaluate the effect of seed proportion and planting pattern on plant height, dry matter yield, compatibility and chemical composition of oat and vetch mixture at Sinana District in Bale Zone, South Eastern Ethiopia.

1.2. Specific Objectives of the Study

- To evaluate the effect of seed proportion on plant height, dry matter yield, compatibility and chemical composition of oat and vetch mixture
- To evaluate effect of planting pattern on plant height, dry matter yield, compatibility and chemical composition of oat and vetch mixture.

2. LITERATURE REVIEW

2.1. The Highland Crop Livestock Mixed Farming System

The highland crop- livestock mixed farming system comprises almost 40% of the country's land area and is situated above 1,500 m.a.s.l (Zinash, 2004). It is featured by a varied farming system where crop cultivation and livestock production are undertaken side by side and counterpart each other. According to the same resource, about 25% goats, 75% sheep and 80% of the cattle from the total national livestock holdings are found in this production system. Regardless of the contribution of livestock to the economy and small holders' livelihood, production system is not sufficiently and market -oriented (Tadesse and Solomon, 2014). Livestock is primarily kept on natural pastures of non-arable (fallow land) between crop fields and majority fed crop residues (Tesfaye*et al.,* 2022)

2.2 Available Feed Resources in the Highlands of Ethiopia

In Ethiopia , there are numerous sources for feeding livestock , most of which are only accessible during certain seasons (Mekuanint and Girma , 2017).The type of agricultural operations (method and intensity of crop production) , population stress ,agro - ecology , climatic factors including rainfall distribution , and the time of year all affect the availability of the feed (Amba*et al.,* 2022) . Natural pasture, crop leftovers, improved forage, and agro-industrial by products were the categories used to describe animal feeds, with the first two accounting for the majority of the livestock production in Ethiopia's highlands (Alemayehu, 2003; Getahun and Tegene, 2019).

2.2.1 Natural Pasture

Natural pasture is the main livestock feed resource in Ethiopia (Solomon *et al*., 2008; CSA, 2015) and it is estimated that grazing on natural pastures accounts for 56.23 percent of all resources. The perennial and annual grasses, as well as herbaceous legumes, are present in the natural pastures (FAO , 2001). The accessibility of natural pasture in the highlands of Ethiopia depends on the intensity of crop production, population stress, the quantity of rainfall, and distribution pattern of rainfall and season of the year (Saleem and Abate, 1995). The contribution of those factors to the entire feed resource base varies from place to place to put support on cropping intensity (Seyoum *et al*., 2001). The major feed resources are generally considered by deprived quality and unbalanced nature of the nutrients they supply to animals (Addisu *et al.,* 2016) and the reliability of natural pasture as a source of feed in Ethiopia is restricted to the wet season and However, grazing fields are important for feeding cattle and are home to a variety of grasses, legumes, shrubs and trees.Based on elements like fiber and protein, which are often inversely proportionate to one another, feed values of natural pasture vary significantly in quality. The main livestock feed resources (natural pastures and crop residues) were of low quality and less efficiently utilized (Getahun and Tegene, 2019) and characterized as poor quality roughage with low intake , abrasive texture, nutrient insufficiency, and low digestibility , particularly with regard to crude protein and metabolizable energy in relation to the needs of the livestock.The efficiency of presently existing pasture lands is low due to poor management and overstocking which causes fluctuation in yield and nutrient density in diverse seasons (Funte, 2010).The increased population pressure, emerging urbanization and expansion of crop farming practices lead to further shrinkage of the existing natural pasture land across agro-ecologies (Workye*et al*., 2018). It has been reported that, the share of natural grazing pasture at the national level has been decreased from 90% (Alemayehu, 1985) to around 56.23%(CSA, 2015).The productivity of the accessible grazing lands is currently estimated in a range of 0.5 to 6 tons of DM/ha, the value of yield per hectare classified under the lowest in productivity when compared to the yield from enhanced pasture (Adane and Berhan, 2005, Alemayehu, 2006).

2.2.2. Crop residues

Crop residue is double purpose resources in the diverse crop –livestock systems of the Ethiopian highlands (Ashraf *et al.,* 2017). Crop left overs include teff (Eragrostis teff) stover , wheat , barley , maize , and sorghum are known feed resources in highlands as well as most areas of Ethiopia (Duressa *et al*., 2014 ; Tegegne *et al*., 2013; Duguma *et al*., 2012), and legume residues such as field pea and fava bean (Yayneshet, 2010 ; Abate , 2012) and natural pasture are among the major one among livestock feed resource (Getahun and Tegene, 2018). Furthermore , being animal feed source , crop residues increase soil fertility, prevent soil from easy exposure to erosions by water and wind ; reduce evapotranspiration, increase soil organic carbon content by 1ton /ha/year , through residue retention and other bio solids (Lal , 2006). Moreover, they are crucial in covering feed gaps when there is a severe lack of a variety of feed resources. Currently, the conversion of pasture area to farmland is happening more often.

This resulted in more biomass of crop residues which contribute for about 50% (that grow up to 80%) of ruminant feeds during the dehydrated season of the year and are now the most important feed resource , providing a substantial amount of animal feed in Ethiopia's highlands , especially during the dry season (Adugna,2007). However , quality and digestibility is very low with less than 50% digestibility, high fiber content (more than 70% NDF) and low crude protein content(< 5%CP) (Gizachew and Smit , 2005).

2.2.3 Agro-industrial by products

Agro-industrial by products havebeen used as animal feed to reduce feed cost (Said *et al*., 2018).Also, agro-industrial processing plants are sectors involved in oil processing, flour milling industry products and brewery. They have exceptional value that can be used for feeding livestock primarily in Urban and peri –urban areas for livestock production system. The main agro-industrial by products commonly used are obtained from flour milling industries (rice bran, wheat bran, wheat middling and wheat short), edible oil extracting plants (sunflower cake, linseed cake, sesame cake, peanut cake, noug cake and cotton seedcake, breweries and molasses (sugar factories) (Alemayehu *et al*., 2017). Most oil removal is done almost entirely by mechanical processing methods (CSA , 2015) , among all wheat bran is the most important by-product of wheat flour milling and mostly accessible energy concentrate feed with CP content ranging from 80-140 g/kg DM (McDonald *et al.*, 2010). Furthermore , noug seed cake is very good protein concentrate with 29.7% ADF , 30.8% CP , and 32.4% NDF on DM basis (Abebe *et al*., 2008).The present trends of rising urban population has an important effect on the establishment of agro- industries due to the corresponding rising demand for the edible main products(Yayneshet , 2010).

In addition , various feed resources of Ethiopia comprise of natural cultivated forages , multipurpose trees , and horticultural by-products (Berhanu *et al*., 2009; Adugna *et al*., 2012; Dawit *et al*., 2013; Geleti *et al*., 2014; Alemayehu *et al*., 2017).Furthermore crop residues, crop aftermath and natural pasture were the principal feed resources (Getahun and Tegene , 2019). However, the major feed resources are generally considered poor in quality and unstable nature of the nutrients they supply to livestock (Addisu *et al.,* 2016).

2.1.3. Improved Forage

Enhanced forages legumes can increase the productivity of natural pastures by improving the fertility status of the soil (Tesfaye , 2020). It can also increase the feed value of the native pasture since they have more protein content than naturally occurring grasses (Yeshitila *et al*., 2008). Recently several studies indicated that only 0.15% of rural livestock keeper's cultivate forage crops on their farm area to enhanced forage nutritional quality (Lemma *et al*., 2010).Though numerous efforts have been made by investigation, extension, development projects and programs, yet, the interventions are not fully accepted package's by most farming communities due to their interest to use their farm lands for cash crops and less appreciations for technologies. Reason fully it was evaluated unsuccessful for extension services particularly on the application, management and improvement intensification efficiency by participated farmers for cultivated forages crop types and varieties, absence of economic stimulus for cultivating such forages, and absence of appropriate seeds (EAFIA, 2012). Even if enhanced forage crop production has immense benefits for farming communities if adopted well. The aim of intervention and adoption has vital profits for producers to produce high quality and quantity forage to be used as feed for farm animals. On the other side they accompaniment crop production through conserving soil productivity by fixing nitrogen was highly appreciated. Moreover, enhanced forage crop production could deliver useful nutrients in the non – urban areas where accessibility to agro –industrial by –products is a difficulty (Mengistu, 2002

Production of cultivated forage and pastures relies on accessibility of species and varieties that are modified to the climatic, topographic and animal physiological factors prevailing in the environment in which they are to be utilized. Cultivated forage and pasture crops are essential as cut-and-carry sources of feed and as a supplement to crop residues and natural pastures. The kind of cultivated forage crop produced is varying from place to place relying upon the prevailing climatic and soil factors. Over the past 50 years, a number of forage species and accessions have been studied and some have been suggested for greater distribution in a variety of agro-ecologies and production systems in Ethiopia. Since the national research system has created a variety release system for forage and pasture crops, the number of registered forage varieties is currently increasing (Geleti, 2014). Ethiopia's agro-ecologies are highly diverse, with a wide range of soil types , from arid and semi-arid low lands to moist , chilly mountains , and are mostly depending on natural moisture rain (for duration of the growing season) (MoARD , 2005) . This high diversity in agro-ecology and soil types is an opportunity to grow diversified forage species adapted to temperate, humid, dry, arid and semi-arid agro-ecological conditions. The cultivated forage crops comprise grasses such as elephant grass (Pennisetum purpureum), Rhodes grass (Chlorisgayana) , Guinea grass (Panicum maximum) and oats (Avena sativa L.) in the highlands. Among the herbaceous legumes , the most common ones include Desmodiums(Desmodiumspp.) , vetch (Viciaspp.) , Lucerne (Medicago sativa), lablab (Lablab purpureus), cowpeas (Vignaunguiculata) while fodder tree legumes comprise Leucaenas (Leucaenaspp.),Sesbania (Sesbania spp.) , Calliandracalothyrsus, Gliricidiasepium , pigeon pea (Cajanuscajan) ,Tagasaste (Chamaecytisuspalmensis) are essential in the highlands (Tolera, 2007).The primary agro-ecologies under Ethiopian conditions have established agronomic techniques such as establishment procedures, seeding rates, and harvesting stages for selected and widely farmed annual and perennial forages.

Table 1.List of major forage species and varieties registered by variety register book of MoARD

	Species	Variety	Common name	Adaptation
Grass	Avena sativa	CI-8237	Oats	High to mid altitude
	Avena sativa	Boons	Oats	High to mid altitude
	Avena sativa	Bona bas	Oats	High to mid altitude
	Phalaris aquatic	Sirossa	Phalaris	Low to mid altitude
	Andropogon gayanus	Dirki Ayifera	Andropogon	Low to mid altitude
	Pennisetum purpureum	ILC-16984	Elephant grass	Low to mid altitude
	Chloris gayana	Massaba	Rhodes grass	Low to mid altitude
	Panicum coloratum	Coloratum	Guinea grass	Low to mid altitude
Legume				
	Vicia sativa	Gebisa	Vetch	High to mid altitude
	Vicia vilosa	Lalisa	Vetch	High to mid altitude
	Vicia narbonensis	Abdeta	Vetch	High to mid altitude
	Vicia dasycarpa	Lana	Vetch	High to mid altitude
	Triflium quartinia	-	Clover	High to mid altitude
	Lablab purpureus	-	Lablab	Mid to low altitude
	Vignaunguiculata	Sewinet	Cow pea	Mid to low altitude

Source: MoARD, (2011).

2.1.3.1. Fodder Oats (Avena sativa L.)Agronomic Practices

Oats grow on a wide range of soils at temperatures ranging from 5 to 26°C and rainfall over 500 mm (Eco port, 2013).Further, oats perform better in loam soils but tolerate acidic and low fertile soils with pH ranging from 4.5 to 8.6 (Heuz *et al.,* 2016). It is well adapted to the cooler climates (Welch *et al.,* 2000).It is a quick growing, palatable, succulent and nutritious fodder (Nazakat *et al*., 2004).Oats is an annual grass that is supplemented to animals for cut and carry, as straw and hay or can be ready for use in the form of silage which can be used for livestock feed during feed scarcity (Suttie and Reynolds, 2004).Oats (*Avena sativa L.*) is a well-modified fodder crop grown for a prolonged period of time in the highlands of Ethiopia for livestock feed. It is an upright annual grass up to 1.5m tall and best modified to elevation range of 1700-3000 m a.s.l. with 500–800mm average annual precipitation (Mengistu, 2008).

Oat forage crop harvesting practices are alterable, relying on seasons in a year and ecology of production. Average DMY range from 4 to 15 t/ha , but much higher harvests are achieved (Assefa, 2006).Time of growth and development stages at cutting and ecological circumstances play an important role in determining harvest (Malik *et al.,* 2011).Oats cultivated specifically for the spring season are the best forage because they provide fodder as soon as they are sown , even in chilly climates (Mues , 2013). Production of oats should not be done on basic or saline soil types. The seed proportion per hectare, on the average, is 80 kg with a range of 75-100kg. When seeded in combination, the seed proportion required for 1 ha is 15 kg vetch with 70 kg oat (Fekede *et al*., 2008).

Intercropping of oat with vetch has not only enhanced dry matter production but also raised the quality of the forage produced for CP improvement (Rahetlah *et al.,* 2010). Now currently, utilization of oats has been also shifted to supplement in diets of human being. This was developed due to frequent failure of belg season crops, like barley as Oats relatively with stand moisture strain according to the farmers. On the other hand, high livestock population distributions demands suitable feed. Thus, Oat is used as the most suit and chief sources of feed for livestock production in the form of green feed, hay, straw and grain as supplementary feed (Gazahegn *et al.,* 2016). It is chosen by farmers due to its superior performance under various biotic and abiotic stresses prevailing in the area. Moreover, higher livestock population in the area demands suitable feed and Oats is one of the major sources of animal feed in several forms (Gezahagn *et al.,* 2016).

Table 2.Agronomic Traits and Nutritional Content of Bonsa and Bona-bas tested for Bale Highlands

Variety	Days to 50% heading	Plant height(cm)	DM(t/ha)	Nutritional content (%)				
				DM	CP	OM	ADF	NDF
Bonsa(Acc.No.79AB384)	106	128.4	10.3	90.1	11.5	88.5	32.7	53.9
Bonsa-bas (Acc.No.1660)	124	156.2	10.1	90.6	12.4	89.7	38.3	62.6

Source: Dawit and Teklu, (2011)

2.1.3.1. Vetch (Vicia sativa L.)

Vetch is an annual forage legume broadly modified to the highlands of Ethiopia. It grows up well on the reddish brown clay soils and the black soils of the highland areas. It has been grown effectively in areas of caustic soil with pH of 5.5-6.With the highest level of crude protein (CP), for tropical ruminants which are suffering from poor quality tropical grasses, low protein feeds and digestible crop residues (Kassahun and Wasihun, 2015). Forages which are moderate to high in CP decrease the need for supplemental purchase of protein feeds (Gezahegn *et al*., 2014).Vetch is an active climbing annual legume with an all –encompassing range of adaptation. It grows well in between 1500 and 3000m.a.s .l range agro-ecology and is appropriate to areas of varied rainfall distribution mainly above 400 mm per annum. Vetch grows on a broad types of soil characteristics and texture‘s but needs good drainage for the finest efficiency.

It develops quickly on a regular seed beds and is perfectly suited to under sowing, mixed pasture, and back yard grazing plots. It develops quickly on irregular seed beds and is perfectly suited to under-sowing , mixed pasture and backyard grazing plots. For broadcasting, the sowing ratio is 20 kg/ha, 12 kg/ha for under-sowing, and 5-12 kg/ha as a pioneer component of mixed pasture. When sown at 12-20 kg/ha with oats, vetch makes extra ordinary hay (Mengistu, 2008). Common vetch (*Vicia sativa L.)* is an only one year legume, which is usually grown in combination with small grain cereals for forage production. It has ascending growth habit and high levels of protein. These combinations increase development circumstances and increase forage value (*Anil et al.,* 1998; Heuzé, 2015). Legumes can contribute up to 90% of their nitrogen fixation through a natural mechanism that is significant in the agricultural industry

(Herridge *et al.,* 2008) as well they enhance soil structure and stability (Mohammadi *et al.,* 2012).

Table 2.Agronomic traits and nutritional content of vetch varieties tested for Bale Highlands

Variety	Days to 50% flowering	Plant height(cm)	DM(t/ha)	Nutritional content (%)				
				DM	CP	OM	ADF	NDF
Gebisa(Acc.No.62632)	93	81.5	4.7	88.7	20.8	88.9	32.6	40.8
Lalisa(Acc.No.6792 DLot-2)	113	126	7	89.2	24.1	88.2	35.4	41.8
Abdeta(Acc.No.118)	97	77.2	3.25	89.2	24.8	89	21.6	29.3

Source: Dawit *et al.,* 2011

2.1.4. Grass-Legume Mixtures

Grass-legume combination could importantly rise the DM and nutritive value , indicating a better choice to utilize per unit area of land for a maximum DM harvest without endangering the quality issue and with the potential to diminish unwanted plant infestation .Oat in combination with vetch could be a potential of intercropping to achieve an improved forage DM yield that could address the condition of mitigating DM deficiency, particularly during winter season (Barsila , 2018).

Legumes supply nitrogen to grass-legume combinations, so combinations may produce more forage yield than grasses grown alone in grass-legume combinations higher yields have always been attained in comparison with sole grass plots Sturludottir *et al. (*2013). Forage quality and seasonal distribution of forage from grass and legume mixtures are higher than that of pure stands (Daniel, 1990).

Poor quality cellulose, which form the basal feeds in tropics, are low in nitrogen , energy, vitamins and minerals. Economic restrictions in tropical countries have not motivated farmers to use industry-based concentrates and chemicals as supplements to increase application of roughage. Leguminous forage crops can increase the utilization of low quality roughage and they are being used more widely all over the world. In several production schemes legumes are proficient of improving both crop production through sustained soil productiveness and livestock production through improved accessibility of high quality feed (Assefa and Lendin, 2001).

