EVALUATION OFBIOMASS YIELD,SEED YIELD AND CHEMICAL COMPOSITION OF VETCH AND OATSGROWN IN PURE STAND AND IN MIXTURE IN MAREKA DISTRICT, SOUTHERNETHIOPIA

MSc THESIS

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February, 2020

Jimma, Ethiopia

EVALUATION OFBIOMASS YIELD,SEED YIELD AND CHEMICAL COMPOSITION OF VETCH AND OATSGROWN IN PURE STAND AND IN MIXTURE IN MAREKA DISTRICT, SOUTHERN ETHIOPIA

A Thesis

Submitted to Department of Animal Sciences, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirement for the Degree of Master of Science in Animal Production.

By

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, I hereby kindly request the department to allow me to present the findings of my work and submit my thesis.

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We, the thesis advisors have evaluated the content of this thesis and found to satisfactory executed according to the approved proposal written, according to the standard and format of the university and ready to be submitted. Hence, we recommend the thesis to be submitted.

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Chairperson, DGC Signature Date

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DEDICATION

I dedicate this thesis manuscript to my son Nathan Tesfaye who toleratedmy love as destitute from me throughout my study and I set aside this script to my wed beloved wife w/o Abebech Tadesse for her moral support and taking full responsibility for the family during my absence for graduate studies at Jimma university.

STATEMENT OF AUTHOR

I hereby declare and confirm that this thesis is my own work and all sources of materials used for this thesis has been acknowledged. I have followed all ethical and technical principles of scholarships in the preparation, data collection, data analysis and completion of this thesis. This thesis has been submitted in partial fulfillment of the requirements for MSc Degree at Jimma University and is deposited at the University Library to be made available to borrowers under the rules of the Library. I declare that this thesis is not submitted to any other institution anywhere for the award of academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born in April 1988from his father Belayneh Abagojam and his mother Atsede UtainMareka district, Dawuro Zone, South Nation Nationality and People Regional State, Ethiopia. He began his primary education at Gozo Shasho Primary school from grade 1-6 in 1995-2000. He then passed to Gozo Bamush elementary school and studied grade 7 and 8in 2001 and 2002. He followedhis high school studies grade 9 and 10 in 2004 and 2005 Waka Secondary SchoolDawuro Zone, Marekadistrict Southern Ethiopia. He joined WolaitaSoddo Agricultural Technical Vocational and Education Training (ATVET) College in 2006 and graduated with Diploma in Animal science in August, 2008.

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ACRONOMS AND ABBREVATIONS

*ADF*Acid Detergent Fiber

*ADL*Acid Detergent Lignin

ANOVAAnalysis of Variance

AOAC Association of Official Analytical Chemists

CECCation Exchangeable Capacity

CP Crude Protein

*CPY*Crude Protein Yield

*CSA*Central Statistical Agency

*CV*Coefficient of Variation

DASDay after Sowing

*DM*Dry Matter

DMYDry Matter Yield

GLM General Linear Model

*HS*Harvesting Stage

MOARDMinistry of Agriculture and Rural Development

NDF Neutral Detergent Fiber

NRCNational Research Center

OCOrganic Carbon

OMOrganic Matter

PHPlant Height

PPMPart per Million

RCBD Randomized Complete Block Design

RCC Relative Crowding Coefficient

RYRelative Yield

RYT Relative Yield Total

SAS Statistical Analysis System

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EVALUATION OF BIOMASS YIELD, SEED YIELD AND CHEMICAL COMPOSITION OF VETCH AND OATS GROWN IN PURE STAND AND IN MIXTURE IN MAREKADISTRICT, SOUTHERN ETHIOPIA

ABSTRACT

The experiment was carried out to assess the effect of varietyon biomass yield, seed yield, foragequality andbiological compatibility of oats and vetchgrown in the pure stand and in mixtures. The experiment was conductedduring main cropping season (March – November, 2019) at Gozo Bamush farmers training center (FTC) in Mareka district, Southern Ethiopia.Eight treatments wereset using two vetch speciesand two oat varietiesin sole and mixed stands as follows: T1 (pure stand Vicia vilosa 6792), T2 (pure stand Vicia sativa), T3 (pure stand Avena sativa 5431A), T4 (pure stand Avena sativa 15153A), T5 (Vicia vilosa 6792 + Avena sativa 5431A), T6 (Vicia vilosa 6792 + Avena sativa 15153A), T7(Vicia sativa + Avena sativa 5431A),T8 (Vicia sativa + Avena sativa 15153A). The experiment was laid outin Randomized Complete Block Design (RCBD) with three replications.Soil samples were collected before planting and after forage harvest. Data on agronomic parameters, biomass and seed yield as well as chemical compositions were recorded and subjected to analysis of variance (ANOVA) following the GLM procedures in SAS version 9.3 (32). Significanceof treatment effects wastastedusing least significant difference method at α = 0.05.Result showed that vetch based cropping increased the soil pH value from 4.7 before planting to5.04 to 5.56 after planting and organic carbon from 1.99 before planting to 2.1 to 2.63 after planting, total nitrogen from 0.17 before planting to0.19 to0.24 after planting. ANOVArevealed that the highest DMY (8.49 t/ha) was obtained from the mixture of Vicia vilosa 6792 + Avena sativa 15153A.Mean values of Ash, CP, EE,NDF,ADL, ADF,cellulose and hemicellulosshowed significant ($p<0.05$) difference.Among vetch species, Vicia vilosa 6792gave higher CPcontent(20.14%)and lower seed yield (1.19t/ha) andADF (40.35)compared to Vicia sativa which had a CP content of(19.4%), seed yield (1.92t/ha) and NDFcontent(49.35%).The nutrient indices showed that the highest TCPY (1.51t/ha) and TNDFY (4.04t/ha)wereobtainedfrom the mixture of Vicia vilosa 6792 + Avena sativa 15153A. Relative yield total (RYT) of oats and vetch varieties were greater than one in all mixed treatments indicating that the yield obtained in mixed stands were higher than the same species grown as sole crops. Thus, the RYT was higher by 70% in Vicia vilosa 6792 + Avena sativa 15153A mixture.The greatest acceptability in term of test was high for seeds frompure standsof Avena sativa 5431A and Vicia sativa.For dry matter yield the best combination wasVicia vilosa 6792and Avena sativa 15153Ain both pure stand and in mixture. This study highlightsthe positive potential of Vicia vilosa 6792 + Avena sativa 15153Ain forage yield, quality and also could enhance soilfertility to complement forage production at experiment site. However,the experiment was conducted in only one location over a single season, therefore,repeating the trialover different location and yearsin orderto draw more concrete recommendation.

Key words:*Chemical composition; Dry matter yield; mixed cropping; Oats accessions; Vetch varieties.*

1. INTRODUCTION

In many developing countries, livestock play an important role in the livelihoods of most small-scale farmers as sources of food in the form of meat and milk, services (transport and draught power), cash income, manure (for soil fertility management and fuel) and as store of wealth and hedge against inflation (Sere *et al.*, 2008). Ethiopia has a huge livestock population with an estimated 59.5 million cattle, 30.70 million sheep, 30.20 million goats, 2.16 million horses, 8.44 million donkeys, 0.41 million mules, 1.21 million camels, 56.53 million poultry (CSA, 2017). The livestock subsector has an enormous contribution to Ethiopia's national economy and livelihoods of many Ethiopians. However, the productivity of the livestock resources and the benefits obtained from the sector does not proportionate with the high livestock population due to various constraints that include poor nutrition and disease prevalence (Asfaw *et al*., 2011;Alemayehu and Getnet, 2012).

Among these constraints issues related to feed shortage are the most severe ones in livestock farming in almost all parts of Ethiopia(Adugna, 2007).Basically, this is due to the dependence of livestock on naturally available feed resources and little development of forage crops for feeding animals. Most of the areas in the highlands of the country are nowadays put under cultivation of cash and food crops. This resulted in keeping large number of livestock on limited grazing area leading to overgrazing and poor productivity. Though, expansion in the cultivation of cereal crops increased the supply of crop residues for animal feeding, crop residues have low nutritive value and could not support reasonable animal productivity(Solomon andTefera, 2010). Hence, shortage of quality and quantity feeds for livestock is increasingly becoming serious.