Benefits of mixed cropping comprise higher feed quality owing to the higher crude protein (CP) concentration of legumes (Umuna *et al.,* 1995) , improved biomass yield (Lithourgidis *et al.,* 2006) , minimized use of non-renewable resources through minimized N fertilizer use , a consistent production pattern, enhanced soil productiveness (Banik and Bagchi , 1993; Lopez-bellido Garrido and Lopez-bellido, 2001) and improved livestock production (*Umuna et al*., 1995).The persistence and contribution to the total forage yield of the legume component in mixed stand depends, among other factors, on the relative seed proportion of the component species. Onifade *et al*. (1994) for example reported a progressive seed proportion increase in the contribution of the legume component as the seed proportion of the legume increases. Use of Oats and Vetches in mixtures not only increases forage yield , but also provides physical support to vetches and other benefits of these mixtures comprise greater use of light, better uptake of water and nutrients, improved weed suppression, and better soil conservation (Anil *et al* ., 1998).

In some study which evaluated oats-vetch mixture with indigenous pasture hay using lactating crossbred cows, oats-vetch combination was described to contribute higher milk yield (5.7 kg cow-1 day-1) than native hay (5.0 kg cow-1 day-1) , and this difference was attributed to improve protein and energy intakes on the oats-vetch diet (EARO, 2000). These suggest the need for mixing of oat- vetch mixtures in to feeding systems for various farming systems and agro-ecologies of the highlands. The variation in growth patterns of legumes is reported to have a capacity of leading to efficient use of resources such as light when grown in a combination than when grown separately. All these various functional traits could support to positive interactions between the species resulting in higher yields for mixtures in comparison to monocultures. The achievement of better DM yield in the grass-legume combination plots may also be credited to useful effects of combining grasses and legumes and also from the differences in the seasonal growth pattern between the grass and legume species (Leuscher *et al*.,2005) or across years (Nyfeler *et al*.,2009). Attaining balanced oat and vetch blended stands needs attention of the interactions existing between the species, which can in turn be manipulated by the relative seed proportions and the pattern in which they are planted, among others (Sanderson *et al.,* 1999; Hadji, 2000).

2.2. Major Factors that Influence Forage Quality

Forage quality is influenced by forage nutritive value such as intake and chemical composition, digestibility. Producers can predict and prepare for changes in forage quality by taking in to account the elements that affect it (Eskandari *et al*., 2010).

2.2.1. Maturity (harvest stage)

Maturity is the most significant factor affecting forage quality. Plants continually vary in forage quality as they mature. As plants cell wall content rises indigestible lignin accumulates which resulted in reduction of yield quality. Maturity strongly influences the digestibility of the forage (Buxton, 1996). Maturity influences forage quality more than any other single factor , but plant environment and agronomic factors modify the impact of maturity on forage quality and cause seasonal , geographical location and year to year effects on forage quality even when harvested at the stage of development (Gezahagn *et al.,*2016).

2.2.2. Species and Varieties

Yielding of grass-legume combinations largely rely on the good selection of species and varieties. Species variances in fodder quality between legumes and grasses can be very enormous. The protein content of legumes is characteristically much superior than of that grasses and legumes fiber tends to digest earlier than grass fiber, permitting the ruminant to eat more of the legumes (Eskandari *et al*., 2010).These characteristics are similarly different under several management practices and environmental condition for grain , forage or both (Getnet , 1999).

2.2.3. Soil Fertility

Soil fertility influences forage yield higher than quality though; it is likely to produce better quality forage on productive soils but difficult to produce high yields of high quality forage on unproductive soil type (Gezahagn *et al*., 2016).

2.2.4. Harvest and Storage

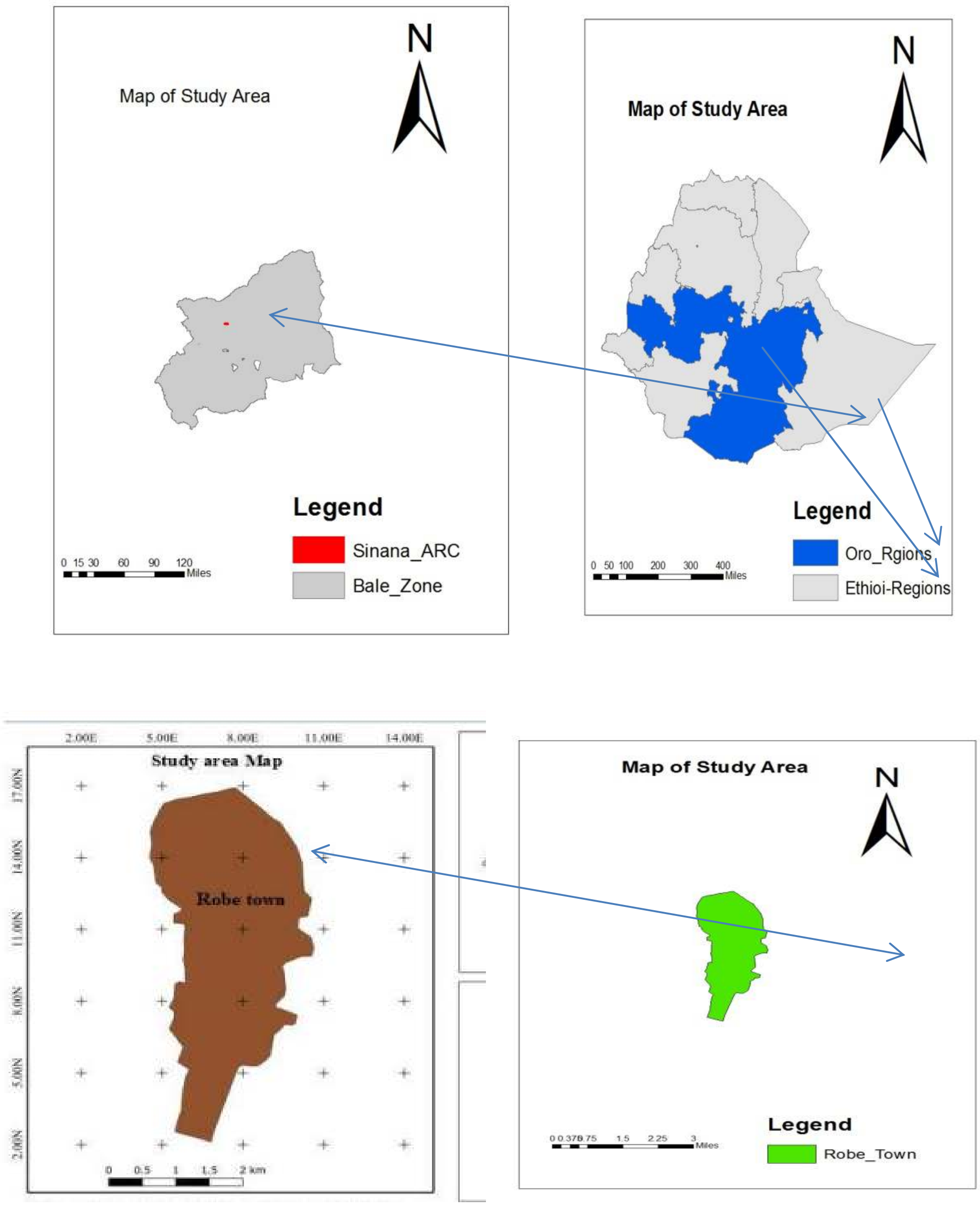
The variation in morphological characteristics such as flower fractions, pod , stem and leaf of forages contain variation in feed quality **(**Gezahagn *et al*., 2014).The variation in morphological characteristics is important in the selection of forage crops , which are agronomical advantageous and used for various purposes such as hay, silage and grazing (Getnet and Ledin , 2001).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted in Madda Walabu University (MWU) and Sinana Agricultural Research Center research site during main cropping season since 2019. The study site of MWU is located at 6^0 5'55" N latitude and $39^0$56’57 ″E longitude in altitude range of 2400 m.a.s.l. The site obtained a mean annual rain fall of 815mm and a minimum and maximum mean annual temperature was 9.5 ^oC and 21.4 ^oC respectively (SOMSC, 2021). Agro-ecologically, it was one of the highlands of Bale Zone with high rainfall of bimodal types.

The SARC site is located at $06^0$50′N latitude and 39^0 17′E longitude with in altitude range of 1700 to 3100 a.s.l. The site receives total annual rainfall of 1015.2mm and the minimum and maximum temperatures are 9.9^0C and 21.4^0C, respectively (SOMSC, 2021). The main cropping season was locally known as (Meher) and extends from 15^{th} of July to December and the other cropping season, locally called (Belg), extended from March to July (Fitsum et *al*., 2017).



Data source: Datum: WGS 1984

Figure 1.Map of Study Area

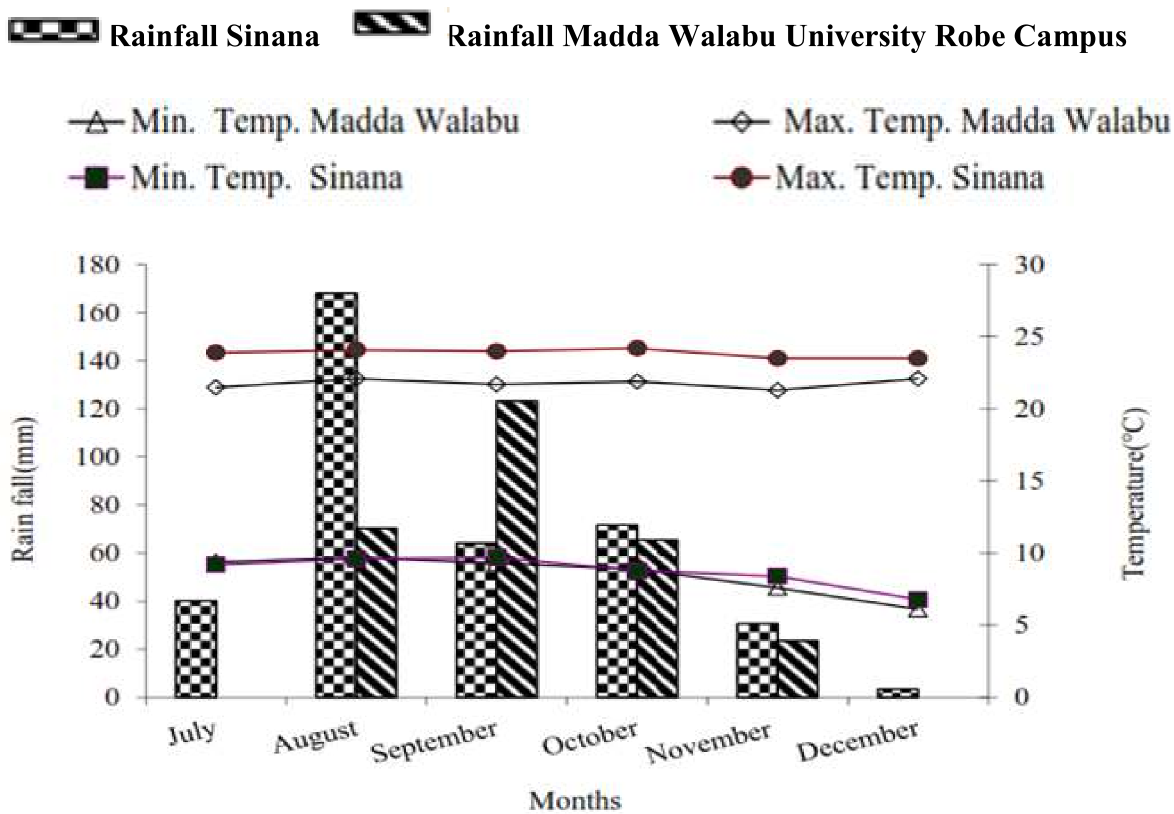


Figure 2. Rainfall Minimum, Maximum and Temperature recorded during 2019 main cropping seasons at SARC and MWU (Bale-Robe Meteorological Station, 2021)

3.2. Land Preparation and Planting

The experiment was done during of main cropping season in a year of 2019. Field experiment, considers the effect of seed proportion and planting pattern on dry matter yield, compatibility and chemical composition of oat and vetch mixtures on both sites.

A fine seed bed was prepared using tractor drawn implements and leveled manually before the experimental plots were laid out. Then the plots were in the same way fertilized with NPS at a rate of 100 kg/ha. For the same row and alternate row planting patterns , 30 cm between row spaces were maintained while the seeds for broadcasting were uniformly distributed over the plots to avoid, irregular spacing of the seeds. Weeds were removed by hand as required to protect their negative effect on forage growth and yields.

3.3. Experimental Treatments and Design

The study was conducted using 5*3 factorial arrangements in randomized complete block design (RCBD). Among oat and vetch varieties; Oat (*Bons*a) and Vetch (*Gebisa*) were used for the experiment. The oat and vetch varieties used for the experiment were released by SARC in 2010. The species were mixed at three varying relative seed rate proportions (25% Oat +75% Vetch, 50% Oat+50% Vetch, 75% Oat+25% Vetch) and the sole of the two varieties were sown in three planting patterns (within the same row, alternate row and broadcasting) in early August of 2019.The experiment comprised of three replications with 15 treatment combinations which had seed proportion and planting pattern as one factor. The spaces between plots and replications were 1m respectively. Each experimental unit had 1.8m*3m with a total area of 5.4 $m^{2.}$ The total area of the experimental sites was 451m^2 each (41 m*11m). Each individual plots sown in row planting were comprised of six rows per plot (4 harvestable rows and 2 border rows). The base seed rate used for the trial was 80kg/ha for Oat (Dawit and Teklu, 2014) and 35 kg/ha for vetch (Gezahegn *et al.,* 2017). The treatment combinations are indicated in Table 4 below.

Table 3.Description of Treatment Combinations

Treatment(Trt)	Treatment combinations	Amount of seed sown (g)
A1B1	50%oat+50%vetch with broadcast	21.6(oat)+9.45(vetch
A1B2	50%oat+50%vetch with same row	21.6(oat)+9.45(vetch
A1B3	50%oat+50%vetch with alternate row	21.6(oat)+9.45(vetch
A2B1	75%oat+25%vetch with broadcast	32.4(oat)+4.7(vetch)
A2B2	75%oat+25%vetch with same row	32.4(oat)+4.7(vetch)
A2B3	75%oat+25%vetch with alternate row	32.4(oat)+4.7(vetch)
A3B1	25%oat+75%vetch with broadcast	10.8(oat)+14.2(vetch)
A3B2	25%oat+75%vetch with same row	10.8(oat)+14.2(vetch)
A3B3	25%oat+75%vetch with alternate row	10.8(oat)+14.2(vetch)
A4B1	100% oat with broadcast	42.3 (oat)
A4B2	100% oat with same row	42.3 (oat)
A5B1	100% vetch with broadcast	18(vetch)
A5B2	100 % vetch with same row	18 (vetch)
A4B3	100 % oat in alternate row	42.3 oat
A5B3	100 % vetch in alternate row	18 vetch

T1=A1B1=50%oat+50%vetch,T2=A1B2=50%oat+50%vetch,T3=A1B3=50%oat+50%vetch,T4 =A2B1=75%oat+25%vetch,T5=A2B2=75%oat+25%vetch,T6=A2B3=75%oat+25%vetch, T7=A3B1=25%oat+75%vetch, T8=A3B2=25%oat+75%vetch, T9=A3B3=25%oat + 75%vetch, T10=A4B1=100% oat in broadcasting, T11=A4B2=100% in same row, T12=A5B1=100% vetch in broadcasting, T13=A5B2=100% in same row, T14=A4B3=100% oat in alternate row ,T15=A5B3= 100 % in alternate row, g=gram, Trt=Treatment

3.4. Data Collection and Measurement

3.4.1. Plant Height

At herbage harvest, the height of five randomly selected plants per plot was measured from the ground level to the tip of the main stem to calculate the plant height for each species (Tarawali *et al*., 1995; Aklilu and Alemayehu, 2007; Gebremedhn *et al., 2*015; Kassahun and Wasihun, 2015). For broadcasting plants, quadrant of 1.2m*3m was used.

3.4.2. Dry Matter Yield

To estimate fresh biomass yield, four adjacent rows from the middle of each plot were harvested when the oat was in the dough stage and the vetch was in the flowering stage (Akililu and Alemayehu, 2007). For the plots planted by broadcasting, a quadrant of 1.2m*3m was used. The herbage was cut manually using sickle and fresh weight for each samples was recorded in the field using a field balance immediately after mowing. Chopped sub-samples (500gm) of each treatment were dried in the oven at 60-65 ^{0}C for 72 hours to determine the DMY on hectare basis. Samples from each treatment used for quality assessment were oven dried at 60 ^{o}C for 72 hours and maintained for laboratory analysis packed in a paper bag. The percentage contribution of the component species to the total DM yield were determined by dividing the DM yield of each of the components by the total DM yield of each treatment. Crude protein yield (CPY) and neutral detergent fiber yield (NDFY) of the treatments were determined as the product of CP and NDF content and herbage DMY (Starks *et al.*, 2006).

DM=Yield (t/ha) = (10*TFW*SSDW))/ (HA*SSFW) James (2008)

Where: 10 = Constants for conversion of yields in Kg/m^2 to tone /ha;

TFW = Total fresh weight from harvesting areas (Kg);

SSDW = sub-sample dry weight (g);

HA=Harvest area (m^2);

SSFW= sub-sample fresh weight (g)

Similarly, a chopped and oven dried forage sample material for each plot was prepared and saved for chemical analysis.

3.4.3. Land Equivalent Ratio (LER)

Land equivalent ratio is defined as the land required for sole grass/legume to obtain the same yield from mixtures under the same management levels (Arshad and Ranamuk, 2012).The LER is explained as the amount of land required under monoculture to get the same DMY as produced in the intercropping. It was calculated according to the equation proposed by (Willey and Rao, 1980):

LERab = (Yab/ Yaa) + (Yba/ Ybb)

Where, Yaa = Pure grass yield of species 'a'; Ybb = pure legume yield of species 'b'; Yab = mixed stand yield of species 'a' in mixture with species 'b' and Yba = Mixed stand yield of species ‘b’ in in mixture with species ‘a’.If LER of ab > 1, there is yield benefit.

The data for sole oat and vetch were collected to calculate and compare the sole yield advantages of both oat and vetch species separately.

3.4.4. Relative Yield

The relative DM yields (RY) of the constituent species in the combinations were calculated following the equations of De Wit (1960).

RYG = DMYGL/DMYGG

RYL = DMYLG/DMYLL

Where: DMYGG is the DMY of any grasses grown within one year ‘G’ as a sole stand; DMYLL is the dry matter yield of any legume grown within one year ‘L’ as a sole stand; DMYGL is the DMY of any grass “G” grown within one year in combination with any one year legume ‘L’; and DMYLG is the DMY of any one year grown legume component ‘L’ in mixture with any one year grown grass ‘G’.

Relative total yield (RTY) was similarly calculated following the formula of De Wit (1960):

RTYGL = (DMYGL/DMYGG) + (DMYLG/DMYLL)

3.4.5. Competitive Ratio (CR)

The CR represents the ratio of individual land equivalent ratio (LER) of the two component grass – legume species in which they are initially sown. Competitive Ratio was calculated according to the equation of Willey and Rao (1980) as:-

CRab = (DMYab/DMYaa) ÷ (DMYba/DMYbb)

CRba = (DMYba/DMYbb) ÷ (DMYab/DMYaa)

Where, ab is the performance of Oat‘a’ mixed with Vetch‘b’; ba is the performance of vetch ‘b’ mixed with oat ‘a’; aa is the performance of oat‘a’ as a monoculture; and bb is the performance of Vetch‘b’ as a monoculture. The yield of one grass species was calculated separately for both oats-vetch interactions in the intercrop.

3.4.6. Chemical Composition

Chemical composition of feed was evaluated by means of the procedures described by AOAC (2000).The fresh subsamples of 500g were dried in the air drying oven at 65^{o}c for 72 hours and then ground to pass a 1mm sieve screens for quality evaluation. The DM and ash were determined by oven drying at 105^{o}c overnight and igniting the samples at 550 ^{o}c in a muffle furnace for 6 hours correspondingly (AOAC, 1990).

Dry matter and ash contents of representative samples were determined by oven drying at 105^{0}C overnight and by combusting in a muffle furnace at 550^{0}C for 3 hours respectively. Total nitrogen (N) content was determined using Kjeldahl method and crude protein (CP) was calculated as N×6.25(AOAC, 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by using the Vansoest *et al.,* (1991) procedures.

3.4.7. Statistical Analysis

The DMY, compatibility, LER, RY, RYT and chemical composition data were analyzed using the General Linear Model Procedure of SAS (SAS, 2009) version 9.3. When significant, Duncan's Multiple Range Test (DMRT) was employed to locate differences and then grand between the treatment means.

The following model was fitted in expressing the data:

Yijk = μ + Ti + Lj + Bk (j) + (TL) ij+eijk.

Where, Yijk = measured reply of treatment i in replication k of location j, μ= grand mean, Ti = effect of treatment i, Lj = effect of location j, TL= treatment and location interaction, Bk (j) = effect of replication k in location j and e ijk = random error effect of treatment i in replication k of location (L), significant differences between means was separated at $P \leq 0.05$ using Tukey honestly significant difference test.

4. RESULT AND DISCUSSION

4.1. Chemical and Physical Characteristics of Study Area Soil

The soil physical and chemical characteristics of the research sites are indicated in Table 5. The result showed that, the soil physical properties of the experimental areas were dominated by clay soil texture with proportion of sand, silt and clay for MWU followed by SARC respectively (Table5). Correspondingly, the soil chemical properties comprised of 6.28%, 1.75%, 3.02%, 0.15%, 14.34%, 26.11%, 6.12%, 2.35%, 0.17%, 12.96% and 49.46% at MWU. The texture properties of the soil influence the aeration, water intake rates, soil fertility and water holding capacity. The PH value of the soil in the present experimental sites were slightly acidic, having available phosphorous, high cation Exchange Capacity (CEC), medium Organic matter, nitrogen contents. This showed that the soil type was good for fodder (Table 5). The probable reasons for the suitable soil type (physiognomies of high quality soils) might be due to adequate depth ,virtuous drainage, resistant to soil productiveness decline, adverse changes in PH or salinity ,erosion, decline of the soils structural circumstances (Gugino*et al.,*2009).Table 5 indicates soil physical and chemical characteristics of the study areas.

Table 4.Soil physical and chemical characteristics

	Soil Physical Properties				Soil Chemical properties					
Site	Sand	Silt	Clay	Textural Class	Soil PH	OC (%)	OM (%)	TN%	Av.(PP) M	CEC(mo l(+) kg-1 soil
MWU	22	26	52	Clay	6.28	1.75	3.02	0.15	14.34	26.11
SARC	20	26	54	Clay	6.12	2.35	2.35	0.17	12.96	49.46

Where TN= Total Nitrogen, Av.P=Available phosphorous, OC=Organic Carbon, OM=Organic Matter, CEC=Cation Exchange Capacity, PPm= Part Permillion, Kg=Kilogram, MWU = MaddaWalabu University, SARC = Sinana Agricultural Research Center, PH =Power of concentration of hydrogen ion in solution.

4.2. Plant Height

The combined analysis of variance of the plant height in vetch and oat showed that highly significant ($P<0.0001$) difference between seed proportion and planting pattern (Trt) and location (L) had been observed in the current study (Table 6).Similarly, the two way interaction of Trt and L (TrtxL) showed that significant difference ($P<0.01$) on plant height of vetch whereas, non-significant ($P>0.05$) difference for the two way interaction of Trt and L (TrtxL) on plant height in oat (Table 6 and Appendix Table 2).

In view of this, the longest plant height (88.3 and 115.83 cm) was recorded for A3B3 (25%oat+75%vetch) followed by A2B3 (75%oat+25%vetch) for vetch and oat in the Trt with the highest vetch and oat seed proportion in the mixture in alternate row planting pattern. Whereas, the shortest plant height (41.9 and 55.7 cm) was recorded for A2B2 (75%oat+25% vetch) followed by A3B2 (25%oat+75%vetch) in the treatment with the highest oat for A2B2 and lowest oat seed proportion for A3B2 in plots treated with both same row planting pattern for both Trt (Table 6). The probable reasons for the longest and shortest plant height in mixed stand in oat and vetch in the treatment might be due to genetic make of the component species (oat and vetch) , soil type and adaptability of the oat and vetch to different environmental conditions (Messina *et al*.,2009).This is quite in line with the finding of Muhammad *et al*. (2010) who reported the longest plant height (79.75cm) in oat followed by wheat (68.03cm),barley (66.94 cm) and shortest by vetch (46.30cm) in Pakistan. Yet, the result of the current study was not in accordance with the finding of Canan and Orak (2002) who reported that the longest plant height from Vicia sativa under pure stand in Bulgaria.

The probable reasons for the shortest plant height observed in the same row for A2B2 and A3B2 might be due to unfavorable growing conditions created with same row and resulted in shorter plant height and lower yield (Gezahagn *et al*., 2017). The average height of the plant is linked to the yield of green forage and its nutritional quality, obviously perceiving that the proportion can enhance the height in oat and vetch. Accordingly, the oat assists the vetch and this develops better height (Contreras *et al*., 2019). When location is considered, the longest plant height in vetch was observed at SARC (80.1cm) when compared to MWU (75.1cm) and the longest plant height in oat was observed at SARC (123.4cm) when compared to MWU (115.85 cm) (Table 6).

The significance difference (P<0.05) observed in plant height of oat and vetch between the two locations indicates that the two locations had more or less variation in distribution and amount of rain fall during the experimental year. The interaction effect of treatment over location was cross-over which indicates change in ranking order of plant height performance between the two locations and this might be because of discrepancy in amount and distribution of rain fall between the two locations.

Overall, the earlier 50% flowering stages at 93 days in vetch than 50% oat heading stage at 106 days observed (visual observation) and this observation agrees with results reported by the previous study of Abdeta (*narbon vetch variety with Acc.No.118*), Gebisa (*Common vetch variety with Acc.No.62632*) and Lalisa (w*oolly pod vetch variety with Acc.No.6792 Dlot-2*) for Bale highlands (Dawit *et al*., 2011).

Table 5.Plant height of sole and mixed stand of oat and vetch as affected by seed proportion and planting pattern (Trt), Location and two way interaction (TrtxL)

Treatments(TrtxL)	PHV(cm)	PHO (cm)
A1B1	73.39 ^{d}	95.2 ^{de}
A1B2	60.27 ^{h}	84.2 ^{e}
A1B3	75.17 ^{c}	99.2 ^{cd}
A2B1	66.47 ^{g}	105.5 ^{b}
A2B2	41.9 ^{k}	65.83 ^{i}
A2B3	80.51 ^{b}	115.83 ^{a}
A3B1	83.25 ^{ab}	92.29 ^{f}
A3B2	71.77 ^{e}	55.7 ^{j}
A3B3	88. 3 ^{a}	99.83 ^{c}
A4B1	-	90.2 ^{fg}
A4B2	-	89.21 ^{g}
A5B1	68.07 ^{f}	-
A5B2	44.9 ^{i}	-
A4B3	-	86.31 ^{h}
A5B3	45.78 ^{j}	-
P-Value	0.0001	0.0001
Interaction(TrtxL)	***	NS
Mean	85	125
SEM	12.74	9.5
CV	16.89	11.63
Location		
SARC	80.1 ^{a}	123 .4 ^{a}
MWU	75.1 ^{b}	115.85 ^{b}
P-Value	0.0001	0.0001

abcdefghijk=Mean values within column and row followed the similar letters are not significantly different at 5% probability level, SEM=Standard error of mean, SL=Significant Level, Trt=Treatment, NS= Non –significant; CV=Coefficient of variation ;= broadcasting , in same row , the symbol “-“ represents absence of oat and vetch (it shows only pure stand vetch and oat in the mixture),***=Highly significant and significant level at 5% , T1=A1B1=50%oat+50%vetch with broadcasting ,T2=A1B2=50%oat+50%vetch with same row, T3=A1B3= 50%oat+50%vetch with alternate row,T4=A2B1=75%oat+25%vetch with broadcasting, T5=A2B2=75%oat+25%vetch with same row, T6=75%oat+25%vetch with alternate row, T7=A3B1=25%oat+75%vetch with broadcasting, T8=A3B2=25%oat+75%vetch with same row, T9=A3B3=25%oat+75%vetch with alternate row ,T10=A4B1= 100% oat with broadcasting, T11=A4B2=100 %oat with same row, T12=A5B1=100% vetch with broadcasting

,T13=A5B2=100% vetch with same row, T14=A4B3=100% oat with alternate row and T15= A5B3=100 %vetch with alternate row.

4.2 Dry Matter Yield

The combined analysis of variance of the main effect of treatment (Trt) and location (L) showed that highly ($P<0.0001$) significant difference on the above ground dry biomass yield in oat and vetch (Appendix Table 2). Similarly, interaction effect of location with treatment showed significant ($P<0.01$) difference on above ground dry biomass yield in oat and highly significant ($P<0.0001$) difference in vetch in the treatment for the two component species (Appendix Table 2).

Treatment type and location has prominent effect on biomass yield of oat and vetch mixture. The maximum fresh biomass yield (53.5 t/ha) and dry matter yield (12.95 t/ha) was observed in the treatment with the highest oat seed proportion for A2B3 followed by GFY (21.7 t/ha) and DM (3.95 t/ha) in the treatment with the highest vetch seed proportion for A3B3 in plots treated with alternate row planting pattern while the lowest GFY (3.91 t/ha) and DM (1.01 t/ha) was found for A3B2 in the treatment with pure stand vetch in plots treated by same row planting pattern followed by minimum GFY (11.33 t/ha) and DM (2.29 t/ha) for A3B2 in plots treated by same row planting pattern respectively (Table 7).

In general, A2B3 (75%oat+25% vetch) in plot treated with alternate row planting pattern performed better in GFY (53.5 t/ha) and DM (12.95 t/ha) than A2B1(75%oat+25% vetch) in plot treated with broadcasting which had GFY (8.92 t/ha) and DM (2.2 t/ha) in the treatment with the highest oat seed proportion when compared to GFY (28.75 t/ha) and DM (7.91 t/ha) and 17.35 and 2.58 t/ha with equal seed proportion (50%oat+50%vetch) for both oat and vetch mixed stand in the treatment for A1B1.

The probable reasons for the highest GFY and DMY for A2B3 and A2B1 (75%oat+25%vetch) in the treatment with the highest oat seed proportion in plot treated with alternate row followed by broadcasting pattern might be due to vital nature of grass growth and its capacity to quickly to utilize nitrogen in the soil which is released following cultivation, contribution of soil nitrogen by the vetch component via nitrogen fixation, DM showed increasing trend with increasing seed proportion(Teshome *et al*.,2004) who reported the highest DMY from mixture of oat-CI8237 with V.atropurpurea and v.villosa at seed rate of 60:22.5 and 40:15kg/ha in the highlands of Bale in Ethiopia . Also, the probable reasons for the maximum FBY and DMY at high seed rate for oat for A2B3 might be due to advancement of growth stage which was higher at dough(heading stage) (Muhammad *et al*., 2010).The probable reasons for the highest DMY observed in oat-vetch mixtures than sole vetch or sole oat might be due to enhanced interception of light and utilization of symbiotically fixed nitrogen (Albayrak and Ekiz , 2005).Yet , probable reasons for the lowest DMY observed with-in same row planting pattern might be due to the competition for water and plant nutrients in the soil decreased the yield of component species densely populated with-in same row when compared to alternate rows and broadcasting (Hakan *et al*., 2008).

Generally in this trial, forage DM yield of oat-vetch mixed treatments were higher when compared to their counterpart treatments. The current result is in accordance with that of Getnet and Ledin, (2001) and Alemu *et al*., (2007) who reported that yields for oat-vetch mixtures were superior when compared to either of the pure stands at Holetta, Ethiopia. This finding also supported by Malede, (2013) who reported that dry matter production in oat-vetch mixture had been superior to pure cropping at North Gondar zone in Ethiopia.

Regarding locations, DMY of oat and vetch mixture sown by different seed proportions and planting pattern over locations showed highly ($P<0.0001$) significant difference (Table 7). The result indicated that effect of treatments over locations showed significantly higher ($P<0.0001$) DMY for oat (7.92 t/ha) and vetch (5.89 t/ha) mixture for SARC when compared to DMY in oat(6.52t/ha) and vetch(3.54t/ha) for MWU (Table 7) .The interaction was cusp (crossover effects) which indicates variation in ranking order for dry matter yield performance between the locations when oat and vetch mixtures are subjected to different treatments which implies that there is a need of site specific recommendation for seed proportions and planting pattern of oat and vetch mixture for both testing sites (Gezahegn *et al*.,2017).

This result agrees with the finding of Hintsa (2016) who reported the highest DMY (8.71 tha^{-1}) and (6.48 tha^{-1}) from Embahasti and Tsibet at Endamehoni District, Southern Tigray. Moreover, the lower DMY obtained for MWU might be due to waterlogged which inhibits root growth, nutrient absorption and soil aeration that made plants stunted and decreased growth rate (Striker, 2012). Relatively climatic circumstances such as soil fertility, better distribution and amount of rain fall might be some of the major causes for getting an improved dry matter yield for SARC when compared to MWU because these factors lead to differences both quality and quantity of fodder plants (Messina *et al*., 2009) .

Table 6.Dry matter yield of sole and mixed stand of oat and vetch as affected by seed proportion and planting pattern (Trt), Location (L) and two way interaction (TrtxL)

	Vetch		Oat	
Treatment(Trt)	FBY	DMY	FBY	DMY
A1B1	17.35 b	2.58 bc	28.75 b	7.91c
A1B2	7.3 f	2.15 e	15.41 f	5.1 e
A1B3	14.95 c	3.5 b	19.87 d	6.19 bc
A2B1	8.92 e	2.2 f	16.31e	8.19 b
A2B2	3.53 g	1.64 h	14.57 f	2.69 g
A2B3	10.5 cd	3.01 c	53.5 a	12.95 a
A3B1	11.29 d	3.78 ab	12.69 g	5.44 e
A3B2	3.91 h	1.01 i	11.33 gh	2.29 f
A3B3	21.7 a	3.95 a	23.41 c	4.61d
A4B1	-	-	13.21ef	3.73 ef
A4B2	-	-	9.69 i	3.3 g
A5B1	4.94 g	1.8 g	-	-
A5B2	3.48 i	1.19 gh	-	-
A4B3	-	-	10.89 h	3.51 ef
A5B3	8.52 e	1.71 fg	-	-
P-Value	0.001	0.0001	0.01	0.0001
Interaction(Trt*L)	**	***	**	**
Mean	7.51	4.1	12.54	6.31
SEM	1.01	1.2	1,31	1.5
CV	28.13	27.9	22.1	20.63
Location				
SARC	15.19 a	5.89 a	18.32 a	7.92 a
MWU	12.13 b	3.54 b	14.71 b	6.52 b
P-Value	0.01	0.0001	0.001	0.0001

abcdefghi=Mean values within column and row followed the similar letters are not significantly different at 5% probability level, SEM=Standard error of mean , The symbol "- " on the left side of oat for A4B1 ,A4B2 ,A4B3 and right side of vetch for A5B1 ,A5B2and A5B3 represents absence of oat and vetch (it shows only pure stand vetch and oat in the mixture) ,*** =Highly significant and significant level at 5% ,NS= Non –significant ,Trt= Treatment , SL =Significant Level

4.3. Relative yield of sole and mixed stand of oat and vetch as influenced by seed proportion and planting pattern, location and two way interaction

The combined analysis of variance showed that the main effect of treatment (Trt) and location (L) showed highly significant ($P<0.0001$) difference on relative yield of oat and vetch component species .Similarly, the two way interaction effect of treatment (Trt) and location (L) (Trt*L) for oat and vetch showed that highly significant difference ($P<0.0001$) on relative yield of oat and vetch mixtures (Table 8 and Appendix Table 2).The maximum relative yield for oat (1.79) and vetch(0.77) was observed for A2B3 and A3B3 in plots treated with both alternate row planting pattern whereas ,the minimum (0.1) and (0.17) was observed for oat and vetch for A3B2 and A2B2 in oat and vetch in plots treated with both same row planting pattern (Table 8).The vetch had superior relative yield values for A3B3 (0.77) in alternate row than in A3B1 (0.66) in broadcasting row planting pattern. This is in line with the finding of Lithourgidis *et al* (2006) who reported that for common vetch grown in blend at 65% vetch +35% oats, the legume component achieved superior relative yield than the grass. The total relative yield values for A1B1(2.6) and A2B3 (3.20) indicates that there was 60% and 20% more biomass yield in blend stand of the oat and vetch than either of its pure stand. Similarly , the total relative yield values observed in A2B1(1.96) and A1B3(1.86) indicates that there was 96% and 86% more biomass yield in blended stand of the oat and vetch than either of their pure stands (Table 8).