One of the alternatives to improve livestock feeding and thereby their productivity could be the cultivation of grass-legume mixtures and offer to animals during critical periods in their production cycle and when other sources of feeds are in short supply(Getnet and lendin, 2001).In the past, attempts have been made to improve the feed resource mainly by making new (high-yielding and better quality grass and forage) species known to farmers. Thus, there has to be an alternative means that will help the smallholder farmers to produce more biomass of forage for their animals from the limited land they own. However, in spite of serious problems of feed shortage and large number of livestock, adoption and popularization of forage crops at farmers level is remained very low due to inter alia shortage of forage seed, lack of awareness among smallholder farmers, lack of well-organized forage demonstration site and lack of well-organized extension services (FAO, 2004). This has resulted in significant decrease in milk production, loss of body weight, reduced draught power, increased susceptibility to diseases, and reduced reproductive performance and retarded growth rate and high mortalities of young animals (Alemayehu,2002). In order to alleviate the feed shortage, in Ethiopia generally and in the study area particular, establishment of forage crops such as oats in mixture with forage legume is mandatory.

Nowadays,many grass and legume species have been tested and recommended for the different agro-ecological zones in the country. Among the forage legumes, vetches are well adapted and more promising as short term fodder crops. One attraction of vetch is its versatility, which permits diverse utilization as either ruminant feed or green manure. Vetch has a higher crude protein content compared to many other tropical herbaceous legumes (Getnet and Ledin, 2001). From the grass species oat is grown very well on poor soils and waterlogged vertisol areas and is used as forage for livestock and as a grain for human consumption (Getnet *et al.*, 2003; Malik *et al.*, 2011; Molla *et al.*, 2018).

Integration of forage legumes into the cereal-based cropping system through different methods is one of the strategic interventions for optimizing the productivity of a given land use system (Tarawali *et al.*, 2002). Introduction and adoption of improved forage crops, which best suits the cropping system, enhances not only livestock productivity but also understanding of the overall farming system (Getnet and Ledin, 2001; Erol *et al.*, 2009; Fantahun *et al.*, 2017). However, to enhance the contribution of the legume component, optional agronomic strategies that help manipulate interspecies interactions and ensure balanced contribution of the component species to the total herbage mass and quality must be designed. In this regard,Dawit and Nebi, (2017) reported that due to high competition and shading effect, intercropping/mixed cropping may result in decrease in yield of one or both of the individual crops in mixture unless proper crop varieties and integration practices are followed. Therefore,this study hypothesized those varietal differences on comparative productivity and compatibility performance of twovetch species and two oat varietieswould increase under agro-ecological settings of the study area.

Smallholder farmers in Mareka district have for many years depended on mixed crop-livestock subsistence farming as a means of survival. Livestock provide these farmers meat and milk, draught power for crop cultivation and transport, and also can be sources of organic fertilizers (Solomon, 2016), as well as an important asset that could be converted to monetary means during bad times to avert risks. Natural pasture and crop residues which provide the bulky of livestock feed are poor in quality and need to be supplemented with better quality forages. Therefore, this study was intended to select the best performing and suitable improved species of vetch and oatsaccessions for their yielding ability and to determine quality of two species in pure stand and in mixturein Mareka districtof Dawuro Zone in south western Ethiopia.

Objectives of the study

General objective

The general objective of this study was to evaluate forage yield, seed yield and chemical composition of vetch and oats speciesgrown in pure stand and in mixture in Mareka district, Dawuro Zone ofSouth western Ethiopia.

Specific objectives

- To investigate the effect of variety on biomass yield, seed yield, compatibility and growth performance of oats and vetches when sown in pure stands and in mixtures.
- To determine the chemical composition of two vetches and two oats accessions grown in pure stand and mixture.
- To evaluate the effect of vetch-oat mixed cropping on soil physico-chemical properties.

2. LITERATUE REVIEW

2.1. Major Livestock Feed Resources in Ethiopia

The major available feed resources in Ethiopia are natural pasture, crop residues, aftermath grazing, and agro-industrial by-products (Mengistu, 1997; Adugna, 2007; Firew and Getnet, 2010; Yaynshet, 2010). The report of CSA (2015) revealed that 56, 30, 1.2, and 0.3% of the total livestock feed supply of the country is derived from grazing on natural pasture, crop residues, agro industrial byproducts and improved forages respectively. According to, Shitahun (2009); Assefa *et al.,* (2013) and Gebremichael (2014) reported that natural pasture, weeds, aftermath grazing, crop residues and maize thinning in wet season and crop residues , aftermath grazing, hay and supplements were the major feed resources in dry season . Their contribution to the total feed resource base varies from area to area based on cropping intensity (Seyoum *et al*., 2001).

The feeding systems include communal or private natural grazing and browsing, cut and carry feeding, hay and crop residues. Grazing is on permanent grazing areas, fallow land and cropland after harvest (stubble). In Ethiopia, the farmers predominantly practices mixed crop livestock kind of farmingand the communal way of livestock grazing requires fencing and protection of cultivated pastures, especially after the crop harvest, which hinders cultivation of annual and perennial forage crops. The availability and quality of forage are not favorable year round. As a result, the gains made in the wet season are totally or partially lost in the dry season (Alemayehu, 2003).

2.2. Improved Forage and Pasture Crops.

One of the best opportunities for highland farmers to use land efficiently will be through the introduction of pasture and forages in the farming system. Improved forage crop production has a number of advantagesthe primary benefits of which are to produce high amount of quality and quantity forage to be used as feed for animals. On other hand, improved forages such as legume species can complement crop production through maintaining soil fertility by fixing nitrogen.Production of cultivated forage and pastures depend on availability of species that are adapted to the climatic, edaphic and biotic factors prevailing in the environment in which they are to be utilized. Suitability of a forage species to a given area is judged based on DM yield potential, persistence, adequate feed quality, compatibility with other species and ease of propagation and establishment. Cultivated forage and pasture crops are mainly important as cut-and-carry sources of feed and as a supplement to crop residues and natural pastures. It is often suggested that producers opt for high biomass yielding and nutritious grass and legume species for sizeable production impact (Tolera *et al*., 2012).

In the highland of Ethiopia, immediate response to population pressure is targeted towards an expansion of cultivated area to maintain per capita crop output. Thus, livestock and crop activities may become competitive for land resources (McIntire *et al.,* 1992). Although in the demand for feed may increase under these conditions, competition with food crops is unfavorable to forage adoption, particularly because farmers tend to be unwilling to sacrifice food production to produce fodder for animals (McIntire *et al.*, 1992). Several forage species and accessions have been tested and a number of them recommended for wider dissemination in different agro-ecologies and production systems over the past five decades in Ethiopia.

The number of registered forage varieties is now increasing as the national research system has now developed a variety release system for forage and pasture crops (Geleti, 2014). Ethiopia has highly diversified agro-ecology mainly based on moisture (length of growing period) and temperature regimes, which ranges from arid and semi-arid lowlands to moist cool highlands and a high diversity of soil types (MOARD, 2005). This high diversity in agro-ecology and soil types is an opportunity to grow diversified crops and forage species adapted to temperate, Mediterranean, humid, dry, arid, and semiarid climates. On the other hand, when this forage species are grown in the different agro-ecologies and soils types, their agronomic requirements vary accordingly. Agronomic practices such as establishment methods, seeding rates or spacing, fertilizer application rates, food forage integration, weed and disease and pest control practices, harvesting stages and conservation strategies for selected and widely cultivated annual and perennial forage crops are established in the major agro ecologies under Ethiopian condition. The most common grass and legume species are listed below in Table1.

Table 1. List of major forage species and varieties registered in the variety register book of MOA**.**

Species	Variety	Common name	Adaptation
Avena sativa	CI-8237	Oats	high to mid altitude
Avena sativa	Boons	Oats	high to mid altitude

Grasses	*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	ILCA-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
Legumes	*Trifliumquartinianum*	-	Clover	high to mid altitude
	Lablab purpureus	-	Lablab	mid to low altitude
	Vignaunguiculata	Sewinet	Cowpea	mid to low altitude
	Vicianarbonensis	Abdeta	Vetch	high to mid altitude
	Vicia dasycarpa	Lana	Vetch	high to mid altitude
	Vicia vilosa	Lalisa	Vetch	high to mid altitude
	Vicia sativa	Gebisa	Vetch	high to mid altitude

Source: MOARD, (2011).

2.2.1. Forage production potential of oats

Oats (*Avena sativa* L.) is cultivated for forage and seed production in the central highlands of Ethiopia especially around Selale, Sheno,Debrebrehan,and Arsi areas(Getnet and lendin, 2001).It is a well-adapted fodder crop grown for a long period of time in the highlands of Ethiopia for human consumption and used as energy source for livestock (Mengistu, 2008). It has an erect annual grassup to 1.5 m tall and best adapted to altitude range 1700-3000 m a.s.l with 500–800 mm mean annual rainfall (Solomon, 2008). Oats is an annual grass that is suit to supplement to animals for cut and carry as straw, hay or can be prepared in the form of silage. The seed rate, on average, is 80 kg/ha with a range of 75-100 kg/ha recommended for pure stand. As animal feed (cut and carry) it can be sown in mixture with vetch. When sown in mixture, the seed rate required for 1 hectare is 15 kg vetch and 70 kg oat (Alemu *et al.*, 2007; Fekede *et al.*, 2008).

Average DM yields yield of oats ranged from 4 to 15 t/ha. Stage of growth at cutting and environmental conditions play an important role in determining oats yield (Malik *et al.*, 2011). Oats have a high crude fiber content compared with barley and wheat but a lower protein content of 11 to 14% (Church and Richard, 2002). Chopped oats are fed to breeding or young dairy cattle and grind oats are fed to poultry. Oats were much more favored by the growers compared with other small grains, as a forage crop, because of its finer stem and higher palatability (Miller, 1984).

2.2.2.Forage production potential of vetch

Vetch is the most important and widely used annual forage legume in the highland farming systems of the country under different production strategies as it grows well on different soil types (Getnet *etal.*,2003). It grows well on the reddish brown clay soils and the black soils of the highland areas. It was grown successfully in areas of acid soil with pH of 5.5-6. It is reported that vetches are rich in protein, minerals, and have lower fiber content. With the highest level of crude protein (CP), vetch could be used as supplement to roughages for dairy cows. All vetches are commercial important species make good pasturage, hay, silage and as cover crops. The most important cultivated vetches are *Vicia sativa*, *Vicia vilosa* and *Vicia dasycarpa* are of very important in agriculture. Forages which are moderate to high in CP reduce the need for supplemental purchased protein (Gezahagn *et al.,* 2014). vetch has very important nutritional value of high in crude protein and minerals whereas low in tannins, whose role in nutrition problematic, low to moderate concentration and thus protect them against digestion in the rumen if protein are too firmly bounded to the tannins they are not digested in the small intestine (McDonald *et al.,* 2002).

Vetch is a vigorous climbing/sprawling annual legume with a wide range of adaptation and high level of farmer acceptability. It grows well between 1500 and 3000 m altitude and is suited to a wide range of rainfall typically anything above 400 mm per annum. Vetch is ideally suited to under-sowing, mixed pasture and backyard forage plots and establishes readily, even on rough seedbeds. Typical sowing rates are 20 kg/ha for pure stands, 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 excellent hay (Solomon, 2008).

2.3. Grass-Legume Mixtures

Grass-legume mixture involves growing two or more crops concurrently with no distinctive row pattern, mainly through broadcasting. Development of grass and legume mixed pasture is one of the recognized strategies to enhance the feed resource development in quality and quantity. Growing mixtures of grasses and legumes improves biomass production as compared to grass monocultures (Matt *et al.*, 2013). Their green foliage parts and roots also can decompose and release nitrogen into the soil where it might be made available to succeeding crops (Lithourgidis *et al.*, 2011). In line with the above, studies have shown that in vetch sown with oats, 90% of the total nitrogen uptake (about 53 kg ha^{-1}) comes from symbiosis, while oat uses about 18 kg of mineral N, which is one third of the nitrogen taken together by plants in the mixture (Triboi, 1985).

According to Keighobadi *et al*., (2014), reported that intercropping cereal with grain legume crops such as cowpea, soybean, common vetch and groundnuts helps maintain and improve soil fertility, because these legumes accumulate about 80 to 350 kg nitrogen (N) ha^{-1}. Mixed planting of grasses and legumes was also indicated to be more productive than monocultures and the approach was thus reported to help control weeds, diseases and pests (Erla, 2011). Productivity of oats and vetch mixtures are also known to be superior to pure stands in yield and quality (Getnet and Ledin, 2001; Erol *et al*., 2009).

Farmers of low income countries like Ethiopia could not afford to use industry-based concentrates and chemicals as supplements to improve utilization of roughages (Fantahun *et al.*, 2017). Leguminous forage crops can improve the utilization of low quality roughages and they are being used more extensively throughout the world. Legumes provide proteins that grasses lack and increase dry matter yield by fixing atmospheric nitrogen and converting it into a soluble inorganic form that can be absorbed into plant tissues. According to EARO, (2000) reported that compared oats-vetch mixture with native pasture hay using lactating crossbred cows, oats-vetch mixture was reported to support high 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 improved protein and energy intakes on the oats-vetch diet. These suggest the study need for integration of oat- vetch mixtures in to ruminant feeding systems for diverse farming systems and agro-ecologies of the country.

2.4. Benefitsofgrowing Vetch-Oats Mixtures

Mixtures of legumes with grass may be used in different ways. In the mixtures, oats can provide support for climbing vetch, improve light interception through the canopy, facilitate mechanical harvesting, and reduce rotting of vetch hay (Solomon, 2008). If they are grown for seeds, they can be used for the production of fodder for mono gastric animals (pigs and poultry), because of the increased protein content compared to the seed of sole cereals. In turn, if they are cultivated for green forage, they provide valuable roughage for ruminants. They can also be used for plowing, as green manure.

Mixtures make a better utilization of habitat resources than sole crops. Differentiation in the size and depth of the root systems of cereals and legumes allows them to utilization water and nutrients from different soil layers, the result of which is a compensatory growth and development of plants. Mixtures mitigate the negative effects associated with consecutive sowing of cereals as they become an element which interrupts the continuity of the crops.In mixed cropping, legumes such as pigeon peas, cowpeas, vetch, green grams, lablab and groundnuts fix nitrogen, which can be used by the other crops. Crops that cover the ground suppress weeds and reduce moisture loss from evapotranspiration. Damage by insect pests is often less serious in mixture. The mixture have different heights, ages and rooting patterns, so farmers can plant more crops in small units of land with minimal competition among the crops (IIRR, 2002). Some of the benefits for this cropping system are discussed below;

2.4.1. Improvement of soil fertility

Legumes are argonomically beneficial because they fix atmospheric nitrogen (N_2) through a symbiotic relationship with Rhizobia bacteria, which form nodules in leguminous roots. These beneficial bacteria enhance soil fertility by increasing N through rhizodeposition, which reduces the amount of synthetic N fertilizer needed for Oats grass (Ashworth, A.J *et al.,* 2015). An important reason for mixed cropping is on the improvement and maintenance of soil fertility. This is reached when a cereal crop (such as Oats) or a tuber crop (like cassava) is grown in association with legumes (Vetch, bean, peas). Rhizobium bacteria are able to have a symbiotic relationship with plants of leguminous family, and thereby can fix atmospheric nitrogen and hence make it available for plants uptake (Eskandari *et al.,* 2010). After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrient for the next crop resulting to less needs for external nitrogen addition (Borin and Frankow-Lindberg, 2005). The above-ground plant material of common vetch may contain more than 100 kg N ha^{-1} originating from N_2-fixation (Mueller & Thorup-Kristensen, 2001).

2.4.2. Increasing forage production per unit land area

Higher yield in terms of total biomass and grain production per unit area in a given season without the use of costly inputs under intercropping system is attributed to better use of growth resources namely, light, nutrients and moisture (Siva Kumar and Virmani, 1980). According to, Ghanbari and Lee, (2002) reported that dry matter production in wheat and beans intercrops had been more than pure cropping.

2.4.3. Improvement of forage quality and manure production

Grass legume mixtureprovide higher feed quality owing to the higher crude protein concentration of legumes (Umuna *et al.,* 1995), increased biomass yield (Getnet and Lendin, 2001; Lithourgidis *et al.*, 2006), reduced use of non-renewable resources through reduced N fertilizer use, a consistent production pattern, improved soil fertility (Lopez-bellido Garrido and Lopez-bellido 2001) and improved livestock production (Umuna *et al.,* 1995). The crop residue of the cereals can also be used as fodder, by cutting and carrying them to the animal, or by letting the animals graze the residues in the field. The nutrients in the crop residue can be recycled when manure is used to fertilize the crops. Animal manure improves soil fertility through supply of nutrients and soil structure, as it increases the amount of humus in the soil (Kumar *et al*., 2012).

2.5. Biological Compatibility in Grass-Legume Mixtures

Legumes, like Vetch can provide N to the non-legume directly through microbial links, root exudates, or decay of roots and nodules; or indirectly when the legume fixes atmospheric nitrogen (N_2), and thereby reducing competition for soil NO_3 with the non-legume (Anil *et.al.,* 1998). Interference occurs among plants of the some species in pure stands and among plants of different species in intercropping systems. Such interference can be non-competitive or complements. Non-competitive interference occurs when different plants shore a growth factor (light, water and soil nutrients) that is present in sufficient amount so that it is not limiting (Tilahun, 2002).