An analogous trend was also noticed for planting pattern treatments where the oat was superior across the patterns evaluated too .The relative yield values of oat and vetch followed an analogous patterns with that of dry matter yield (Table 7) in that the alternate row planting pattern significantly ($P<0.0001$) showed superior relative yield followed by that of broadcasting, and with the minimum value for same row planting pattern which indicates that direct proportional relationship existing between dry matter yield and relative yield in the mixture.
The oat in alternate row planting pattern for A2B3 also resulted superior relative yield values (1.79) than A3B3(0.77) which was being more than fourfold higher than that of vetch component in both treatments (Table 8).The probable reasons for the superior relative yield

values obtained in alternate row planting pattern might be due to sowing of oat and intercrop vetch in alternate row facilitated well circulation of air and light penetration, providing appropriate conditions for fodder growth and development than broadcasting and same row pattern. This is in line with the finding of Asif *et al.,* (2006) who reported sowing of maize and intercrop legume in alternate row for better DMY than line sowing and broadcasting in Pakistan.

Regarding the locations, the relative yield of oat and vetch across locations showed highly ($P<0.0001$) significant difference (Table 8). The highest total relative yield value in oat was observed for SARC (0.62) when compared to MWU (0.33) which differed significantly across the locations. Similarly, when the relative yield values of vetch was considered over locations, the highest total relative yield was obtained for SARC (0.33) when compared to MWU (0.29) for vetch (Table 8).

An analogous trend was likewise noticed for relative yield values of vetch treatments for the two locations where relative yield values of vetch was higher for SARC compared to MWU where, the relative yield value of vetch for SARC was (0.33), while that of MWU(0.29) (Table 8). As can be observed from the main effects of the two factors, the vetch and oat performed poorly in relation to the oat-vetch mixed stand for the agronomic traits assessed such as DMY and plant height for both component species in pure stand. The probable reasons for the lowest performance of vetch observed in this experiment might be due to climatic, soil fertility deficiency and water logging problems were reasonably the main factors which decreased performance of vetch for MWU when compared to SARC.

Table 7.Relative yield of sole and mixed stand of oat and vetch as affected by seed proportion and planting (Trt), Location (L) and two way interaction (TrtxL)

Treatment(Trt)	Oat	Vetch	Total Relative Yield
A1B1	0.58 [d]	0.53 [c]	2.6 [b]
A1B2	0.21[f]	0.37 [d]	0.6 [e]
A1B3	1.19 [b]	0.55 [c]	1.86 [c]
A2B1	0.86 [cd]	0.24 [e]	1.96 [c]
A2B2	0.28 [e]	0.17 [e]	0.45 [e]
A2B3	1.79 [a]	0.3 [d]	3.2 [a]
A3B1	0.33 [e]	0.66 [b]	1.45 [d]
A3B2	0.1 [fg]	0.37 [d]	0.5 [e]
A3B3	0.9 [c]	0.77 [a]	1.33 [d]
Interaction (TrtxL)	*	**	**
Mean	0.202	0.211	
SEM	0.05	0.076	0.25
CV	21.56	29.1	24.04
P-Value	0.0001	0.04	0.032
Location			
SARC	0.62 [a]	0.33 [a]	1.33 [a]
MWU	0.33 [b]	0.29 [b]	1.01 [b]
P-Value	0.0001	0.0001	0.0001

abcdefg=Mean values within column and row followed the similar letters are not significantly different at 5% probability level; SEM=Standard error of mean, Trt =treatment, MWU=MaddaWalabu University, Sinana Agricultural Research Center, CV=Coefficient of variation

4.4. Competitive Ratio and Land Equivalent Ratio of Oat and Vetch Mixed Stand as Influenced by Seed Proportion and Planting Pattern, Location and their Interaction

Land equivalent ratio (LER) shows the effectiveness of combinations for using the available land resources compared to sole cropping. Hence, LER value is being used often to compare efficiency of the combination and sole stand growing (Yilmaz*et al.*, 2005; Dhima *et al.*, 2007; Atis *et al.,* 2012; Arshad and Ranamuk, 2012). Results from the combined analysis of variance for the total land equivalent ratio (LER) and competitive ratio (CR) of oat and vetch mixtures as influenced by seed proportion and planting pattern (Trt), location (L) and two way interaction of Trt and L (TrtxL) is presented in Table 9. The result showed that the main effect of treatment

(Trt) ,location (L) and two way interaction of treatment and location (TrtxL) showed highly significant ($P<0.0001$) difference on competitive ratio for oat (CRO) ,vetch (CRV) and total land equivalent ratio (Total LER) in mixed stand of oat and vetch for the treatments (Table 9).

The current study showed that the highest competitive ratio of oat (CRO) , competitive ratio of vetch (CRV) (9) ,(1.2) and total land equivalent ratio (LER) (5.94) were observed for A2B3 and A3B3 with in alternate row planting whereas, the minimum CRO (2.13) ,CRV (0.29) and total LER (0.57) were observed for A1B3 , A2B1 and A3B2 for CR for oat ,vetch and total LER with alternate ,broadcast and same row planting pattern in the mixture. The maximum total LER for A2B3 (5.94), A2B1 (4.1)and A3B3 (2.2) shows more yield advantage and a total LER less than 1 shows less yield advantage in the mixture (Mazaheri and Overysi , 2004).The probable reasons for the total LER attained in plots treated for A1B1 (1.52) , A2B3 (5.94) and A3B1 (1.69) might be due to the fact that the area planted to monocultures would need to be 52% ,94% and 69% greater than the area planted to mixtures to produce the same combined yields (52% ,94% and 69% more land would be required as sole stand to produce the same yield as mixture) (Mead and Willey , 1980 ; Dariush*et al.,*2006).

For A2B3, the competitive ratio of vetch was decreased by 32% whereas; it was decreased by 20% for A3B3 within alternate row planting pattern for both treatments. The probable reasons for the decreased competitive ratios of vetch for A2B3 (0.32%) than at A3B3 (20%) might be due to the fact that dense plants compete for light, nutrients, shading effect of oat over vetch, the suppression of aggressive oat (grass) in oat-vetch mixture intercropping and high seed proportion of oat for A2B3 that negatively impact the growth rate of vetch (which reduced competitive ratios of vetch). This result is in line with the finding of Sadig *et al* (2014) who reported plant height increased with rising seed rate in Pakistan.

When location is considered, the highest CR in oat was recorded for SARC (1.7) when compared to MWU (0.7). Similarly, the highest CR was recorded for vetch at SARC (0.35) when compared to MWU (0.3) (Table 9). A similar pattern to that of the CR for oat and vetch was observed for the total LER observed for SARC (1.97) when compared to MWU (1.1). The probable reasons for the highest CR recorded for oat and vetch mixture at SARC than MWU might be due to stronger competitiveness, greater capacity to acquire resources and superior ecological niche, productivity dominated total biomass yield and superior competitor of oat when compared to vetch (Grace 1990; Jalal *et al.,* 2017).

Table 8.Competitive ratio (CR) and land equivalent ratio (LER) of oat and vetch mixed stand as affected by seed proportion and planting pattern (Trt), Location (L) and two way interactions (TrtxL)

	Competitive Ratio (CR)		
Treatment (Trt)	CRO	CRV	LER Total
A1B1	5.04 [d]	0.6 [d]	1.52 [c]
A1B2	6.1 [c]	0.56 [d]	0.99 [d]
A1B3	2.13 [g]	0.84 [bc]	2 [c]
A2B1	6.11 [c]	0.29 [e]	4.1 [b]
A2B2	7.78 [b]	0.77 [c]	0.7 [d]
A2B3	9 [a]	0.32 [e]	5.94 [a]
A3B1	4.96 [e]	0.97 [b]	1.69 [c]
A3B2	2.98 [f]	0.79 [c]	0.57 [d]
A3B3	6.4 [c]	1.2 [a]	2.2 [c]
Interaction (TrtxL)	***	***	
Mean	5.03	0.43	
SEM	1.1	0.13	0.5
CV	19.62	29.24	
P-Value	0.0001	0.0001	0.0001
Location (L)			
SARC	1.7 [a]	0.35 [a]	1.97 [a]
MWU	0.7 [b]	0.3 [b]	1.1 [b]
P-Value	0.0001	0.0001	0.0001

abcdefg =Mean values within column and row followed the similar letters are not significantly different at 5% probability level, CV=Coefficient of variation; SEM=Standard error of mean;; CRO =Competitive ratio in oat; CRV= Competitive ratio in vetch; LER Total=Total land equivalent ratio in oat and vetch=Location

4.5. Crude protein Yield and Neutral Detergent Fiber Yield

The CP yield (CPY) and NDFY was highly ($P<0.001$) affected due to seed proportion and planting pattern (Trt) , location (L) and two way interaction of treatment (Trt) by location (L) (TrtxL) (Table 11 and Appendix Table 4). Crude protein yield is a measure that relates to CP concentration to the dry matter yield per unit area and gives a better estimate of a total CP available in the season (Muhammad *et al.,* 2014).Table 11 shows the calculated CPY and NDFY from the DMY of sole and mixed stand of oat and vetch in the treatments. The highest CPY(4.98 t/ha) and NDFY (7.65 t/ha) for oat and vetch was obtained in the treatment with the highest oat seed proportion for A2B3 and vetch at A3B3 whereas , the minimum CPY (0.19 t/ha) and NDFY(1.1 t/ha) found in A5B2 for both treatment in pure stand vetch respectively (Table 11).The probable reasons for the highest CPY obtained for A2B3 (75%oat+25%vetch) in alternate row planting pattern might be due to the maximum total dry matter yield observed in the treatment with the highest oat seed proportion in oat-vetch mixture which contributed for the superior CPY (Minichle *et al.,*2019). Also the probable reasons for the lowest CPY obtained for A5B2 (0.19) in plots treated with same row planting pattern might be due to the lower dry matter concentration , higher water content in the plant tissues resulted in inferior dry matter yield since CPY is the product of total dry matter yield and CP concentration in the plant.

In case of location (L), the highest CPY (1.87 t/ha) and NDFY (6.01 t/ha) was attained for SARC when compared to MWU which was 1.45 and 4.1 t/ha with the total CPY and NDFY of 7.88 and 5.55 t/ha. This is in line with the finding of Diriba, (2000) who reported that the highest CPY being an indicative of importance of forages in Panicum Coloratum under varying stages of harvest due to its nutritive values. Also it is in agreement with the finding of Minichle *et al.*, (2019) who reported that the highest (1.43 t/ha) CPY in DsDeHT3 followed by (1.27 t/ha) in StDeHT3 in their report from Debre Markos University in Ethiopia.

Table.9. CPY and NDFY as affected by seed proportion and planting pattern, Location and two way interactions

Treatments(Trt)	**CPY(t/ha)**	**NDFY(t/ha)**
A1B1	3.52 b	6.34 bc
A1B2	1.49 e	3.92 d
A1B3	2.37 c	5.17 c
A2B1	1.75 bc	5.02 c
A2B2	1.99 f	5.23 c
A2B3	4.98 a	6.74 bc
A3B1	1.88 e	6.82 b
A3B2	1.1 g	2.88 f
A3B3	2.18 d	7.65 a
A4B1	0.52 h	1.74 g
A4B2	0.42 i	1.36 gh
A5B1	0.42 i	1.19 k
A5B2	0.19 m	1.1 i
A4B3	0.29k	1.18 l
A5B3	0.2 l	1.57 h
SEM	0.43	1.78
SL	***	***
Interaction(TrtxL)	**	**
Location(L)		
SARC	1.87 a	6.01a
MWU	1.45 b	4.1 b

abcdefghklm =Mean values within column and row followed the similar letters are not significantly different at 5% probability level, SARC=Sinana Agricultural Research Center; MWU=MaddaWalabu University; SEM=Standard error of mean; SL=Significant level; CPY=Crude protein yield; NDFY=Neutral detergent fiber yield; CPY+NDFY=Crude protein yield and Neutral detergent fiber yield

4.6. Biological Compatibility of Oat and Vetch Mixtures

The relative yield (RY) which equate yield of the component species in the combinations with the respective to sole stand species; as designated it was less than one. The RY values less than one means that the yields achieved in mixed stand is less than those achieved in sole stands. In the current study, the RY of oat (1.79) designated that the DM yield achieved from mixture of 75% oats+25%vetch was higher than 79% in pure stand of vetch(*Gebisa*) followed by 19% for A2B3 and A1B3 in plots treated by alternate row planting patterns respectively. Similarly, the RY exhibited relationship with the seed proportion which indicates a rising trend with better seed proportion and vice versa and report is comparable to others (Lithourgidis *et al*., 2006; Dhima *et* *al*., 2007). It appears that yield of forages was influenced by seed rates (proportions).The intercropping system resulted in superior cumulative total biomass yield than either of the sole oat/vetch, caused in RYT values greater than one. This RYT does not only give a better indication of the relative competitive capacity of the constituent species, but also it exhibited the actual benefit due to intercropping (De wit and Van der Bergh, 1965). In the current study, oat (*Bonsa*) mixed with vetch at 75%oat+25%vetch and 50%oat+50%vetch seed proportion showed that the yield achieved from combinations of this species was better than yield achieved in the sole stand. This report was in accordance with that of Ibrahim *et al.* (1993) who reported a comparable result in sorghum/lablab intercropping. Erol *et al.* (2009) also reported that intercropping maize with faba bean gave maximum RYT than unity. The probable reasons for the higher cumulative total biomass yield at A2B3 followed by A1B3 in plots treated by alternate row planting pattern might be due to a better light use efficiency of the intercrops, which has resulted in maximum cumulative leaf area of the intercrops. It was also exhibited that the maximum RYT (1.79) shows that 79% more area would be required for a sole cropping system to achieve the yield attained from an intercropping system. Geleti (2000) similarly reported a comparable result from intercrops of *Panicum coloratum* and *Stylosanthes giuanensis*. Jaballa, (1995) similarly reported that intercropped treatments had maximum combined leaf area than sole/pure stand and the intercrops gave the highest biomass yield per unit area than sole crops. Reddy, (2000) reported that rise in leaf area would lead to a rise in light interception and photosynthesis, which results in better productivity.

4.7. Chemical Composition of sole and mixed stand of oat and vetch

4.7.1. Dry Matter Content (%)

Chemical composition of oat (*Bonsa*) and vetch (*Gebisa*) samples in pure stand and mixtures were presented in Table 10. The combined analysis of variance for the main effects of treatment (Trt) and location (L) showed highly ($P<0.0001$) significant difference on DM content of oat and vetch mixture. However, the two way interaction effect of Trt and L (TrtxL) showed non-significant ($P>0.05$) difference on DM content of sole and mixed stand of oat and vetch (Table 11 and Appendix Table 3).

The maximum DM content was found for A3B1 (92.6%) in the treatment with the highest vetch sowing rates at A3B1(25%oat+75%vetch) in plot treated with broadcasting whereas , the minimum DM content was found for A3B2 (88.2%) in the treatment with the highest vetch seed proportion in plot treated with same row planting pattern (Table 11).

In case of location, there was no significance (P>0.05) difference observed on DM content for SARC (91.47) when compared to MWU (91.13) in terms of DM content (Table 11). This shows that sole oat and vetch as well as their mixed stand had lost much of its water at 65 °C for 24 hours in the oven within a narrow range of 91.47 for SARC when compared to MWU 91.13 (Table 11).

4.7.2. Total Ash

The combined analysis of variance revealed that the main effects of treatments and locations showed highly significant (P<0.0001) difference on ash content of sole and mixed stand of oat and vetch (Table 10 and Appendix Table 3).However, the two way interaction of seed proportion and planting pattern (Trt) and location (L) (TrtxL) showed non-significant (P>0.05) difference on ash content of sole and mixed stand of oat and vetch (Table 10 and Appendix Table 3).

The highest ash content was observed from A2B2 (12.72%) in mixed stand with the highest oat seed proportion in plot treated with same row planting pattern whereas, the lowest was observed from in pure stand at A5B'1 (8.37%) in plot treated with broad casting respectively (Table11).The probable reasons for the highest ash content recorded for A2B2(12.72%) in mixed stand might be due to exogenous minerals which are associated with soil such as silica, forages that are lodged due to heavy rains and wind might be more contaminated with unwanted soil which rises ash content (Hoffman and Tayson, 2005).
The probable reasons for the lowest ash content recorded for A5B1 (8.37%) might be due to the best management practices including minimum contamination with soil, wide strips and cutting (Digma *et al*., 2011) and this result was in accordance with the finding of Fantahun ,(2016) who reported that 9.35% ash content in his trial at Bishoftu in Ethiopia.

In case of location , the ash content recorded for SARC(9.55%) was lower when compared to the ash content recorded for MWU(12.33%).The probable reasons for the highest ash content recorded for MWU might be due to high mineral concentration, soil characteristics, plant developmental stage, higher rainfall and morphological fraction and varieties which can result in splashing of soil particles on to plants , mixed with sandy soil type may have contributed to the increment in ash percentage (George and Jerry, 1994;Greene, 2000;Jukenvicius and Sabiene, 2007 ; Abby *et al*.,2017).

In general, the probable reasons for the variation of ash content in oat-vetch mixture, sole oat and vetch might be due to the seasonal conditions, soil type, soil nutrient status, translocation of different minerals associated with harvesting time and vegetative portion of leaf Mc Donald *et al*. (2002).