A competition function is proposed as a measure of intercrop competition to indicate the number of times by which one component crop is more competitive than the other (Willey and Rao, 1980). This competition function could be use full, to compare the competitive ability of different crops and to measure competitive changes within a given combination which can identity which plant character is associated with competitive ability therefore it could determine what competitive balance between component crops is most likely to give yield advantage. To enhance the contribution of the legume component, optional agronomic strategies that help manipulate interspecies interactions and ensure balanced contribution of the component species to the total herbage mass and quality must be designed. In this regard, indices such as relative yield total, relative crowding coefficient and Aggressivity index are used to assess yield advantages in mixed cropping (Ghosh, 2004).

2.6. Biological Nitrogen Fixation

Biological process of atmospheric nitrogen fixation by *Rhizobium*bacteria that live in symbiosis with legumes has great significance for agriculture. In the symbiosis process, legumes provide the bacteria with carbohydrates, and in return they receive nitrogen assimilated by them, which they use to produce high-value protein. Cereals growing in the vicinity of legumes use the nitrogen assimilated by nodule bacteria, as it is transferred to the soil in the form of aspartic acid or β- alanine. This phenomenon is particularly important in low-input farming systems, (Hauggard-Nielsen *et al.,* 2009) especially in organic agriculture, (Bedoussac and Justes 2010) where the biological fixation is the most important source of nitrogen (Neumann*et al*., 2007).

The amount of nitrogen fixed by the nodule bacteria in the process of symbiosis depends primarily on the species of legume as a component, its share in the mixture and the level of nitrogen fertilization. Biological nitrogen fixation also depends on the soil conditions (nitrogen content, moisture content, and pH) and the severity of disease and pests (Ledgard and Steele, 1992).A large impact on the amount of symbiotic nitrogen fixation has also soil temperature. The optimal temperature range which allows for the maximum nitrogen fixation is (^{o}c) for big-leaved lupine-25, common vetch-20, Faba bean-20, field pea-25, blue lupine-20-30, and for soybean-20-25 (Liu*et al.*,2010).

2.7. Major Factors that Influence Forage Quality

Forage quality is, the degree to which forage meets animal nutritional needs, is expressed in terms of animal production, such as growth, milk, meat, skin or wool production. Forage quality is affected by forage nutritive value (i.e., chemical composition and digestibility) and intake, and it can be estimated when forage is the sole source of nutrients to the animal and offered without quantity restrictions (ad libitum). An understanding of factors affecting forage quality will help producers anticipate and plan for changes in forage quality (Eskandari *et al*., 2010). Major factors affecting forage quality, ranked by their impact on forage quality including:

Maturity (harvest stage): is the most important factor affecting forage quality. Plants continually changes in forage quality as they mature. As plants cell wall content increases, indigestible lignin accumulates which results in decreasing forage 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 year to year, seasonal and geographical location effects on forage quality even when harvested at the same stage of development (Gezahagn *et al.*, 2016).

Species and varieties: Yielding of legume-grass mixtures largely depend on the proper selection of species and varieties. Species differences in forage quality between grasses and legumes can be very large. The protein content of legumes is typically much higher than that of grasses and legumes fiber tends to digest faster than grass fiber, allowing the ruminant to eat more of the legume (Eskandari *et al.*, 2010). Within oats varieties and vetch species and between oats and vetches there is variation in terms of their days to maturity, plant height, growth rate, and plant vigor. In the same species between varietal differences makes distinctly different in their forage yield, grain yield, height, leafiness, and days to maturity and adaptation to soil types. These characteristics are also different under various management practices and environmental situations. Hence selecting appropriate varieties is of paramount importance in producing both vetches and oats either for grain or forage or both (Getnet, 1999).

Soil fertility: Soil fertility affects forage yield much more than it does quality. While it is possible to produce high quality forage on poor unproductive soils, it is generally very difficult to produce high yields of high quality forage with an unproductive soil resource (McDowell, 2003; and Gezahagn *et al.,* 2016). Proper soil phosphorus (P) and potassium (K) levels help to keep desirable legumes in a mixed seeding and also reduce weed problems. It is necessary to balance soil fertility to avoid mineral imbalances in ruminants. Low soil fertility, as well as very high fertility, has resulted in reduced forage quality.

Harvest and storage: The variation in morphological characteristics such as leaf, stem, pod and flower fractions of forages accounts for parts of the difference in feed quality (Gezahagn *et al.*, 2014). This variation in morphological characteristics is important in the selection of forage crops, which are agronomical suitable and used for various purposes such as hay, silage and grazing (Getnet and Ledin, 2001). The proportion of leaves in dry matter also depend on genetic factors, i.e. variety (Katic *et al.*, 2005b), as well as on stand density and the phonological stage of plant development (Lamb *et al.*, 2006). Improper harvest techniques can seriously reduce forage quality, primarily through the loss of leaves. Storing a hay crop at an incorrect moisture content, or improper ensiling of a forage crop, can dramatically lower its quality.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Gozo-bamush farmers training center (FTC), in Mareka District of Dawuro Zone. Mareka district is one of the 5 districts of Dawuro Zone located inSouth Nations' Nationalities Peoples' (SNNP) regional state in south western Ethiopia (Figure 1). The district consists of 36 kebeles, among which 4 are urban and 32 are rural. The district is bordered in the southwest by Isara district, on the west by Tocha district, on the northeast by Gena Bosa, and on the southeast by Loma districts.The district lies between 6^0 09' - $7^0$2' N latitude and 37^0 01' - 37^0 26' E longitude, and its total area is 44050 hectare (MWANDO, 2017).Based on the 2007 Census conducted by the CSA, the district has a total population of 126,022, of whom 65,321 are men and 60,701 women; 18,988 or 15.07% of its population are urban dwellers.

In terms of land use system, of the district consists2000 hectare (4.5%) forest, 11500 hectare (26.1%) grazing land, 28140 hectare (63.9%) cultivated land and the remaining 2410 hectare (5.5%) are bushes, savanna, rivers, springs, stagnant waters and hills(MWANDO, 2017). The livestock population of the districtsis estimated to be about 122,084 cattle, 47,438 sheep, 18,854 goats, 4,860 horses, 2,759 mules, 1,699 donkey, 63,042 chicken and 2,750 traditional and 863 modern bee hives with bee colonies(MWAFRO, 2017).

The elevation of the district ranges from 1160-2541 meter above sea level(m.a.s.l). The divisions of relief features in Mareka district include plateau, plain and valley. The district located at 500 kms Southwest of Addis Ababa across Shashemene and 449 km across Hosana but 505km across Jimma, 337 Kms from Hawassa, town of SNNPR and 140 km far away from Jimma. Mareka district is divided in to three agro-climatic zones,including 41.67% highland,50%midland and 8.33% lowland altitude. An estimated mean annual rain fall variesbetween800-1500mm and the mean annual temperature varies between 15-25^{o}c (MWANDO, 2017).

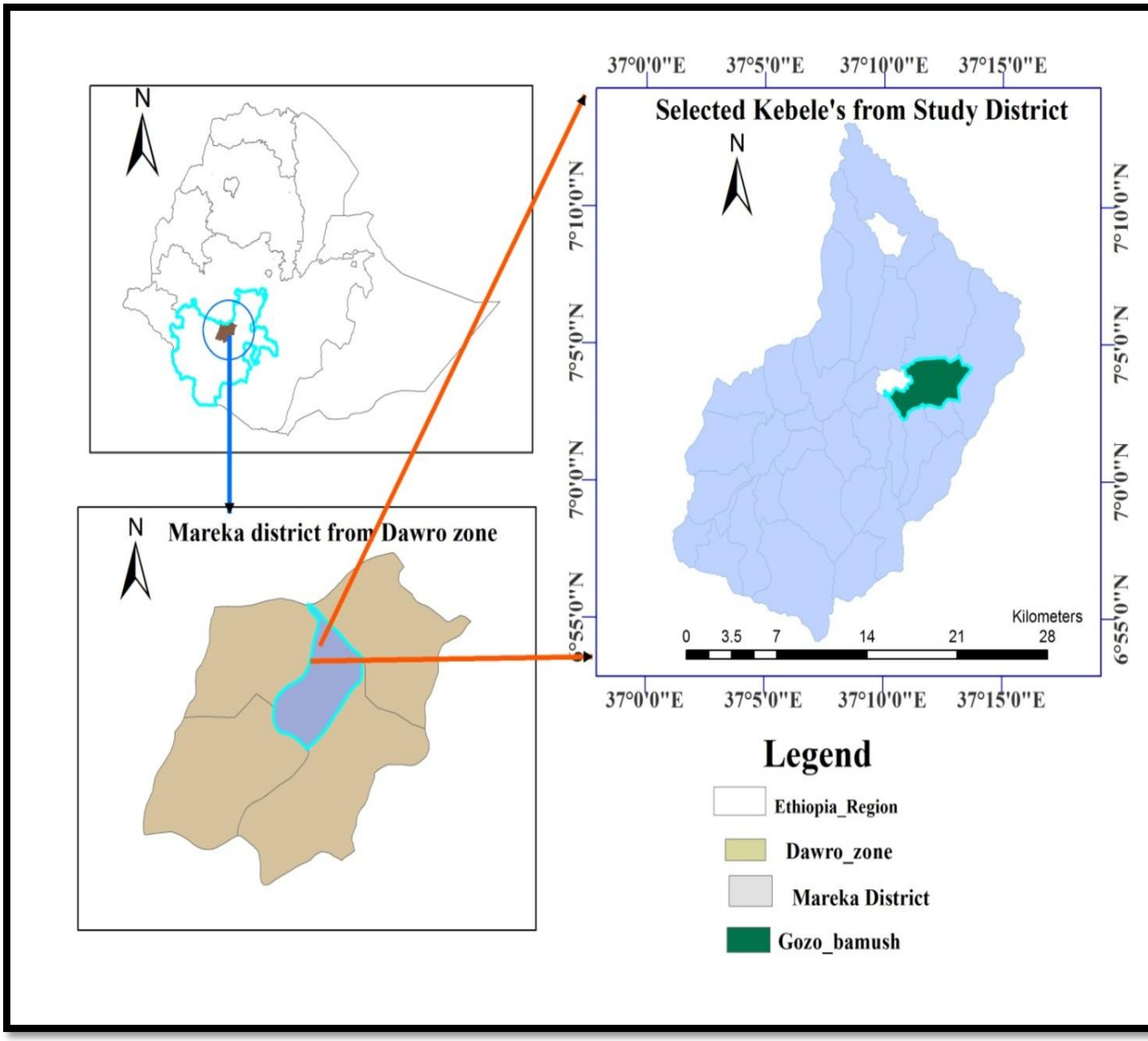

Figure 1. Map of the study area

3.2. Land Preparation and Planting

The experimental field was cleared from weeds and trees before ploughing. The land was ploughed three times during the short rainy season (March to May) using oxen to get a fine seedbed and the plots were leveled manually. The plots were uniformly fertilized with NPSB at a rate of 100 kg ha^{-1}(72g/plot) at the beginning of the experiment by broadcasting and then mixed with the upper soil layer using hand rakes (Alemu *et al*., 2007; Fekede, *et al*., 2008). Planting was done duringthe main rainy season (May 16/2019)at Gozo Bamush farmers training center(FTC).

3.3. Experimental Design and Treatment

The field experiment was carried out in 2019 during cropping season between (May and November). The experimentinvolved two species of vetch;*Vicia vilosa*6792, *Vicia sativa*andtwo varietiesof oats; *Avena sativa* 5431A, *Avena sativa* 15153A, which weresourced from Bonga research center in 2019 having determinate growth habit,with altitude adaptation from 1570-2150 a.s.l with the rain fall of more than860-1500mm in growing season.The experimental treatments were assigned to individual plots using Randomized Completely Block Design (RCBD) in three replications which were randomly assigned to each experimental unit.The spacing between blocks and plots was 1.5m and 1m, respectively (Aklilu and Alemayehu, 2007). The plot size of each experimental unit was 7.2m^2 (2.4m*3m). In each plot, there were 7 rows and seeds were uniformly drilled in rows with intra-row spacing of 30cm.

The seed proportions were calculated on the basis of the recommended seed rates of 80 kg and 25 kg ha^{-1} for pure stand and 70 kg and 15 kg ha^{-1} for mixture of oats and vetch, respectively (Alemu *et al.,* 2007; Fekede *et al*., 2008). The calculated seed rates 57.6gand 18g per plot for purestand and50.4g and 10.4g per plot for mixture of oats and vetch were used respectivelyand uniformly drilled in rows at a constant depth of 5 cm. The total experimental area for two varieties of vetches and oats grown as sole and mixture was 33m*13.2m =435.6m^2. All plots were weededat 15 days interval from date of sowing up to the forage harvested.

Table 2. Description of Treatment combination and number of replications

Treatments	Variety	Replications
T1	Pure stand Lalisa (*Vicia vilosa*6792)	3
T2	Pure stand Gebisa (*Vicia sativa)*	3
T3	Pure stand Oats *(Avena sativa* 5431A*)*	3
T4	Pure stand Oats *(Avena sativa* 15153A*)*	3
T5	Lalisa (*Vicia vilosa*6792) + Oats *(Avena sativa* 5431A*)*	3
T6	Lalisa (*Vicia vilosa*6792) + Oats *(Avena sativa* 15153A*)*	3
T7	Gebisa (*Vicia sativa)* +Oats *(Avena sativa* 5431A*)*	3
T8	Gebisa (*Vicia sativa)* + Oats *(Avena sativa* 15153A*)*	3
Total plots		24

3.4. Data Collection

The Data collected in the experiment included soil data and plant-based data. Plant based datawere collected from germination to harvest maturity such as; phonological, yield and yield components. Soil Samples were taken from experimental field at sowing of the forage and after harvest according to the procedures described below:

3.4.1. Soil data

3.4.1. 1. Soil samplecollection procedure

An initial soil sample was randomly collectedfrom experimental field in zigzag pattern at the depth of20cm using an auger before forage sowing (Wilding, 1985).Soil samples after forage harvest was collected from each plots representing five surfacesoil samples (in each corner and center of plots)taken diagonally at adepth of 0-20 cmby using auger (Jackson, 1958).The collected soil samples were composite and the compositedandreduced to working sample size (200g) for analysis.

3.4.1.2. Soil sample analysis procedure

The 200g composite soil sample collected,were air dried and grounded to pass through a 2mm sieveand subjected to determination of physical and chemical analysis. It was analyzed for organic carbon, total nitrogen, soil pH, available phosphorus, organic matter, cation exchange capacity (CEC), soil texture,available potassium and exchangeable potassium. Particle size distribution (soil texture) was analyzed by the modified Buoyoucos hydrometric method (Day,1965) after destroying OM using colgon solution (sodium hexametaphosphate solution) as soil dispersing agent hydrogen peroxide (H_2O_4) and sodium carbonate, (Na_2CO_3)were used as soil dispersing agents (silt, clay and sand).

The pH of the soil was determined according to Peech, 1965 using 1:2.5 soil water ratio methods. For soil water ratio methods, 25ml of distilled water were added to 10g of soil. The mixture was shaken for 30 minutes with the mechanical shaker and allowed to stand the solution which was stirred for one minute andleft for one hour. After this, the soil suspension was stirred and measured by glass electrode pH meter until the reading is constant.Determination of total N of samples was performed by the Kjeldahl method as described by Jackson, (1958).A1.0 gram of air dried samples were passed through a 0.5 mm sieve and added in to the digestion tube.These were 1.0 gram of selenium mixture catalyst added followed by 10 ml of concentrated sulpheric acid to start the digestion process. Digest the block digester at375 $^{o}{}_{c}$ the set-up was left in digestion chamber for 2 hours. After 2 hours, the digests were retrieved from digestion chamber and allowed to cool for 5 minutes after which they were transferred into distillation flask and40 ml of 45% NaOH were added followed by distillation process. Then, the released $NH_3$was collected into 30 ml of Boric acid(H_3BO_3) and titration was done against 0.01 M H_2SO_4(Okalebo *et al.,* 2002).The collected NH_3 titrated with 0.1N HCL (Hydrochloric acid) and recorded the volume of titrant (Hydrochloric acid) determined by the formula.

$$\%N = (V\text{-}B)\ N * \frac{Eq.Weight\ of\ N * 100}{1000 * W}$$

Where; %N = percentage of total nitrogen, V= volume of hydrochloric acid consumed by the sample; B = blank used for error reduction, N = Nitrogen, Equilibrium weight of N per 1000gram; W = weight of soil used (gm).

The CEC was measured after saturating the soil with 1 N ammonium acetate (NH_4OAC) solution (Chapman, 1965). Available soil phosphoruswas determined by Olsen methods of the Bray II (Bray and Kurtz, 1945). Five gramsof air dried soil was passed through 2 mm sieve and weighed into a 100 ml extracting tube and 50 ml double acid reagent added. The tubes were corked tightly, placed horizontally in a rack on a mechanical shaker and shaken for 30 minutes. The soil was filtered through Whitman filter paper No. 42 and filtrate collected in specimen bottles. A suitable aliquot of the soil extract was measured and put into a 50 ml volumetric flask. Twenty-five ml of distilled water was added to each tube followed by 8 ml of reagent B and immediately distilled water was added to the mark and mixed thoroughly. The solution was allowed to stand 25 minutes before readings (Okalebo *et al*., 2002). Then the concentration of the sample was read from the graph using the observance value recorded or calibrates the spectrophotometer with the standard series and read the sample concentration directly.