4.7.3. Crude Protein

Crude protein content is one of the very vital criteria in forage quality evaluation (Geleti, 2000; Lithourgidis *et al*., 2006). The CP content of oat and vetch mixture showed highly ($P<0.0001$) significant difference due to the main effect of treatment (Trt) and location (L) whereas non-significant ($P>0.05$) difference for the two way interaction of treatment (Trt) and location (L) (TrtxL) (Table 11 and Appendix Table 3).

In the current study, the highest CP content (22.23%) was recorded for A5B1 (sole stand vetch) in plot treated with broadcasting whereas, the lowest (11.1%) was recorded for A4B2 (sole stand oat) in plot treated with same row planting pattern (Table 11). The current result is in accordance with the finding of Starks *et al.,* (2006) who reported the superior (26%) content in case of sole stand vetch at flowering stage. The CP content recorded at A3B3 (18.7%) was in accordance with the finding of Gezahagn *et al.*, (2016) who reported 18% CP in oat-vetch mixture.

The probable reasons for the highest CP content recorded in A5B1 (pure stand vetch) might be due to the increased proportion of vetch (higher seed proportion) than in oat, genetic makeup of the component species, chemical composition of plants might be varied depending on the species (Borawska*et al*.,2022) , less fiber ,fiber during growth stage might be changed (Fazel *et al*.,2012) , species difference (Chapman *et al*., 2014) , stage of maturity of the plants (Hakl*et al*., 2016), the nature of soil existing in the study areas (Schjoerring*et al*.,2019),altitude (Koidou*et al*.,2019) and climatic situation of the study areas (Ghahramani*et al*., 2019).This is in accordance with the finding of Mehdi *et al*., (2009) who reported that (19.65%) and (12.11%) crude protein in bean sown alone than maize in Iran.

In case of location, the highest CP content (17.68%) was recorded for SARC when compared to MWU (14.51%) (Table11).The probable reasons for the lowest CP content recorded for MWU might be due to the dilution of the CP contents of the forage by the rapid accumulation of cell wall carbohydrates at the latter stage of growth, environmental conditions such as waterlogged soils, soil aeration, rainfall, temperature and nutrient absorption difficulties, which make plants stunted and lessen its growth rate (Seyoum *et al.,* 1998; Tessema *et al.,* 2002; Kataryzna *et al.,* 2021).

4.7.4 Neutral Detergent Fiber

The NDF showed highly (P<0.0001) significant difference due to the main effect of treatment (Trt) but not due to location(L) and their interaction (TrtxL) on NDF content of sole and mixed stand of oat and vetch respectively (Table 11 and Appendix Table 3).

The maximum NDF (59.6%) was found in the treatment for A4B2 in pure stand oat in plot treated with same row planting pattern whereas , the minimum was for A5B1 (35.41%) in pure stand vetch in plot treated with broadcasting row planting pattern (Table 11). The outcome of the study was supported by the report of Karachi (1997) who reported the minimum NDF contents of legumes than grass at the similar stage of growth. Rising dietary NDF concentration most often has undesirable impact on the amount of DM consumed by the animals (Allen, 2000).
The probable reasons for the highest NDF content observed for A4B2 might be due to an increase of oat seed sowing rates that caused increase of NDF content , genetic makeup , an increase in fiber content which could be accompanied by a decrease in CP content associated with an increase in proportion of lignified structural tissue(Castro *et al.,*2000).

Generally, the NDF values of A3B3 , A5B1, A5B2 and A5B3 in sole vetch and mixed stand was in a good quality forage category and the NDF value of A1B1 and A4B3 was in a medium quality forage quality category and this is quite in line with the finding of (Singh and Oostng ,1992) who reported feeds comprising NDF value of less than 45% are ranked as high, those with values ranging from 45% to 65% as a medium and those with values higher than 65% having poor quality in India .

The highest value of NDF recorded for A4B2 (59.6%) followed by A2B1 (57.4%) in mixed stand of oat and vetch in this observation was in close agreement with results reported by Geleti (2000), who reported the NDF value of 60% in panicum coloratum mixed with stylosanthes guinensis in Bako agricultural research center in Ethiopia. However, the present result argued with that of Vansoest (1965) who reported the critical value of NDF to be 55%.

In case of location (L), there was no significant ($P>0.05$) difference observed in NDF content for SARC (50.8%) when compared to MWU (51.4%. The non –significant difference observed between the two locations in NDF content in sole and mixed stand of oat and vetch implies that cultivation of sole and mixed stand of oat and vetch over locations had neither difference at SARC nor at MWU on NDF content in the study areas.

4.7.5 Acid Detergent Fiber

Acid detergent fiber was highly ($P<0.0003$) affected due to the main effect of treatment(Trt) but not due to location (L) (Table 10 and Appendix Table 3).Similarly, the two way interaction of treatment(Trt) by location(L) (TrtxL) showed non- significant($P>0.05$) difference on ADF content of sole and mixed stand of oat and vetch mixture (Table 11 and Appendix 3).

The ADF content is the percentage of indigestible and gradually digestible material like pectin, lignin and cellulose in a forage or feed (McDonald *et al.,* 2002). In the current result , the highest ADF content of (33.39 %) was obtained in the treatment with the highest oat seed proportion for A4B1 (in sole stand oat) in plot treated with broadcasting whereas, the lowest (24.03%) was obtained in the treatment with the highest vetch seed proportion for A3B3 in plots treated with alternate planting pattern (Table 11).The lowest ADF content recorded for A3B3(24.03%) in plot treated by alternate row planting pattern shows that it is more palatable and more appropriate which is in accordance with the finding of Negash *et al*., (2014) who reported that 23.7% of CV-SRCPX80 Ab2806 variety at Haramaya University. The grand mean of ADF content 28.36% found in the current study was slightly comparable with Kezemi *et al*., (2012) who reported that ADF value falling within value less than 40 % are rated as first grade quality standard and above 40% as low quality.

The probable reasons for the lowest ADF % observed in this study might be due to the increase in leaf to stem proportion and the decrease in cell wall lignification which may lead to lowered ADF concentrations at 50% heading and 50% flowering stage for sole and mixed stand of oat and vetch respectively.

In case of location, the ADF content observed for SARC (27.76%) and MWU (28.88%) showed non-significant (P>0.05) difference over locations (Table 11).The probable reasons for the non-significant difference observed on ADF content over locations might be due to the similar development of lignified structures in the cell walls over location on the contrary, Mohammad and Halim (2014) reported that a higher lignin in legume than grasses, as legume synthesis lignin for strength. The actual values for ADF found in this trial and the absence of significant difference agrees with other studies (Castro *et al*., 2000).

4.7.6. Acid Detergent Lignin

The ADL content showed highly (P<0.003) significant difference due to seed proportion and planting pattern (Trt) (Appendix Table 3) yet non –significant (P>0.05) difference due to locations(L) and two way interaction of treatment(Trt) and location(L) (TrtxL) (Table 11 and Appendix Table 3) . The non –significant (P>0.05) difference observed on ADL content of sole and mixed stand of oat and vetch implies that neither locations nor two way interaction of treatment with locations could affect the ADL content in the treatments (Appendix Table 3).
The maximum ADL content (7.65%) was recorded in the treatment with the highest oat seed proportion for A4B1 in plot treated with broadcasting whereas , the minimum(3.23%) was attained in the treatment with the lowest vetch seed proportion for A5B2 in plot treated with same row pattern in sole stand vetch (Table 11) .

This result is higher than the finding of Umunna *et al.*, (1997) who reported that 3.7% ADL content of oat-vetch mixture in Debrezeit Research Center and lower than the finding of Garduno-Castro *et al*. (2009) who reported the ADL content of 12.4% for oat-vetch silage in the highlands of Mexico which is higher when compared to the ADL content of the present value.

The probable reasons for the highest ADL content observed in the treatment with the highest oat seed proportion for A4B1 (7.65%) might be due to ADL increment with advancing maturity, rapid lignification's as the result of concentrations structural carbohydrates and prolonged plant growth stage McDonald *et al*., (2002). This finding is in close agreement with the finding of Negash *et al.,* (2017) who reported the contents of NDF and ADF appeared to rise with rising proportion of oat in the mixture. However, the content of ADL decreases with increasing seed proportion of vetch (Maynard and Lousli , 2009).This study is in contradictory with the finding of Elgersma and Soegaard, (2018) who reported that legumes have higher ADL content than grasses. Generally, the presence of insoluble fibers especially lignin, reduces the overall digestibility of the feed and restricts nutrient availability (Mustafa *et al.,* 2000).

In case of locations, the content of ADL recorded for SARC (4.99%) was at par with MWU (5.45%) which showed non –significant difference between the locations.

Table 10.Chemical composition of sole and mixed stand of oat and vetch as affected by seed proportion and planting pattern, Location and two way interactions

Trt	% DM	%Ash	%CP	% NDF	% ADF	%ADL
A1B1	91^{c}	9.91^{cd}	15.5^{cde}	52^{d}	25.31^{e}	4.74^{cd}
A1B2	88.7^{ef}	11.82^{b}	13.3^{e}	53.8^{de}	30.71^{ab}	4.53^{de}
A1B3	91.6^{bc}	11.1^{c}	17.9^{c}	50^{cd}	26.31^{de}	4.75^{cd}
A2B1	89.7^{de}	12.1^{ab}	14.1^{de}	57.4^{b}	29.46^{abcd}	6.1^{bcd}
A2B2	90.5^{cd}	12.72^{a}	14.3^{de}	51.89^{bcd}	26.56^{cde}	6.5^{abc}
A2B3	91.8^{ab}	8.76^{fg}	16.7^{bc}	56.6^{bcd}	29.77^{abcd}	6.22^{bcd}
A3B1	92.6^{a}	8.87^{f}	18.2^{b}	45.1^{def}	30.49^{abc}	4.05^{fgh}
A3B2	88.2^{f}	10.96^{bc}	15^{cd}	49.6^{cd}	26.88^{abcde}	3.88^{gh}
A3B3	92.1^{bcde}	11.33^{d}	18.7^{ab}	43.4^{de}	24.03^{f}	3.53^{ghi}
A4B1	89.6 def	11.47^{cd}	14.8^{cde}	55.51^{abc}	33.39^{a}	7.65^{a}
A4B2	91.3^{c}	11.62^{bc}	11.1^{h}	59.6^{a}	30.71^{ab}	5.11^{cde}
A5B1	91.85^{bcd}	8.37^{i}	22.23^{a}	35.41^{fgh}	27.1^{cde}	5.28^{cde}
A5B2	90.6^{cde}	8.56^{h}	17.7^{bc}	39.7^{fg}	27.65^{bcde}	3.23^{ghi}
A4B3	91.1^{c}	11.31^{d}	11.7^{g}	54.31^{c}	29.85^{ab}	5.97^{cd}
A5B3	89.51^{h}	9.1^{cde}	16.43^{d}	36.3^{ghi}	24.51^{e}	4.9^{def}
TrtxL	NS	NS	NS	NS	NS	NS
Mean	91.3	10.94	17.1	51.1	28.32	5.22
SEM	1.7	1.65	2.1	6.7	3.4	1.43
CV	18.2	15.1	12.1	13.1	12.11	27.4
Location						
SARC	91.47^{a}	9.55^{b}	17.68^{a}	50.8^{a}	27.76^{a}	4.99^{a}
MWU	91.13^{a}	12.33^{a}	14.51^{b}	51.4^{a}	28.88^{a}	5.45^{a}

Abcdefgh = Mean values within column and row followed the similar letters are not significantly different at 5% probability level, Trt =Treatment, TrtxL= Treatment interaction by location ;DM % =Dry matter percentage ;CP=Crude protein ;NDF=Neutral Detergent Fiber ; ADF=Acid Detergent Fiber; ADL=Acid Detergent Lignin; SEM=Standard Error of Mean ;CV=Coefficient of variation ;NS=Non -significant at %5 ; L= Location ;SARC= Sinana Agricultural Research Center ;MWU= MaddaWalabu University.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Ethiopia has huge livestock population in Africa (Central Statistical Agency, CSA, 2020 a) which contribute significant portion to the economy of the country (Negash e*t al* ., 2017) . However , the productivity level of the livestock resources was shown to be very low (Asfaw *et al* ., 2011; Anteneh and Moges , 2017) . This is because of the reasons attributed to the scarcity of feed in quality and quantity (Malede , 2013) . Animal feed deficiency is one of the primary limitations that hamper productivity of the sector (ILRI, 2014; Salo *et al* ., 2017).Climatic change and seasonal variations highly affect the availability of quantity and qualities of feed resources have been a common phenomenon inflecting serious challenges in livestock production and productivity (Alemayehu , 2005) . The use of enhanced feed is restricted to 0.3% in non-urban areas of Ethiopia (CSA , 2015) and used crop residues are poor in quality and known with high fiber content which causes low livestock return /output due to malnutrition and exposed easily to diseases with high prevalence rate (Malede and Takele , 2014) . As to other Ethiopian highlands, the highlands of Bale are known by crop livestock mixed farming systems. Because of steady alteration of grazing lands into crop lands, and lack of access for sufficient range land was the most significant causes of feed shortage (Belay and Geert, 2016) . As a result, scarcity of feed in quantity and quality is becoming the principal challenge to enhance livestock production and productivity (Solomon, 2004).

Therefore, production of enhanced fodder as a protein source and feed quality improvement strategies is mandatory to satisfy feed and nutrient demand of livestock if better production and productivity is needed (Shimelis and Temesgen, 2016). One of the potential and strategic methods to enhance livestock feed availability in terms of quality and quantity is the use of improved forages crops (Alemu *et al.,* 2007). Among the most economically as well as future improvement of agricultural activities in ways of maintaining soil fertility , easily fulfilling the livestock feed quality was oat-vetch mixture which is a good source of protein and energy to satisfy the nutrient requirement of growing and young productive animals (Shimalis , 2018).

The effect of seed proportion and planting pattern on dry matter yield ,compatibility and chemical compositions (quality) of the sole oat (*Bonsa*) and vetch (*Gebisa*) as well as their mixed stand were evaluated.

The result revealed that plant height and herbage DMY in vetch-oat mixture was significantly ($P<0.0001$) affected by treatments with seed proportion for A3B3 (25%Oat+75%svetch) for vetch and A2B3 for oat with alternate row planting patterns in both treatments. In view of this, the longest plant height (88.3 and 115.83 cm) in vetch and oat was recorded for A3B3 (25%oat+75%vetch) and A2B3 (75%oat+25% vetch) in plots treated by alternate row whereas, the minimum (41.9 and 55.7 cm) was recorded for A2B2 and A3B2 in plots treated with same row planting pattern respectively. When location is considered, the longest plant height (80.1 and 123.4 cm) was recorded for vetch and oat at SARC when compared with the plant height of vetch and oat at MWU (75.1 and 115.85 cm).

The combined analysis of variance of the main effect of treatment (Trt) and location (L) showed that highly ($P<0.0001$) significant difference on the above ground dry biomass yield in oat and vetch (Appendix Table 2). In view of this, the highest FBY (21.7 and 53.5 t/ha) and DM (3.5 and 12.95 t/ha) was recorded for A3B3 and A2B3 respectively. However, the minimum FBY (3.48 and 1.01 t/ha) and DM (9.69 and 2.29 t/ha) in vetch and oat was recorded for A5B2, A3B2, A4B2 and A3B2 in plots treated with same row planting pattern respectively. With regard to locations, the highest FBY (15.19 and 5.89 t/ha) and DM (18.32 and 7.92 t/ha) was recorded for vetch and oat at SARC than MWU which was (12.13, 3.54, 14.71 and 6.52 t/ha) FBY and DMY respectively.

The combined analysis of variance showed that the main effect of treatment (Trt) and location (L) showed highly significant ($P<0.0001$) difference on relative yield of oat and vetch component species. In view of this, the maximum relative yield in oat (1.79) and vetch (0.77) was recorded for A2B3 and A3B3 in plots treated with alternate row planting pattern with the total RY of 3.2 for A2B3 whereas, the minimum (0.1) and (0.17) in oat and vetch was recorded for A3B2 and A2B2 in plots treated with same row planting pattern with the total RY of 0.45 for A2B2 respectively.

The two locations displayed significant ($P<0.05$) differences for a number of agronomic and nutritional characters for different seed proportion of oat-vetch mixture and planting pattern (Table 8).The maximum RY in oat (0.62) and vetch (0.33) was recorded at SARC than the RY of oat (0.33) and vetch (0.29) at MWU with the TRY of 1.01.

The result showed that the main effect of treatment (Trt) ,location (L) and two way interaction of treatment and location (TrtxL) showed highly significant ($P<0.0001$) difference on competitive ratio for oat (CRO) ,vetch (CRV) and total land equivalent ratio (Total LER) in mixed stand of oat and vetch for the treatments (Table 9). In view of this , the maximum competitive ratio in oat (9) , vetch (1.2) and total LER (5.94) was recorded for A2B3 and A3B3 in plots treated with alternate row planting pattern whereas the minimum (2.13 ,0.29 and 0.57) CRO , CRV and LER total was recorded for A1B3 , A2B1 and A3B2 in plots treated with alternate and same row planting pattern respectively. With regard to location CR in oat (1.7), vetch (0.35) and total LER (1.97) was recorded at SARC when compared to MWU which was 0.7, 0.3 and 1.1 in oat, vetch and total LER respectively.

The CP yield (CPY) and NDFY was highly ($P<0.001$) affected due to seed proportion and planting pattern (Trt) , location (L) and two way interaction of treatment (Trt) by location (L) (TrtxL) (Table 11).The maximum CPY (4.98) and NDFY (7.65) was recorded for A2B3 and A3B3 in plots treated with alternate row planting pattern whereas the minimum CP (0.19) and NDFY (1.1) was recorded for A5B2 respectively. With regard to locations, the maximum CPY (1.87) and NDFY (6.01) recorded at SARC when compared to MWU which was 1.45 and 4.1 CPY and NDFY respectively. The relative yield values greater than one in A2B3 and A1B3 means that the yield achieved in mixed stand is greater than those achieved in sole stands in oat. In the current study, the relative yield of oat (1.79) designated that DM yield achieved from mixture of 75%oat+25%vetch was higher than 79% in pure stand of vetch (Gebisa) followed by 19% for A2B3 and A1B3 in plots treated by alternate row planting pattern respectively (Table 8).