Soil organic carbon was determined by the wet digestion method as described by (Walkey and Black, 1934) and soil OM was calculated by multiplying percent OC by a factor of 1.724. Soil samples were analyzed at SouthernAgricultural Research Institute,Areka Agricultural Research Center soil, plant and water analysis laboratory.

3.4.2. Phonological data and growth parameter

Data on growth parameters for oats and vetches (seedling count, number of tillers per plant, number of branch per plant, plant heightand days to forage harvest) were recorded from date of sowing to the date when plants reached 50% flowering stage.

Days to emergence: Was recorded as number of days from date of sowing to the day when the majority (90%) of the planted seeds have emerged just above the ground (Aklilu and Alemayehu, 2007).

Seedling count: Was taken two weeks after emergence using a 1m x1m quadrant from each plot. Seedling emergence percentage was calculated using the formula according to (Hartmann *et al.*, 1990).

$$\textbf{Seedling emergence\%} = \frac{\textbf{Total number of emerged seedilings} * \textbf{100}}{\textbf{number of seeds planted}}$$

Number of branches per plant:was determined by counting total number of branches from the main steam of five randomly selectedvetch plants frommiddle rows of each plot at forage harvesting(Molla *et al.*, 2018).

Number of tillers per plant:tillers count for grass was measured at70days after sowing. Fiveoat plants were randomly selected in the middle three rows of each plot to avoid edge effect and count the number of tillers found from individual plants and then after, the average number of tillers per plantwas calculated (Khan*et al*., 2014;Amanuel*et al.*,2019).

Days to forage harvest: Days to forage harvest was recorded from plantingdate to the date when vetch plants reached50% flowering stage and oats at heading stage (Aklilu and Alemayehu, 2007). Data on days to 50% flowering stage of two forages were recorded from the net plot area from date of planting when 50% plants plot reach their respective phonological stage(Amanuel *et al.*, 2019).

Plant height: At forage harvest for dry matter yield determination, the plant height for each species were determined by measuring the height of five randomly selected plants from ground level to the tip of the main stem for both oats and Vetches at 50% flowering from each plot (Aklilu and Alemayehu, 2007; Kassahun and Wasihun, 2015).

Legume nodulation: Nodules werecounted from the roots of three randomly selected legume plants from each plot at 30 and 70 days after sowing (DAS) (Chapagain, 2014).The parameters were measured number of nodulesin the crown-root zone (regarded as the region up to 5 cm below the first lateral roots) with elsewhere on the root system per plant. Nodulation was scoredusing 0-5 scale assigned based on nodule number and distribution as described by (Corbin *et al.,1977*). These were then averaged to obtain the mean nodule score per treatment. A mean nodule score of:

4 - 5 represents excellent nodulation; excellent potential for N_2 fixation

3 - 4 represents good nodulation; good potential for fixation

2 - 3 represents fair nodulation; N_2 fixation may not be sufficient to supply the N demand of the crop.

1- 2 representpoor nodulation, little or no N_2 fixation.

0-1 represents very poor nodulation and probably little or no N2 fixation

0 represents No nodulation and no N2 fixation

Days to 90% physiological maturity: Days to forage seed harvest was recorded as the number of days from date of sowing to the date when 90% of the plants showed yellowing of leaves and pods and seed hardening in the pods (Salem *et al., 2015)*.

3.4.3. Yield and yield related parameters

Biomass yield determination: Three adjacent rows from the center wereharvested at approximately 3 cm above ground when 50% oats reachheading and vetches reach flowering stage from (1mx1m)area excluded about 0.5m border area from each side (Aklilu and Alemayehu, 2007). The total biomass was weighed and separated into oats and vetch to estimate yield advantage. The fresh weight was recorded in the field using aweighing balance.The fresh sub samples were measured from each plot and each plant species wereseparately weighed and chopped in to short length (2-4cm)to estimate fresh biomass yield. The fresh subsample of 300gmwere taken from each treatment and dried at $65^{o}{}_{C}$ for 72 hrs in an oven forquality determination. A 200 g sub sample was taken and dried in a forced draft oven at a temperature of 105 °C overnight for total dry matter yield determination (Molla *etal.,*2018).The oven dried samples werere weighed to determine the total dry matter yield as:-

DM yield (t/ha) = (10 x TFW x SSDW) / (HA x SSFW)(James, 2008).

Where: 10 = is a constant for conversion of yields in kg/m^2 to tone/ ha

TFW = Total fresh weight from harvested area (kg)

SSDW= Sub-sample dry weight (g)

HA = Harvest area (m^2)

SSFW = Sub-sample fresh weight (g).

Crude protein yield (CPY) and neutral detergent fiber (NDFY) of the treatments were further determined as the product of CP and NDF content and herbage DM yield (Starks *et al.*, 2006).

Crude protein yield (CPY) (t/ha)=$\frac{\boldsymbol{DMY\ t/ha *\%CP}}{\mathbf{100}}$

Where: DMY (t/ha) = dry matter yield (ton per hectare)

%CP = crude protein contentof forage.

Neutral detergent fiber yield (NDFY) (t/ha)=$\frac{\boldsymbol{DMY\ t/ha*\%\ NDF}}{\mathbf{100}}$

Where: DMY (t/ha) = dry matter yield ton per hectare

%NDF = neutral detergent fiver content of forage.

Plant N uptakes were determined by multiplying the N concentrations of each treatment by their respective dry matter weights (Ansarul *et al.*, 2018; Abreha *et al.*, 2013).

N uptake (t/ha) = $\frac{\%N*DMY\ (\frac{t}{ha})}{100}$

Seed yield (t/ha)

Seed yield was determined by harvesting both vetch and oaton 1 m^{2}area from each plot when seedswere matured and after cautiously separating the seed from the straw. Then,the seed yield (t/ha) was determined by weighing seed from the net plot and expressed at 10 % moisture content for vetch and 12.5% for oats using the following formula(Salem *et al., 2015;*Amanuel*et al.,*2019).

Seed yield (t/ha) = $\frac{\boldsymbol{seed\ yield\ per\ 1m*1m\ area(kg)\ *10*subsample\ dry\ weight(g).}}{\boldsymbol{sub\ sumple\ pre\ drying\ wieght(g)*harvest\ area(1m*1m).}}$

Thousand seed weight (g): Thousand seeds were counted from the harvested bulk of seeds per net plot and their weight (g) was determined at 12.5% moisture content for oats and 10% for vetch by using a sensitive balance.Thousand seed weight is also an important yield component which reflects the magnitude of seed development that ultimately affects the final yield of a crop.

Thousand seed weight (g)=$\frac{\mathbf{100-DMAM}}{\mathbf{100-CM}} * \mathbf{FWTS}$

Where, DMAM =Dry matter of adjusted moisture %of seeds

CM = Constant moisture adjusted to (10%) for vetch and 12.5 for Oats

FWTS = Fresh weight of 1000 seeds (g)

3.4.4. Competition indices

The benefit of intercropping system and the effect of interspecific competition between the intercropped species, the relative yield, relative yield total, the relative crowding coefficient (RCC), and Aggressivity Index (AI) were calculated.

Relative yield: The relative yield of the mixed components was calculatedwith the formuladescribed by(Ghosh, 2004; Midya *et al*., 2005):

RYG = DMYGL/DMYGG

RYL = DMYLG/DMYLL

Where; RYG =is Relative yield of grass and RYL= is Relative yield of legume.

DMYGL = is the dry matter yield of oats grown in mixture with vetch

DMYGG = is the dry matter yield of oats grown as monoculture

DMYLG = is the dry matter yield of vetch grown in mixture with oats.

DMYLL= is the dry matter yield of vetch as monoculture.

IfRY > 0.5; higher yield in the mixture than sole.

RY < 0.5;lower yield in the mixture than sole and

RY=0.5; no effect of cropping system on yield(Caballero *et al.,* 1995; Rauber *et al.,* 2001; Lithourgidis *et al.,* 2006).