Therefore, to get the maximum DM yield A2B3 was appropriate for oat and vetch seed proportion whereas to get maximum CP, A5B1 in sole stand vetch was suitable among thetreatment.

5.2 Recommendation

Based on the research findings obtained the following recommendations forwarded:

- The mixture A2B3 (75%oat+25%vetch) was the best performed followed by A3B3 in most agronomic and nutritional parameters at bloom stage (50% flowering and heading or dough stage in vetch and oat respectively) and it is recommended for improved fodder production in Sinana district and associated agro-ecology to know proper seed rates and planting pattern in order to solve improved fodder production difficulty for optimum production.
- When growing oats-vetch mixture in different seed proportion and planting pattern over location to know quality of the mixture is preferable to sow oat two weeks before vetch, this is because vetch reaches 50% flowering stage earlier than oat heading (dough) stage according to this thesis.
- Though, this study was conducted over locations in a single season and it is better if studied for more than a year (more than one seasons).
- In addition, researchers should evaluate the effect of seed proportion and planting pattern on oat and vetch mixture on animal performance to give fine /tuned recommendation.

6. REFERENCES

Abby EN.Craigcs.,Daniel JU ., Marvin H., Daniel Mk., Scott MW., Devan NC., and Krishona LM.2017. Hay rake type effect on ash forage nutritive values of alfalfa hay.*Agronomy Journal 109 (5).*

Abebe M.,Simon J., Oosting S.and Fernandez R.2008 Farmers perceptions about exotic multipurpose fodder trees and constraints to their adoption. *Agroforestry systems 73(2): 141-153.*

Abeyou W.,Yihun T.,Dile TD.,Petraschimitter .,Melkamu B.,Aberra A., Jean CB., SrinivasanR., Nicole L. and Neville .2021.Constraints of Small- scale irrigated fodder production and nutrition assessment for livestock feed, Acase study in Ethiopia. *Agricultural Water Management, Volume 251*

Adane K., and Berhan T., 2005 .Effects of harvesting frequency and nutrient levels on natural pasture in the central highlands of Ethiopia.*Tropical Science 45:77-82.*

Addisu E., Firew T. and Genet A.2016 Constraints and Opportunities on Production and Utilization of improved Forages in East Gojjam Zone, Amhara Region, Ethiopia .The Case of Enebsie Sar MidrDistrict. *Journal of Biology, Agriculture and Healthcare, Vol.6, No.9*

Adugna T. 2007. Feed resources for producing export quality meat and livestock in Ethiopia. *Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing project (SPS-LMM). 77p.*

Adugna T.and Said A.N.1994.Assessment of Feed Resources in Walayita Sodo: Quality estimation and laboratory evaluation. *Ethiopian Journal of Science 14:69-87.*

Akililu M.and Alemayehu M.2007.Measurements in pasture and forage cropping system. *Technical manual 18, EIAR, Addis Ababa, Ethiopia.pg 41.*

Albayrak S.and Ekiz H.2005.An investigation on the establishment of artificial pasture under Ankara's ecological conditions.*Turkish Journal of Agriculture and forestry.29:69-74.*

Alemayehu M. 2005 .Feed resources base of Ethiopia: Status and opportunities for integrated development.*Proceedings of the 12th Annual Conference of the Ethiopian Society of Animal Production (ESAP), Addis Ababa, Ethiopia.Pp.377-386.*

Alemayehu M., Gezahagn K., Fekede F. and Getnet A.2017 . Review on major feed resources in Ethiopian Conditions, Challenges and opportunities. *Academic Research Journal of Agricultural Science and Research, Vol.5 (3), pp.176-185*

Alemayehu M.1985. Feed resources in Ethiopia;*Pp.35. In Animal feed resources for small scale livestock producers ; proceedings of the second PANESA work shop; held in Nairobi , Kenya ,11-15 November ,1985.*

Alemayehu M.2003.Country pastures /forage resources profiles: Ethiopian Food and Agriculture Organization of the United Nation (FAO). Website:http://www.fao.org/ag/agp/agpc/doc/count prof/Ethiopia.htm (Accessed on Septembe 30, 2019).

Alemayehu M.2006.Country pasture/forage resource profiles: Ethiopia Available at http://www.fao.org/AGP/agpc/doc/countpr of Ethiopia.htm. Accessed on 10/05/2021

Alemu B., Melaku S.and Prased N. 2007. Effects of varying seed productions and harvesting stages on biological compatibility and forage yields of oats and vetch mixture, *Livestock Research for Rural Development: 19(1)*

Amanuel W.,Kassa S. and Deribe G.2019 .Biomass Yield and Nutritional Quality of Different Oat Varieties (Avena sativa) Grown under Irrigation Condition in Sodo Zuriya District, Wolaita Zone. Ethiopia. Agricultural *Research and Technology Open Access Journal, ISSN: 2471-6774*

Amba C., Yilkal T. and Denbela H.2022.Assessment on Livestock Feed Resources and Utilization Practices in Derashe Special Districts, Southern –Western Ethiopia: Status, Challenges and opportunities: *Journal of veterinary Medicine and Animal Sciences, Volume 5(1) :1110*

Anil L., Park J., Phipps R. H., and Miller F. A. 1998. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass and Forage Science, 53(4), 301-317.*

Ansarul S. Haq,K., Shiekh T.A., Bahar F., A,A.Dar Khurshid ,Raja Waseem,A.Wani Rayees and Khuroo N.S.2018. Yield and Quality of Winter Cereal-Legume Fodder Mixtures and their Pure Stand under Temperate Conditions of Kashmir Valley, India. *International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 7 Number 02.*

Anteneh W.and Moges D.2017.A Review on Current Status of small ruminant meat production comparison yield and carcass characteristics in Ethiopia.Advances in Life Science and Technology, ISSN 2224-7181(Paper) ISSN 2225-062X (on line)

AOAC, (Association of Official Analytical Chemists) .1990.Official method of analysis .15th ed. Washington, DC, 69-83.

AOAC..2000. Associ*(16th ed.)Virlington, Virginia*ation of Official Agricultural Chemist.*Official Method of Analysis, USA.*

Asfaw S., Shiferaw B., Simtowe F.and Haile M.2011. Agricultural Technology Adoption, seed access constraints and commercialization in Ethiopia *.Journal of Development and Agricultural Economics 3(9) PP:436-477.*

Asif I.,Muhammad A.,Nadeem A. and Riaz A.2006. Growth and forage yield response of maize-legume mixed cropping to different sowing techniques in Faisalabad*. Pakistan Journal of Agricultural Science, Vol.43 (3-4).*

Assefa G. and Ledin I.2001 .Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology92: PP;95-111*

Assefa G.1999. Feed resource assessment and evaluation of forage yield, quality and intake of oats and vetch grown in pure stand and mixtures in the highlands of Ethiopia.

Assefa G.2006. Avena *sativa L..In:* Brink M. and Belay G.(Editors). PROTA 1: Cereals and Pulses (CD_ROM) PROTA, Wageningen , Netherlands

Atis A., Kokten K,HatipogluR,Yilmaz.S,Atak.M,Can.E.,2012. Plant density and mixture ratio effects on the competition between common vetch and wheat.*Australian Journal of Crop Science 6 (3): 498-505.*

Ayele S., Assegid W., Belachaw H., Jabbar A. and Ahmed M. 2003. Livestock marketing in Ethiopia: A review of structure, performance and development initiatives; Socioeconomic and policy research working paper 52: *ILRI (International Livestock Research Institute), Nairobi, Kenya. Pp35*

Aysen U. and FerdaA.2012.The effect of mixture rates and cutting stages on some yield and quality characters of pea(Pisum sativum L.)+ Oat (Avena sativum L.)mixture.*Turkish Journal of Field crops. 17(1):62-66*

Ayub M.,Abbas ,H.,Tarik M., Tahir M., Nadeem A.M. and Siddiqui HM.2013.Periodic assessment of dry matter production and nutritional value of millet legumes mix fodder. *Agricultural Research 2: 265-269.*

Baba M., Halim, R A., Alimon A.R., Abubakar I., 2011. Grass –legume mixtures for enhanced forage production. Analysis of dry matter yield and competition indices. *African Journal of Agricultural Research 6(23):5242-5250.*

Bacchi M.,Calvi A.,Presti E.,Pellicano A. and Preiti G.2021. Forage potential of cereal/legume inter-crops: Agronomic Performances, Yield quality forage and LER in two Harvesting Times in a Mediterranean Environment. *Agronomy 2021, 11,121*.

Bale zone Agriculture report.2021.

Banik P. and Bagchi D.K. 1993. Effect of legumes as a sole and inter-crop on residual soil fertility and succeeding crop in upland situation .*Indian Journal of Agricultural Sciences*, 37: 69–75.

Barsila S.R.2018. The fodder oat (Avena sativa) mixed legume forages farming ,Nutritional and ecological benefits . Journal of Agriculture and Natural Resources (2018) 1(1): 206-222,

Bediye S.,Silashi Z. and Fekadu D.2007. Composition and nutritive value of Ethiopian feed stuff ,Research Report no.73;*Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.PP.9-19.*

Behnke R. and Metaferia F. 2011.The contribution of livestock to the Ethiopian economy –part II:*IGAD LPI Working Paper: 02-11, IGAD. Livestock Policy Initiative.*

Belay D. and Geert P.J.2016. Assessment of Feed resources, Feeding practices and Coping Strategies to Feed scarcity by Smallholder Urban Dairy producers in Jimma town, Ethiopia ;*Springer plus 5, Article Number: 717, Available on 2/9/2021.*

Berhanu A.,Solomon M.and Prsad N.2007. Effect of varying seed proportion and harvesting stages on biological compatibility and forage yield of oats (*Avena sativa L.*) and vetch (*Vicia villosa R.)* blends *.Livestock Research for Rural Development 19(1).*

Berhanu G.,Adane H. and Kahsay B.2009. Feed marketing in Ethiopia, Results of Rapid Market Appraisal, Improving productivity and Market success (IPMS) of Ethiopian farmers project working paper 15 :*International Livestock Research Institute (ILRI)(,Nairobi, Kenya, Pp.64.*

Bogale S.,Melaku S.and Yami A.2008. Potential use of Crop Residues as Livestock feed Resources under Smallholder Farmer conditions in Bale highlands of Ethiopia *.Tropical and Subtropical Agro ecosystems 8(1), Pp.107-114.*

Borawska J.,Mastalerczuk G.,Janicka M. and Barbara W.2022. Effect of Silicon Containing Fertilizers on nutritional value of Grass-Legume Mixtures on Temporary Grasslands *.Agriculture 2022,12,145.*

Buxton D.R.1996. Quality related characteristics of forages as influenced by plant environment and agronomic factors. *Animal feed science and technology :59)1-3)Pp. 37-49*.

Canan T. and Orak A.2002 Yield and yield components of some important common vetch (Vicia sativa L.) genotypes. *Bulgarian Journal of Agricultural Science, National Center for Agrarian Sciences 15:215-218.*

Castro MP., Pineiro J., Sau F. 2000 .Effect of seeding rates of oat, wheat and common vetch on the yield, botanic composition and nutritive value of the mixtures, *In: Legumes for Mediterranean forage crops, pastures and alternative uses (Ed. Sulas L). CIHEAM-IAMZ, Zaragoza, pp. 207-211.*

Chapman D.F., Lee J.M.; Waghorn G.C. 2014 .Interaction between plant physiology and pasture feeding value: *A review on Crop Pasture Science. 2014, 65, 721–734.*

Contreras P., Felio U.,Liber I., AlejandroF. , Rufino C.E., Rusmel T. , Kelly S.2019. Behavior of the forage mixture *Avena sativa* and *Vicia sativa* in its different proportions at Peru *,Volume 9 Issue 3 – 2019 Cornell University, USA p: 373*

CSA (Central Statistical Agency) .2018. Agricultural Sample Survey. Report on Livestock and Livestock characteristics (private peasant holdings), volume II, Statistical Bulletin, 587, Addis Ababa, Ethiopia.100p

CSA (Central Statistical Agency) .2015 .Agricultural Sample Survey on Livestock and Livestock characteristics (private peasant holdings), Ethiopia

CSA (Central Statistical Agency) .2017. Agricultural sample survey 2016/17 Volume II, report on livestock and livestock characteristics (private peasant holdings), CSA: Addis Ababa, Ethiopia.

CSA.2020a. Agricultural Sample Survey 2019/20 (2012 E.C.). Volume II report on livestock and livestock characteristics (private peasant holdings). Central Statistical Agency CSA/Addis Ababa, Ethiopia.

Daniel K. 1990. Effect of development stage at harvest, N application and Moisture availability on the yield and nutritional value of Rhodes grass (chlorisgayanakunth) – Lucerne (Medicago sativa L.Pastures, PhD Thesis.*Swedish University of Agricultural sciences, Uppsala, Sweden*

Dawit A. and TekluW.2011.Registration of Bonsa and Bona-bas Fodder Oats Varieties for the Bale highlands, Ethiopia.*East African Journal of Sciences (2011) Volume 5 (2) 57-59, ISSN 1992-0407*

Dawit A., Ajebu N. and Banereje S.2013. Assessment of feed resource availability and livestock production constraints in selected Kebeles of AdamiTulluJiddoKombolcha District, Ethiopia. *African Journal of Agriculture Resaerch 8(29): 4067- 4073.*

Dawit A., Aliye K. and Sisay B.2011. Registration of Abdeta ,Gebisa and Lalisa vetch varieties for Bale highlands, Ethiopia.*East African Journal of Sciences. Volume 5(2):135-137.*

Dawit A.,Solomon B., Tekilu W.,Usman S.and Wamtu J.2012. Characterization of the livestock production systems and the potential of feed based interventions for improving livestock productivity in Sinana District Bale Zone South Ethiopia. *International Livestock Research Institute*

De Wit C.T. and Van der Bergh J.P. 1965.Competition between herbage plants .*Netherlands*

Dewit C.T.1960. On competition Verslag Land bouw kundig Onderzoek 66(8):1-82

Dhima K.V., Lithourgidis A. S., Vasilakoglou I.B., and Dordas C. A. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Research, 100(2), 249-256.*

Digman M.,Undersander D., Shinners K., and Saxe C.,2011.Best practices to hasten field drying of grasses and alfalfa.

Diriba D. and Adugna T.2013.Effect of Planting Pattern and Cutting Height on *In Vitro* Digestibility and in Sacco Degradability of Napier Grass Mixed with Silver Leaf Desmodium at Bako, Western Ethiopia. *Science, Technology and Arts Research Journal 2(2): 22-29.*

Diriba D. and Diriba G.2013 .Effect of seed proportion and planting pattern on dry matter yield, compatibility and nutritive value of Panicum coloratum and Stylonsanthes guianensis mixtures under Bako conditions, Western Oromia, Ethiopia.*Science, Technology and Arts Research Journal. Volume 2(4):56-61.*

Diriba G, Vaars R.2000. Productivity of panicum coloratum under varying stages of harvest,low level pf nitrogen fertilizer and in combination with stylosanthes during establishment year. MSc thesis, Alemaya University,Ethiopia.

Duressa D., Kenea D., Keba W., Desta Z., Berki, G., Leta G. and Adunga T. 2014.Assessment of livestock production system and feed resources availability in three villages of Diga district Ethiopia: *ILRI: Addis Ababa, Ethiopia*.

EAFIA (Ethiopian Animal Feed Industry Association) .2012. Livestock Feed Resources in Ethiopia.Challenges, Opportunities and the need for transformation. Addis Ababa, Ethiopia.

EARO (Ethiopian Agricultural Research Organization) .2000.Livestock Research Strategy Summary.Livestock Research Directorate, EARO, Addis Ababa, Ethiopia. 133p.

Ecoport , 2013.Ecoport database.

Elgersma A. Soegaard K. 2018. Changes in nutritive value and herbage yield during extended growth intervals in grass-legumes mixture effects of species, maturity at harvest, and relationships between productivity and components of feed quality. *Grass forage Science 73:78-93.*

Erla.2011.Forage quality and yield in grass-legume mixtures in Northern Europe and Canada, Master's thesis, Faculty of Physical Sciences, University of Iceland, pp. 62

Erol A.,Kaplan M. and Kizilsimsek M. 2009.Oats (*Avena sativa*)-common vetch (*Vicia sativa*) mixtures grown on a low-input basis for a sustainable agriculture, Kahramanmaras, Turkey. *Tropical Grasslands, Vol 43,191-196*

Eskandari H., Ghanbari A., Dahmardeh M.,Siahsari,B.A. and Ramroud M.2010. Effect of maize (Zea mays L.) –Cow pea (Vignaunguiculata L.) intercropping on light distribution ,soil temperature and soil moisture in arid environment. *Journal of Food, Agriculture and Environment, 8(1), Pp.102-108.*

Fantahun Dereje. 2016.The effect of variety and seed proportions on yield, nutritional quality and compatibility of oats and vetch mixtures.MSc thesis Bishoftu Ethiopia.

FAO (Food and Agriculture Organization of the United Nations) .2001.Production year book.Volume.55, FAO, Rome, Italy.

FAO(Food and Agricultural Organization, 2006 .FAOSTAT data of Ethiopia. htt://WWW.Fao.org.agp/Agpc/doc/counprHtm. Accessed March, 2019.

Fazel A.,Abdulrashidb .and Mohamad S.2012. Comparison of nutritive values of grasses and legume species using forage quality index,University of Putra,Malaysia. Songklanakarin *. Journal of Science Technology, 34(5), 577-586,*

Fekede F., Adugna T. and Solomon M. 2008.Proportions of morphological fractions of oats (*Avena sativa L.*) as affected by variety and growth stage.*20: Article 89.Retrieved* August 9, 2019, http://www.lrrd.org/lrrd20/6/feyi20089.htm

Fitsum B.,Nega M.and Dejen T.2017. Analysis Current Rainfall Variability and Trends Over Bale Zone ,South Eastern Highland of Ethiopia. *Science Fed Journal of Global Warming, Volume 1, Issue 2.*

Food and Agriculture Organization (FAO) .2018.Country Profile, Ethiopia.