Relative yield total (RYT): Relative total yield (RTY) is used as the first criteria to show the advantages of sole and mixed cropping over the other among the different species. It was used to show the effectiveness of mixture in resource utilization in the environment in comparison with mono cropping. Relative yield total was calculated according to the formula used byDhima*et al.,* *(*2007)and Dawit and Nebi, (2017):

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

Where; DMYGL is the dry matter yield of oats grown in mixture with vetch; DMYGG is the dry matter yield of oats as monoculture; DMYLG is the dry matter yield of vetch grown in mixture with oats; DMYLL is the dry matter yield of vetch monoculture.

If RYT> 1, it shows yield advantage of mixtures compared to the pure stand.

RYT <1 indicates a disadvantage of mixtures compared to sole cropping.

RYT=1 shows no biological yield advantage from mixed crops.

Relative crowding coefficient (RCC): Crowding coefficient is used to measure the relative dominance of one species over the other in multiple cropping (Banik *et al*., 2006). This parameter was calculated to determine the competitive ability of the annual grass and legume in the mixture by measuring the component that have produced more or less DM than expected in a 50:50 grass legume mixture(Ghosh, 2004; Midya *et al*., 2005): This 50:50 grass legume mixtures calculated as:

RCCGL=DMYGL / (DMYGG - DMYGL)

RCCLG =DMYLG / (DMYLL - DMYLG)

Where; RCCGL =is RelativeCrowding coefficient of grass grown with legume.

RCCLG= is Relative Crowding coefficient of legume grown with grass.

DMYGL = is the dry matter yield of oats grown in mixture with vetch

DMYGG = is the dry matter yield of oats monoculture

DMYLG = is the dry matter yield of vetch grown in mixture with oats.

DMYLL= is the dry matter yield of vetch monoculture.

Aggressivity index (AI): Measures the competitive ability of grass against the legume in mixture and vice versa.The DM yield of vetch species and oats accessionswas calculated on a per unit area basis, if vetch species and oats varietieshad the same competitive ability the value of Aggressivity index is zero. The numerical value of the Aggressivity index of both species is the same but the sign of the dominant species is positive and that of the dominated negative; the greater the numerical value the bigger the difference in competitive abilities and the bigger the difference between the actual and the expected yields. TheAggressivity index (AI)wascalculated according to the formula (Ghosh, 2004; Midya *et al*., 2005).

AIGL = (DMYGL/ DMYGG) - (DMYLG / DMYLL)

AILG = (DMYLG/DMYLL) - (DMYGL/DMYGG)

Where, AIGL = Aggressivity index of grass grown in mixture with legume

AILG =Aggressivity index of legume component grown in mixture with grass.

3.4.5. Chemical analysis

Chemical composition of feed was analyzed by using the procedures described by AOAC (2000).The fresh sub samples of 300gmweredried in the forced air drying oven at 65 °C for 72 hours and then ground to pass a 1 mm sieve screens for quality determination.The DM and ash were determined byoven drying at 105^{o}c overnight andigniting the samples at 550 °C in a muffle furnace for 6 hrs respectively (AOAC, 1990). Nitrogen (N) content wasdetermined by Kjeldahl method and CP wascalculated as Nx6.25 (AOAC, 1990). Van Soest *et al* (1991) procedure was used to determine Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and acid detergent lignin (ADL). Hemicellulose was determined by subtracting acid detergent fiber from neutraldetergent fiber (NDF- ADF) and cellulose by subtracting ligninfrom fiber (ADF – ADL). All feed sample analyses were doneat Jimma University College of agriculture and veterinary medicine (JUCAVM) animal nutrition and post-harvest laboratories.

3.4.6. Statistical analysis

The data on days ofemergence, nodule score, herbage DM yield, number of tillers and branches per plant, plant heightand chemical compositionwere subjected to ANOVA procedure by using SAS 9.3(32).Least significance differences (LSD)was used to determine the statistical significances between treatment means at 5% level of significance (Gomez and Gomez, 1984). The following statistical model was used to fit the data:

$Y_{ij} = \mu + T_i + B_j + E_{ij}$

Where,Y_{ij} = measured variable,

μ=overall mean of the population.

Ti= the ith Treatment effect (T1 - T8).

Bj= jth Block effect (r1 - r3).

Eij=random error assumed normally and independently distributed.

4. RESULTS AND DISCUSSION

4.1. Soil Physical and Chemical Properties of the Study Area

4.1.1.Physico-chemical properties of soil before forage planting

The soil physico-chemical analysis results before planting forage are shown in Table 3. The pre sowing soil analysis showed that the experimental soil had a pH of 4.7indicatingthat the soil wasstrongly acidicwhich was also reportedby Hazelton and Murphy,(2007)andMesfin(2007).

The preferable pH ranges for most crops are in the range of 6.0 and 7.5 (Hazelton and Murphy, 2007; Hall; 2008). However, the pH of the experimental soil wasbelow the recommended level which is strongly acidicthat more likely be deficient of some of available nutrients for optimal plant growth.Therefore, selecting and growing species and variety adaptable to acidic soils is one solution (Scott *et a., 1997*).Similarly,Helufand Wakene(2006)reportedthat agronomic and management options to correct acid soils, improve nutrient use efficiency and increase crop production on acidic soils include application of organic materials, appropriate crop rotations and crop mixtures and use of plant species and varieties tolerant to Al and Mn toxicity.

The soil analysis result showed that available phosphorous 13.88ppm rated in the experiment site before forage plantingwasmediumaccording to classification of a relative range of extractable phosphorous of <5 ppm, 5-10 ppm, 11-15ppm, 16-20ppm and 21-25ppm as verylow, low, medium, high and very high respectively(Marx, *et al.*, 1999).The total nitrogen, organic carbon and organic matter content of soil in the study area before planting was0.17%, 1.99% and 3.43%, respectively. According to Hazelton andMurphy (2007)rating, nitrogen is very high and organic carbon contents are medium in the present finding. The texture class of the soil composition was 42% clay, 34% of sand and24 % silt.The soil could be classified as sandy clay loam with medium organic matter. The cation exchange capacity (CEC) of the soil was high (38 meq/100g), implying that the soil has high resistance to changes to soil chemical properties inflicted by changes in land use (Hazelton and Murphy, 2007).

4.1.2.Physico-chemical properties of soil after forage harvest

The analysis of soil samples after forage harvestshowed an increased level of some of soil nutrients based on treatment combinations (Table 3). Except for T3 and T4, the pH level of the soil in all treatment groups indicated a slight change in pH values above the initial recorded value of 4.7 in the experiment site. The pH of the soil after forage harvest was numerically higher(5.04 to 5.56)in pure vetch cropped plots and their mixtures than sole oatscropped plots(4.69 and 4.75).

This slightly higher changeafter forage harvest in soil pH might be attributed to increase in organic matter and exchangeable bases or basic cations content of the soil that influenced the change in soil pH value.The present result is in line withthat of Mesfin (2007) who reported that the soil which has high pHvalue contain high organic matter. Wong and Swift(2003) who reported that the most effective way of managing and correcting soil acidity byappropriate crop rotations and crop mixtures, and use of plant species and varieties can ameliorate the effect of soil acidity on crop growth.

The available phosphorus (av.P) for soil samples after forage harvestin vetch based treatments werecomparativelyhigher (13.43ppm to15.71 ppm)than pure stand oat (10.41 ppm and 10.73 ppm) treatments (Table 3). The highest av.P value was obtained in sole vetch*Vicia sativa* (15.7) and the lowest av.P was obtained in*Avena sativa 5431A* (10.41) and *Avena sativa 15153A* (10.73) respectively. The highest av.P pure stand *Vicia sativa* might be due to the fact that vetch varieties increased phosphorus availability by mobilization of soil mineral due to its nodulation that enhance the soil fertility. This result isin line with the result of Hassen *et al.*, *(*2012) who reported that including legume in crop rotation increases the phosphors availability to the succeeding crop due to their deep roots. However, the av.P obtained in *Avena sativa 5431A* (10.41) and *Avena sativa 15153A* (10.73) was less than before sowing. The lowest valueof soil available phosphorusin pure stand oat based treatmentshowed thatthere was more utilization of phosphorus by oats plants.

The result of organic carbon percentage of the experimental plotis presented in Table 3. Organic carbon percentage (OC %) of the soil was slightly higher, ranging from1.95% to 2.63% after forage harvest in all vetch and oat-vetch mixture treatments whereas, lower in sole oats treatments ranging from 1.68% and 1.73% compared to pre planting.The higher organic carbon percentage in tested soilafter forage harvest in all vetch based treatments was probably due to improved soil structure and fertility. The lower OC % in pure standoat crop treatments showed that there was more utilization of organic carbon by oat plants.