Funte S.,Negesse T and Legesse G. 2010.Feed resources and their management systems in Ethiopian highlands: the case of UmbuloWacho watershed in southern Ethiopia. *Tropical and Subtropical Agro ecosystems, 12: 47 – 56*

Garduno-castro Y.,Espinoza-Ortega A.,Gonzalez –Esquivel CE.,Mateo-Salazar B.and Arriaga – Jordan CM.2009. Inter cropped oats(Avena Sativa) with common vetch(Vicia sativa) silage in the dry season for small scale dairy systems in the highlands of central Mexico.*Tropical animal health and production,41(5):827-834.*

Gebremedhn ,B., Araya, HA., Gebremedhn ,BH .2015. Evaluation of different oat varieties for fodder yield and yield related traits in Debre Berhan Area, Central Highlands of Ethiopia.*Livestock Research for Rural Development 27(9).*

Geleti D.2000. Productivity and nutritional qualities of panicum coloratum under varying stages of harvest , different levels of nitrogen fertilizer and in combination with stylosanthes guianensis during establishment year. M.Sc. thesis submitted to Alemaya University, Ethiopia.

Geleti D.2014. Agronomic and nutritional evaluation of selected forage legumes and locally available feed stuff, and characterization of forage and dairy innovation systems in Bako and Nekemte -peri urban areas, Oromia, Ethiopia.Pp.87-103.

Gemechis B. Diriba D. and Gemeda D.2019.Biomass Yield and Nutritive Values of Pennisetum pedicellatum and Lablab purpureus Mixed Pasture as Affected byPlanting Pattern Under Nekemte Condition, Western Ethiopia. *Middle-East Journal of Scientific Research 27 (5): 455-464.*

Genet A. and Ledin I.2001. Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology, 92: 95-111.*

Getahu B. and Tegene N. 2019 .Feed resource availability and their nutrient contribution for livestock evaluated using feed assessment tool (FEAST) in Burie Zuria District, North Western Ethiopia. *Agricultural and Technology Open Access Journal 17(3).*

Getnet A. 1999. Feed resource assessment and evaluation of forage yield, quality and intake of oats and vetches grown in pure stands and mixtures in the highlands of Ethiopia

Gezahagn K, Getnet A., Alemayehu M. and Fekede F., 2014. Forage nutritive values of vetch species and their accessions grown under nitosol and vertisol conditions in the central highlands of Ethiopia .*Livestock Research for Rural Development.Vol.26, Article #20.*

Gezahagn K., Fekede F., Getnet A., Alemayehu M.,Muluneh M., Tadesse T., Mamaru T.2017a .Response of vetch species for different drainage methods on vertisols in the central highland areas of Ethiopia. *International Journal of Research Study Agricultural Science.3 (2): 6-16.*

Gezahagn K., Genet A., Fekede F.and Alemayehu M. 2016. Forage Legumes in Crop Livestock Mixed Farming Systems –A review. *International Journal of Livestock Research, vol.6 (4), ISSN2277-1964*

Ghahramani A., Howden S.M., Del Prado A.,Thomas D.T., Moore A.D., Ji B., Ates S. 2019. Climate change impact, adaptation, and mitigation in temperate grazing systems: *A review. Sustainability , Volume 11, 7224. [CrossRef]*

Girma D., Ashenafi M. and Gebreyohanes B.2017.Farmers 'Perceptions of Climate Change and its Implication on Livestock Production in Mixed – Farming System Areas of Bale Highlands, South East Ethiopia. *Journal of Agricultural Research and Development; Volume 7(2).Pp.092-0102*

Gizachew L.and Smit G.N.2005. Crude protein and mineral composition of major crop residues and supplemental feeds produced on Verti soil of the Ethiopian highland. *Animal Feed Science and Technology, 119:143-53.*

Greene L.W. 2000.Designing mineral supplementation of forage programs for beef cattle. *Journal of Animal Science.77: 1-9.*

Gugino B. K., Idowu O.J.,Schindelbeck H.M., Van Es D.W., Wolfe B.N.,MoebiusClune J.E.,Thies and Bawi G.S.2009.Cornel Soil Health Assessment Training Manual.2nd ed. Communication Services, NYSAES , Geneva, NY.

Hadji M.E.2000.Compatibility, Yield, and Quality of Perennial Warm-Season Grass-Legume Mixtures. Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Crop and Soil Environmental Sciences, Blacksburg, Virginia.

Hakan G., Riza A., Hikmet S.and Behcet K.2008 . Intercropping of corn with cow pea and bean biomass yield and silage quality in Turkey. African Journal of Biotechnology, Volume 7(22), Pp.4100-4104.

Hakl J., Fuksa P., Koneˇcná J., Šantr ˚uˇcek J. 2016.Differences in the crude protein fractions of lucerne leaves and stems under different stand structures. *Grass Forage Science, 71, 413–423. [CrossRef]*

Herridge DF, MBPeoples, RM, Boddey.2008. Global inputs of Biological nitrogen Fixation in agricultural systems. Plant and Soil :311:1-18.

Heuzé V., Tran G.,BoundA.,and Lebas F.2016. Oat Forage. Feedipedia, a Programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/Node/500 last updated on April 13, 2016, 16:26."OatForag/Feedipedia, 13 Apr. 2016, www.feedipedia.org/node/12390.mmm

Heuzé V.,TranG.,Bound A., and Lebas F.2016.Oat Forage. Feedipedia, a Programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/Node/500 last updated on April 13, 2016, 16:26."Oat Forage | Feedipedia, 13 Apr. 2016, www.feedipedia.org/node/12390.

HeuzeV.,TranG.,GigerReverdinS.2015a.Peaforagefeedipedia,programbyINRA,CIRAD,AFZand FAO.https://www.feedpedia.org/model/7047 .

Hintsa HB. 2016 The effect of improved Fodder Production on Livestock Productivity in Endamehoni District, Southern Tigray, Ethiopia. A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Land Resource Management and Environmental Protection. Mekele University Ethiopia.

Hoffman P.C. and Taysom D. 2005. Ash content of forages, Volume 149, NO.20:659

Horticoop Ethiopia (Horticulture) PLC 2018/2019.Soil and Water Analysis Laboratory, Debere Zeit, Ethiopia

ILRI.2014. International Livestock Research Institute report, Nairobi, Kenya ,2

Jaballa O.R. 1995.Response of upland rice varieties to nitrogen fertilization and intercropping.

James K., Mutegi D., Mugendi L.V., Verchot J.B., Kungu.2008. Combining Napier grass with leguminous shrubs in contour hedge rows controls soil erosion without competing with crops.*Agroforestry systems, 74:37-49. Journal of Agricultural science,13: 212 – 221.*

Jukenvicius S. and Sabiene N. 2007.The content of mineral elements in some grasses and legumes. *Ecological, 53:44-52.*

Karachi M.1997. Growth and nutritive value of lablab purpureus accessions in Semi –arid Kenya .*Tropical Grasslands 31:214-218.*

Kassahun D. and Wasihun H.2015. Evaluation of Biomass Yield and Nutritional Value of Vetch (*vicia)* at Agricultural Research Center of Jimma University, Ethiopia .*Academic Journal of Nutrition, 4(3):99-105.*

Katarzyna P.,Agnieszka S., Stanislaw P.,Jan B.,Kazimierz K.,and Andrzej L.,2021. The performance of oat-vetch mixtures in organic and conventional farming systems.*Agriculture 2021, 11,332.*

KecheroV.2008. Effects of seed proportions of Rhodes grass (*Chloris gayana*) and White sweet clover (*Melilotus alba*) at sowing on agronomic characteristics and nutritional quality. *Livestock Research for Rural Development, Pp. 2-20.*

Kelling K.A. and Schulte E.E.2004.Soil and applied calcium. Understanding plant nutrients .A2523 .University of Wisconsin-Extension.

Kezemi M, .Tahmasbi A.M., Naserian A.A.,Valizadeh R. and Moheghi MM.2012. Potential nutritive value of some forage species used as ruminant feed in Iran. *African Journal of Biotechnology .11:12110-12117*

Khan A, Anjum MU, Rehman M, Zaman Q, Ullah R. 2014. Comparative Study on Quantitative and Qualitative Characters of Different Oat (*Avena sativa* L.). Genotypes under agro-climatic conditions of Sargodha , Pakistan. *American Journal of Plant Sciences 5(20): 3097- 3103.*

Koidou M.,Mountousis I.,Dotas V., Zagorakis K.,YiakoulakiM.2019.Temporal variations of herbage production and nutritive value of three grasslands at different elevation zones regarding grazing needs and welfare of ruminants. *Arch. Animal Breed. 62, 215–226. [CrossRef]*

Lal R. 2006.Enhancing crop yields in developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degrad. Dev. 17, 197–209.*

Lamb J.A.,Fernandez F.G .and Kaiser D.E.2014.Understanding nitrogen in soils. Nutrient management.University of Minnesota, Twin Cities, MN.

Larbi A.,Hassan ,S., Kattash,G., A.M.Abd Elmoneim ,Jammal ,B., Nabil,H.,Nakkul,H. 2010. Annual feed legume yield and quality in dry land environments in North West Syria: Herbage yield and quality. *Animal feed science technology, 160:81-89.*

Lemma T.,Puskur R.,Hoekstra D. and Tegegne A.2010. Commercialization of dairy and forage systems in Ethiopia: An innovation systems perspective.*Working paper 17.ILRI, Nairobi, Kenya.*

Leuscher A, J Fuhrer, PCD Newton. 2005. Global atmospheric change and its effect on managed grassland systems. *In: McGilloway,DA.,(ed.). Grassland: a global resource. Wageningen, Academic Press: Pp. 251-264.*

Lithourgidis A.S., Vasilakoglou I.B., Dhima K.V., Dordas C.A. and Yiakoulaki M.D. 2006. Forage yield and quality of common vetch mixtures with oat and triticalein two seedling ratios. *Field Crops Research, 99: 106–113.*

Lopez-bellidoGarrido, R.J. and Lopez-bellido L . 2001.Effects of crop rotation and nitrogen fertilization on soil nitrate and wheat yield under rain fed Mediterranean conditions. *Agronomy, 21: 509–516.*

Malede B.and Takele A.2014. Livestock Feed Resources Assessment, Constraints and Improvement Strategies in Ethiopia, University of Gondar, Faculty of Veterinary Medicine Department of Animal Production and Extension, Gondar, Ethiopia. *Middle-East Journal of Scientific Research 21 (4), 616-622*

Malede.B.2013. Forage Agronomic Evaluation and Biological Compatibility on Grasse: Legume Intercropping in North Gondar Zone, Ethiopia. *American Eurasian Journal of Scientific Research 8(4):Pp. 157-162*

Malik R.; Paynter, B.; Webster, C.; McLarty, A.2011. Growing oats in Western Australia for hay and grain.Department ,Agriculture and Food. Government of Western Australia, Bull.

Matt A., Sanderson., Geoffrey B., Robert S. and Leah R. 2013. Grass–Legume Proportions in Forage Seed Mixtures and Effects

Maynard LA,Loosli JK.2009. Animal nutrition (6 thed).Tata Mc Graw –Hill Publishing company Ltd ,New Delhi ,*India pp:108-148.*

Mc Donald P.,Edwards R.A., Greenhalgh J.F.D., Morgan C.A., Sinclair L.A. and Wilkinson R.G.2010. Animal nutrition 7th edition. Ashford colours press ltd, Gosport.

Mc Donald, P.,Edwards,Raj.,Green, halgh FD .,Morgan,CA.2002.Animal nutrition 6thed.Longman ,UK

Mc Dowell LR., 2003. Minerals in animals and human nutrition, 2nd ed., (Elsvier,Amsterdam,the Netherlands).

McDonald P., EdwardiRA.,GreenhalghiJFD.,MorganiGA.2002. Animal nutrition 6th ed. Pearson Educational Limited: Edinburgh; 2002.p.544.

Mekuanint G. and Girma D.2017.Livestock feed resources, nutritional value and their implication on animal productivity in mixed farming system in Gasera and Ginnir

Districts, Bale Zone, Ethiopia . *International Journal of Livestock Production, Vol. 8(2), pp. 12-23,*

Melkamu B., Duncan A.J., AdieA., Kindu M., Khan N.A. and Thorne P. 2016. The Role Of Irrigated Fodder Production to Supplement the Diet Of Fattening Sheep By Smallholders In Southern Ethiopia. *Tropical and Subtropical Agro ecosystems, 19 (2016),263 -275*

Melkamu B.,Kindu M., Aberra A., Peter T.,2016 . Guidelines on the utilization of cultivated oat-vetch and tree lucern fodder in the Africa Rising Sites of the Ethiopian highlands. *International Livestock Research Institute. www.africa-rising.net.*

Mengistu A. 2002.Forage production in Ethiopia: A case study with implications for livestock production.*Ethiopian Society of Animal Production, Addis Ababa, Ethiopia Addis Ababa, Ethiopia. P. 125*

Mengistu S. 2008. Forage development for sheep and goats, Sheep and goat production handbook for Ethiopia.Ethiopian Sheep and Goat Productivity Improvement Program.

Messina C, Hammer G, Dong Z, Podlich D, Cooper M .2009.Modeling crop improvement in a GxExM framework via gene-trait phenotype relationships. In: Sadras, V.O., Calderini, D. (Eds.), Crop physiology: Applications for Genetic Improvement and Agronomy. *Elsevier, Netherlands . Pp. 235-265.*

Minichle YG.,Berhanu A. and Asnake A.2019. Dry matter yield and nutritional value of Desho and Setaria grasses mixed with green leaf Desmodium at different harvesting times Debre Markos Ethiopia. *Academic Research Journal of Agricultural Science and Research*

MoARD (Ministry of Agriculture and Rural Development) .2011.Crop development department, crop variety register.*Issue NO.10.MoARD, Addis Ababa, Ethiopia.Pp.167-169.*

MoARD(Ministry of Agriculture and Rural Development) 2005. Agro-ecological zones of Ethiopia. MOARD, Addis Ababa, Ethiopia

Mohammadi KSY., GKS Heidari., M Majidi., 2012. Effective factor on Biological Nitrogen Fixation.*African Journal of Agricultural Research7 (12):1782-1788.*

Mohammed S.,M.A.and Abate T.1995. Feed improvement to support intensification of ruminant production systems in the Ethiopian highlands.Pp.296-306. *In: proceedings of the 3rd Annual conference of the Ethiopian Society of Animal Production, Addis Ababa, Ethiopia*

Mues N.2013 .Growing oats for extra pasture, silage, hay, silage.*High Plains Journal: 129 20: 11*

Muhammad N., Ansar M.,Adeel A.,Ashiq H. and Sartaj K.2010. Performance of winter cereal-legumes fodder mixtures and their pure stand at different growth stages under rain fed conditions at Pothowar ,*Pakistan.Journal of Agricultural Research, Volume 48(2).*

Muhammad S.,Muhammad A.,Muhammad S.,Naveed A.,Muhammad T. and Muhammud ,A.2014.Dry matter yield and forage quality of oat , barley and canola mixture. *Pakistan Journal of Agricultural Science, Volume 51(2), 433-439.*

Muhammad T. and Nawal Z.2016. Forage yield and quality performance of Rabi cereals sown alone and in blended population at variable seed ratios. *Pakistan Journal of Agricultural Research.Vol.29 .No.2*

Muluneh M.2006. Effect of Rhizobium inoculation on nodulation,Nitrogen fixation and yield of some annual forage legumes (*Vicia Spp*.) on nitisol and vertisol of the central highlands of Ethiopia.MSc.Thesis. Alemaya University of Agriculture ,Ethiopia.

Mustafa A.F., McKinnon J.J. and Christensen D.A.2000. The nutritive value of thins tillage and wet distiller's grains for ruminants. *Asian Australian Journal of Animal Science.13:1609-1618.*

Nazakat, N., Razzaq, A., Ali, Z.,Sarwar. G. and Yousaf . M. 2004 .Performance of Different Oat (Avena Sativa L.)Varieties under Agro-Climatic Conditions of Bahawalpur–Pakistan.*International Journal of Agriculture & Biology, 1560–8530/2004/06–4–624–626, http://www.ijab.org*

Negash D .2014. Evaluation of yield and nutritive value of oats (*Avena sativa*) grown in mixture with vetch (*Vicia villosa*) with or without phosphorus fertilization. Haramaya University, Ethiopia.

Negash D.,Animut G.,Urgie M. and Mengistu S.2017. Chemical composition and nutritive value of oats (Avena sativa) grown in mixtures with vetch (Vicia villosa) with or without phosphorus fertilization in East Shoa zone ,Ethiopia. *Journal of Nutrition and Food Sciences, Volume 7(4), ISSN: 2155-9600.*

Nyfeler D, O-Elie Huguenin, M Suter , E Frossard , J Connolly , A Lüscher.2009. Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive over yielding. *Journal Applied Ecology 46:683-691.*

Onifade .OS.,Akinola JO. andAdu IF.1994. An Evaluation of Stylosanthes- Grass Mixtures for Pasture leys. *In: proceedings of the regional workshop on the use of stylosanthesin West Africa held in Kaduna, Nigeria, 26-31.*

Rahetlah VB.JM .,Randrianaivoarivony LH., Razafimpamoa,Ramalanjaona VL.2010. Effects of seeding rates on forage yield and quality of oat (avena sativa l.) vetch (vicia sativa L.) Mixtures under Irrigated Conditions of Madagascar *.African Journal of Food Agriculture Ntutrition and Development, Volume 10 NO.10, ISSN 16845374, Peer Reviewed*

ReboleA.,Alzueta ,C., Ortiz L.T., BaroC.,Rodriguez M.L.,Caballero,R.2004. Yields and chemical composition of different parts of common vetch at flowering and at two seedling stages.*Spanish Journal of Agricultural Research, 2(4):550-557.*

Reddy R.S.2000.Principles of crop production.Kalyani Publishers *,New Delhi-110 002, India. Pp 45-47.*

Said M. P., Sitti W., Anuraga J. and Samadi . 2018.Evaluation of Agro-Industrial By Products as Potential Local Feed for Ruminant Animals: Chemical Composition, Fiber Fractions and In Vitro Rumen Fermentation *.Volume 20(3).: 155-164*

Saleem M. and Abate T.1995. Feed improvement to support intensification of ruminant production systems in the Ethiopian highlands.

Salo S., Tadesse G.and Haylemeskel D.2017. Survey on Constraints of Improved Forage Adoption in Anelemo Woreda, Hadiya Zone, Ethiopia *.Agricultural Research and Technology Open Access Journal, ISSN: 2471-6774, Research Article, Vol.12 (2).*

Samson L.and Frehiwot M.2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market assess, Springer plus 3, Article number: 310(2014)

Sanderson, M.A. and Gerald F.E.1999 .Grass species and cultivar effects on establishment of grass-white clover mixtures.*Agronomy Journal* 91(6), Pp. 889-897.

SAS, 2009 .Statistical Analysis System Software, Version 9.3. SAS Institute. Inc., Cary.NC. USA.

Schjoerring J.K., CakmakI., White P.J. 2019. Plant nutrition and soil fertility: Synergies for acquiring global green growth and sustainable development. *Plant Soil, 434, 1–6.*

Seyoum B.,Getnet A.,Abate T.and Dereje F.2001. Present status and Future direction in Feed Resources and Nutrition Research Targeted for Wheat Based Crop Livestock Production System in Ethiopia. Pp.207-226.In:P.C.Wall (eds.), Wheat and weed Food and Feed. Proceedings of Two stake holder work shops

Shah,S.,Akhtar L.H.,Minhas R., Bukhari M.S.,Ghani,A.,Anjum M.H.2015.Evaluation of different oats(*Avena sativa L.*) varieties for forage yield and related characteristics. *Science lett.3 (1):13-16.*

Shanker RB. 2018. The fodder oat (*Avena sativa*) mixed legume forages farming: Nutritional and ecological benefits. *Journal of Agriculture and Natural Resources, 1(1):206-222*

Shimelis M. 2018. Assessment of Forage Production, Feed Resource Utilization and Substitution Effect of Oat-Vetch Forage for Concentrate mix on Performance of Sheep Fed Desho Grass as a Basal Diet in Damote Gale District of Wolaita Zone, SNNPR

Shimelis M. and Temesgen A. 2016.Training report on forage production, feed management and utilization for Africa RISING project farmers in Basona Worena, Ethiopia

Shoaib ,M.,Ayub,M.,Zamir ,M.,Akhar M.J.2013. Dry matter yield of oat –Egyptian clover mixture under varying proportions and different growth stages of oat. *International Journal of Agricultural Biology: 15(4): 673-9.*

Singh G.P. and Oosting S.J. 1992.A model for describing the energy value of straws. *Indian Dairy man XLI, pp.: 322-327.*

Sisay B.,Teklu W.,Dawit A., Sultan U., and Adugna T.2012.Application of Tech Fit to prioritize feed technologies in Sinana Distrct of Bale Highlands, Southeastern Ethiopia.

Solomon B. 2004 .Assessment of Livestock Production System and Feed Resource Base in Sinana-Dinsho District of Bale Highlands, Southeast Oromia. M.Sc. Thesis, Alemeya University, Alemeya Pp. 24-26

Solomon B.,Solomon M. and Alemu Y.2008. Potential use of crop residues as livestock resources under holder farmers conditions in Bale highlands of Ethiopia. *Tropical and sub-tropical agro ecosystems, 8(1), Pp.107-114*

SOMSC (South Oromia Meteorological Service Center) .2021.Bale Robe , Ethiopia.

Starks P.J.,Zhao D.,Philips W.A.,Coleman S.W.2006 .Herbage mass, nutritive value and canopy spectral reflectance of Bermuda grass. *Grass Forage Science, 61:101111.*

Striker GG.2012.Flooding Stress on Plants: Anatomical, Morphological and Physiological Responses *.Botany, PP, 3-8 Accessed on 15/9/2021*

Sturludottir E, Brophy C, Elanger GB, Gustavsson AM, Jorgensen M, Lunnan T, Helgadotti A 2013. Benefits of mixing grasses and legumes for herbage yield and nutritive value in Northern Europe and Canada.*Journal of the British Grassland Society 12037:1-12.*

Suttie JM. and Reynolds .SG .2004.Fodder oats. A world over view.*FAO, ISBN: 92-5-105243-3. http:/www.fao.org/008/y5765 e/y 5765 e00.htm.*

Swotantra D.2020. Oats as Green Fodder and its Intercropping Benefits. Agricultural Reviews

Tadesse A. and Solomon A. 2014.Assessment of Grazing Land and Livestock Feed Balance in Gummara_Rib Watershed, Ethiopia. *Current Agricultural Research Journal : Vol.2(2)pp;114-122.*

Tarawali S.A., Tarawali G.,Lirbi,A. and Hanson J. 1995. Method for the evaluation of Forage legumes, Grasses and Fodder Trees for Feed Use as Livestock Feed , *International Livestock research Institute; Nairobi, Kenya.*

Tegegne A., Gebremedhin B., Hoekstra D., Belay B., and Mekasha Y. 2013. Smallholder dairy production and marketing systems in Ethiopia: IPMS experiences and opportunities for market-oriented development. *Working Paper No. 31. ILRI: Addis, Ababa, Ethiopia*

Tesfaye B.A.2020. Evaluation of Biomass Yield , Seed Yield and Chemical Composition of Vetch and Oats Grown in Pure stand and in Mixture in Mareka District , southern Ethiopia ,MSc Thesis , February 2020 , Jimma Ethiopia.

Tesfaye F.,Adugna T., Ajebu N.,Mulubrahan B., Sintayehu Y., Misaye B.,Morkata B. and Adegbola A. 2022.Assessment of fodder resources in Ethiopia. Biomass production and nutritional value *.Agronomy Journal, Volume 114, Issue 1.*

Teshome A., Bekele M.and Tekleyohannes B.2004. Evaluation of different oat/vetch mixtures for forage yield performance and compatibility in the highlands of Bale Ethiopia.*12th ESAP-proceedings.*

Tessema Z. and Baars R.M.T. 2004.Chemical component, in vitro dry matter digestibility and Ruminal degradation of Napier grass (Pennisetum purpureum (L.) Schumach) mixed with different levels of Sesbania sesban (L.) Merr.) . *Animal Feed Science and Technology, 117:29–41.*

Tessema Z.and Baars R.M.T.2006 .Chemical composition, dry matter production and yield dynamics of tropical grasses mixed with perennial forage legumes. *Tropical grasslands*, Volume (40), 150-156.

Thompson D. J., Stout D. G., and Moore T.1992. Forage production by four annual cropping sequences emphasizing barley under irrigation in southern interior British Columbia. *Canadian Journal of Plant Science, 72(1), 181-185.*

Thomson E.F., Rihavi S. and Nersoyan N.1990. Nutritive value and yields of some forage legumes and barley harvested as immature herbage, hay and straw in North-West Syria. *Experimental Agriculture, 26, 49–56.*

Tolera A. 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 (SPS-LMM) Program, Addis Ababa, Ethiopia Pp. 77

Tolera T.,Alemu Y., Alemayehu M.,Dawit A., Diriba G.,Getnet A.,Lemma G.,Seyoum B. and Yirdaw .2012 .Livestock feed resources in Ethiopia: Challenges, Opportunities and the need for transformation ,*National feed committee reports, Ethiopian animal feed industry association (EAFIA) and the Ministry of Agriculture and Rural Development (MoARD), Addis Ababa, Ethiopia.*

Tsehay R.2002 .Small-scale milk marketing and processing in Ethiopia.352-367 Pp. In: Small holder dairy production and market opportunity and constrains. Proceedings of south workshop held at NDDB,Anand, India,13-16 March ,2001 NDDB(National Dairy

Development Board),Anand, India and ILRI(International Livestock Research Institute) ,Nairobi ,Kenya

Umuna N.N., Osuji P.O., Khalili H., Nsahlai I.V. and Cross S. 1995. Comparative feeding value of forages from two cereal-legume based cropping systems for beef production of crossbred (Bos Taurus X Bosindicus) steers and subsequent performance of underfed and realimented steers. *Animal Science, 61: 35–42.*

Umunna NN.,Osuji PO.and Nsahli IV.1997. Strategic supplementation of cross bred steers fed forages from cereal-legume cropping systems with cow pea hay. *Journal of Applied Animal Research, 11(2):169-182.*

Unathi G.,Mgujulwa N. and Solomon TB.2018. Benefits of grass-legume inter-cropping livestock systems in South Africa .*African Journal of Agricultural Research*, Vol. 13(26), pp. 1311-1319

Van Soest P.J.1965. Symposium on factors influencing the voluntary intake in relation to chemical composition and digestibility.*Journal of Animal Science24: 834.*

Van soest, P.J., Roberston JB., Lewis BA.1991.Methods for dietary fiber, neutral detergent fiber, and non –starch polysaccharides in relation to animal nutrition.*Journal of Dairy Science 74: 3583-3597.*

Vansoest, P.J. and Robertson, J.B. 1985. Analysis of forages and Fibrous Foods.A laboratory *Manual for Animal Science 613. Cornell University, Ithaca, New York, USA*

Vansoest, P.J.1982.Nutritional ecology of the ruminant O and B books, *Inc cornell University, U.S.A, Pp 373.*

Wakgari K.,Taye T. and Abdo M.2022. Evaluation of grain/seed yield and yield components of finger millet and three vetch species intercropped at various seeding ratios at Bako,Ethiopia. *Advances in Agriculture, Article ID1608499,https://doi.org/10.1155/2022*

Welch R.W., Brown J.C.W. and Leggett J.M. 2000 .Interspecific and intraspecific variation in grain and groat characteris-tics of wild oat (Avena) species: Very high groat (1-3), (1-4)-ß-D-glucan in an Avenaatlantica genotype. *Journal of Cereal Science, 31, 273-279.*

Willey RW.and Rao MR.1980. Competitive ratio for quantifying competition between intercrops: *Experimental Agriculture, 16(2), 117-125.*

Workye M.,Aschalew A. and Kirkim D. 2018. Improved forage production practice and challenges in Libokemkem District, Ethiopia. *Agricultural Science Digest - A Research Journal,* 38(4), pp; 280-284

YamiM.Begna B.and Teklewold T.2013.enhancing the productivity of feeding strategies and utilization. *International Journal of Livestock Production1:15-29*

Yayneshet T.2010. Ethiopian sanitary and phytosanitary standards and livestock and meat marketing program (SPS-LMM) Texas A and M University system: Feed resources availability in Tigray region, northern Ethiopia, for production of export quality meat and livestock.

Yeshitila A., Tessema Z.and Azage T.2008. Availability of livestock feed resources in Alaba Woreda, Southern Ethiopia. *In proceedings of the 16th annual conference of the Ethiopian society of Animal production (ESAP) held in Addis Ababa, Ethiopia*

Zinash S., Seyom B., Lulseged G.and Tadesse T.1995. Effect of harvesting stage on yield and quality of natural pasture in the central highlands of Ethiopia *.In: Proceedings of 3rd national conference of the Ethiopian society of animal production.27-29, April 1995.pp.316-322. Addis Ababa, Ethiopia.*

Zinash S.2004. Livestock production system, Short-term course in Awassa University, Awassa, Ethiopia.Pp.47

7. APPENDICES

Appendix Table 1 .The meteorological data of MWU and SARC on station from June to November

Location	Months	Temperature (^oc)		Rainfall(ml)
		Max.	Min.	
	June	23.5	6.8	3.5
	July	23.9	9.2	40.3
	August	24.1	9.6	168.1
	Sept	24	9.7	64.1
	Oct	24.2	8.8	1.7
SARC	Nov	23.5	6.8	30.7
MWU				
	June	22.1	6.1	0
	July	21.5	9.4	0.4
	August	22.1	9.7	123.3
	Sept	21.7	9.3	70.3
	Oct	21.9	8.9	65.57
	Nov	21.3	7.6	23.5

Source: Bale -Robe Meteorological Station, (2021)

Appendix Table 2.Mean square of ANOVA for plant height (PHV,PHO, DMY, DMYT, RYT, LERT, CRO and CRV as affected by seed proportion and planting pattern (Trt) , location(L) and two way interaction of TrtxL

Parameters	DF	PHv	PHO	DMYO	DMYV	DMYT	RYO	RYV	RYT	LERO	LERV	LERT	CRO	CRV
Rep	2	795.74 ns	17.63 ns	0.22ns	4.5ns	6.32ns	0.200 ns	0.14 ns	0.12 ns	0.301 ns	0.33 ns	0.34ns	0.9ns	0.1ns
Trt	#	8700.74***	20808.7***	192.731***	71.1***	358.22***	0.2933 ***	0.272***	0.905***	13.94***	0.51 ***	16.461***	175.5***	11.1 ***
L	1	1095.5***	839.3 ***	49.61 ***	101.34***	292.8 ***	0.063***	0.00292 ns	0.094**	15.88 ***	0.0298*	14.5042***	43.32***	0.51 ***
TrtxL	#	155.54 ***	62.023 ns	4.695 *	14.52 ***	25.33 ***	0.0053*	0.02 **	0.03 **	6.26 ***	0.0098**	6.148 ***	14.1 ***	0.203***
TrtxRep	#	17.73 ns	47.9 ns	2.402 ns	0.86 ns	4.58 ns	0.003 ns	0.0029 ns	0.01 ns	0.2 ns	0.006 ns	0.192 ns	1.03 ns	0.013ns
LxRep	2	130.41ns	109.94ns	1.393 ns	2.631 ns	2.78ns	0.00311 ns	0.02 ns	0.0074ns	0.253 ns	0.00452 ns	0.323 ns	0.019 ns	0.0017ns
Error	#	135.5	58.8	1.69	1.3	4.27	0	0		0.11	0.004	0.1293	0.97	0.016
Corrected T	#	2159	4830	47.3	22	95.241	0.1	0		4.986	0.123	5.54	44.7	0.302

DF=Degree of freedom; Rep=Replication ;Trt=Treatment; PHV=Plant height in vetch; PHO=plant height in oat; DMYO =Dry matter yield in oat ;DMYV=Dry matter yield in vetch; DMYT=Dry matter yield total ;RYO =Relative yield in oat ;RYV=Relative yield in vetch ;RYT=Relative yield total ;LERO =Land equivalent ratio in oat ;LERV=Land equivalent ratio in vetch ,LERT =Total land equivalent ratio in oat and vetch ;CRO =Competitive ratio in oat; CRV =Competitive ratio in vetch ; NS= Non- Significant ,Corrected T= Corrected Total

Appendix Table 3 .Mean square of ANOVA for NDF, Ash, DMO,CP,ADF and ADL content of sole and mixed stand of oat and vetch as affected by seed proportion and planting pattern(Trt) ,Location(L) and two way interaction of Trt and L(TrtxL)

Source of variation	Mean squares						
	DF	NDF	Ash	DMO	CP	ADF	ADL
Rep	2	19.167NS	40.421NS	0.373NS	0.235NS	4.763NS	0.236NS
Trt	14	371.545***	6.880**	19.058**	36.529***	32.34*	4.62***
L	1	145.140NS	151.813***	1.257***	16.358***	22.130NS	1.332NS
TrtxL	14	143.626NS	4.512NS	10.589NS	10.037NS	14.270NS	3.667NS
TrtxRep	28	90.031NS	5.294NS	4.710NS	3.213NS	13.242NS	1.266NS
LxRep	2	42.988NS	0.830NS	11.682NS	3.795NS	4.424NS	1.903NS
Error	28	83.452	3.710	5.086	5.063	12.66	2.251
Corrected T	89	163.98	9.01	9.381	12.563	1407.317	2.58

DF=Degree of freedom ,NDF= Neutral Detergent Fiber ,DMO=Organic Dry Matter ,CP= Crude protein ,ADF=Acid Detergent Fiber=ADL= Acid Detergent Lignin, L= Location ,Trt= Treatment,Rep=Replication ,TrtxL=Treatment interaction by location ,TrtxRep= Treatment interaction by Replication ,Corrected T= Corrected Total ,NS= Non-significant at % 5, *,**,and ***=significant and highly significant

Appendix Table 4.Mean square of ANOVA for CPY, NDFY and CPY+NDF Content of sole and mixed stand of oat and vetch as affected by seed proportion and planting pattern (Trt) , Location(L) and their interaction (TrtxL)

Source of variation		Mean squares		
	DF	CPY	NDFY	CPY+NDFY
Rep	2	0.138NS	2.934NS	3.718NS
Trt	14	0.61**	11.433**	16.78**
L	1	3.999***	84.541***	125.315***
TrtxL	14	0.607**	11.433**	16.98**
TrtxRep	28	0.247NS	3.173NS	3.98NS
LxRep	2	0.00743NS	1.431NS	1.584NS
Error	28	0.185	3.169	4.349
Corrected Total	89	2.353	24.22	40.392

** =Significant difference at ($P<0.05$); ***= Highly significant difference at($P<0.01$);NS= Non-significant difference at ($P>0.05$);DF= Degree of freedom ;Rep=Replication; Trt=Treatments ;L=Locations;;TrtxL=Treatment interaction with location ;TrtxRep=Treatment interaction with replication ;LxRep=Location interaction with replication

a) SARC b) MWU

Appendix Figure 1. Partial view during land preparation and sowing sole and mixed stand of oat and vetch

a) MWU b) SARC

Appendix Figure 2. Partial view during weed removal from sole and mixed stand of oat and vetch in experimental sites at left side MWU and right SARC at right side

a) Pure(sole) stand vetch b) mixture of oat and vetch c) Pure (sole) stand oat

Appendix Figure 3. During 50% flowering stage and heading stage of sole and mixed stand of vetch and oat

Appendix Figure 5. During Sample Preparation for Laboratory Analysis for SARC and MWU