In the current study, the increasing amount of organic matter percentage which ranged from3.37 % to 4.54 %were obtained in vetch and vetch-oats mixed treatments compared to before forage planting with the average 3.43 % OM anddecreased to 2.9% and 2.98 % ofOM were obtained after forage harvested inpure stand *Avena sativa* 15153Aand*Avena sativa* 5431A respectively.This might be due to the reason that high amount of organic matter applied to the soils in vetch based treatments and low amount or complete removal of biomass from oatcultivated field. This indicates that vetch based treatments, which build up organic matter content and arrest pH declining are likely to create soil condition that encourage survival, persistence and higher population of *Rhizobium* in soil.The current result agrees with Eshetu (2011), who reported that the soil which was cultivated on acid tolerant legume plantsfield havehigh organic matter contentthancereals like wheat cultivated fieldafter crop harvested at Hanoqdegem and Anoqere kebeles,Degem Woreda, North Shoa Zone, Ethiopia.

According to Barber (1984) rates that percent of organicmatter greater than 10 percent to be very high, 5-10 percent high, 2-5 percent medium, 1-2 percent low and less than 1 percent very low. Employing this rating,the organic matter percent of this studyafter forage harvested to be ranked medium for all experimental treatments.

Total nitrogencontentof the soil was increasedin all of sole vetch plots whereas, it was decreased in sole oats accessions after harvested compared to pre-planting (Table 3). The total nitrogen content after forage harvest varied from (0.19% to 0.24%)in pure stand vetch and vetch-oats mixture treatments whereas, the lowest (0.16%)was obtained under pure stand oats accessions which is below 0.17pre planting soil nitrogen level in the experiment soil.Thus, mixed cropping oats with vetch in this study offers better opportunities of complementary nitrogen use under low input farming systems without compromising the yield of both species.

The highest total nitrogen percentage after forage harvest in vetch varietieswere attributed due to the ability of vetch plants to biologically fix atmospheric nitrogen (N_2) in to the soil and improving the soil N status.On other hand, the decreased total nitrogen percentage observed in pure stand oats crop might be due to more utilization on soil N by oats than vetches.In mixed treatments, the percentage of total nitrogen inter-mediates between pure oats and pure vetch varieties after forage harvest.Thisvariations might be attributed to the vetch component of the mixtures may have fixed N in to the soil while, the amount of N absorption from the soil by the associated oats crops.

This result issupported byHauggaard-Nielsen *et al*., (2001a) who reported that legumes such as, vetch and alfalfa can cover their N demand from atmospheric N_2, therefore intercropped with cereals compete less for soil mineral N. Similarly the current result is in line with the finding of Keighobadi*et al*., (2014), who reported that intercropping cereal with seed legume crops such as cowpea, soybean, common vetch and groundnuts helps maintain and improve soil fertility, because these legumes accumulate about 80 to 350 kg nitrogen (N) ha^{-1}.

Mixed cropping had a significant positive effect on soil available potassium and exchangeablepotassium (Table 3). The soil available potassium and exchangeable potassium levels were seen to slightly increase in all treatments after forage harvest compared to before forage planting in experiment soils.The exchangeable potassiumwas corrected from low level to medium in all vetch based treatments after forage harvested butremained the same in pure stand oats accessions such a level of rating also suggested by Marx,*et al.*,(1999).Numerically, a slight change was observed on the available potassium amounts;however the rating was low and similar to before forage planting. The soil available potassium and exchangeable potassium byMarx,*et al*.,(1999) the rating level for available potassium<50, 150-250, 250-800, >800 and for exchangeablepotassium rated <0.4, 0.4-0.6, 0.6-2.0, >2.0,which was presented bylow, medium, high and excessive,respectively.According to the current result both oats and vetch species had a positive effect on available potassium and exchangeable potassium in the soil.

According to Landon (1991), who rated the top soils having CEC of > 40meq/100g, 25 - 40 meq/100g, 15-25 meq/100g, 5-15 meq/100g and < 5 meq/100g were classified as very high, high, medium, low and very low, respectively. The cation exchange capacity (CEC) values of the soils in the experiment site wereobtained in all treatments after forage harvest,whichwere below CEC value indicated before forage planting.The reduction of CEC values after forage harvest has seenin all pure stand and mixed components. However, the CEC value of the current experiment soil has 30.5 to 37.96 meq/100g after forage harvest.Thus, the present experiment soils containing high clay and medium organic matter contents have high cation exchange capacity. The current result supported by Marx, *et al.*,(1999) who reported that both clay and colloidal OM have the ability to absorb and hold positively charged ions.

Table 3. Soil physical and chemical properties before forage sowing and after harvest

A pooled soil sample	Soil physical and chemical properties before forage sowing							
	pH ($1:2.5H_2o$)	OC (%)	OM (%)	TN (%)	Av.P (ppm)	Av. K (ppm)	Exch. K (meq/100g)	CEC (meq/100g)
Before sowing	4.7	1.99	3.43	0.17	13.88	29.87	0.37	38
Texture class	Value	Rating						
Clay	42							
Sand	34	Sandy clay loam						
Silt	24							
Treatments	Soil test after forage harvested							
	pH ($1:2.5H_2o$)	OC (%)	OM (%)	TN (%)	Av.P (ppm)	Av. K (ppm)	Exch. K (meq/100g)	CEC (meq/100g)
T1	5.56	2.63	4.54	0.24	15.07	40.96	0.77	30.5
T2	5.39	2.42	4.17	0.23	15.71	50.67	0.59	35.46
T3	4.69	1.73	2.98	0.16	10.41	41.82	0.42	33.8
T4	4.75	1.68	2.9	0.16	10.73	44.37	0.37	37.96
T5	5.24	2.15	3.71	0.21	13.74	36.81	0.55	37.16
T6	5.04	2.1	3.62	0.20	14.06	31.5	0.53	33.76
T7	5.18	1.95	3.37	0.19	15.36	33.13	0.59	35.5
T8	5.23	2.17	3.74	0.20	13.43	39.28	0.43	32.43

OC% = Organic carbon percentage, OM% = Organic matter percentage, TN% = total nitrogen percentage, Av.P = Available phosphorous (parts per millions), Av.k (ppm.) = Available potassium (parts per millions), Exch.K (meq/100 g) = Exchangeable potassium (mills equivalent per 100 g), CEC (meq/100g) = Cat ion Exchange (Capacity mills equivalent per 100 gram), T1= *Vicia vilosa* 6792, T2= *Vicia sativa*, T3= Avena *sativa* 5431A, T4 =*Avena sativa* 15153A, T5= *Vicia vilosa* 6792 + *Avena sativa* 5431A, T6=*Vicia vilosa* 6792 + *Avena sativa* 15153A, T7=*Vicia sativa* + *Avena sativa* 5431A, T8=*Vicia sativa* +*Avena sativa* 15153A.

4.2. Phenological Parameters

4.2.1. Emergence percent and days to emergence

The results of emergence count in both oat and vetch species were presented in AppendixTable 1.The emergence percentage was not statistical analyzed but it was calculated using formula given for emergence count.The calculatedemergence percentage of *Vicia vilosa* 6792was high (94 %) compared to*Vicia sativa* having an emergence percentage of 90 %. The emergence percentage difference between the two vetch varieties was 4 %whereas;the two oataccessionshavealmost similar emergence percentage of 91 % and 92 % respectively. The differences between emergence percentages of both species might be attributed to differences on quality of seed.This result is in line with that of Getnet and Gezahagn (2012) who reported that the germination percentage for *Vicia* species 89 % to 93 % and for *Avenasativa* species 77 % to 93 %at different storage duration under room temperature and humidity at Holetta in the high land of Ethiopia.

Differentvarieties of vetch and oats accessionsshowed significant differences (P<0.05) indays to emergence (Table 4). Day to emergence was longest(11 days)for *Vicia sativa*both in sole and when mixed with oats varieties. The shortestdays of emergence (7.33 days)was recordedfor*Avena sativa 15153A*in both sole and mixed plots. The differences in days to emergence between the varieties were due to varietal and species differences of both oats and vetch. From the results, it was shown that the legumes took more days to emerge compared to oats. This was attributed to the growing nature of the legume or may be related to hardy seed coat of vetch species. This result agrees withthe finding of Solomon (2016) who reported that the maximum days to emergence were recorded in sole cropped legume (lentil and dekoko)plotscompered to cereals (wheat) intercropped plots at Mekelle university main campus northern Ethiopia.

4.2.2. Days to forage harvest

Analysis of variance revealed that the number of days required for 50% flowering for vetch and dough stage for oats showed significant different (p<0.05) between varieties and mixed cropping (Table4).The result of present study showed that, oats*Avena sativa 15153A* and vetch *Vicia sativa*were flowered relatively early90 and 106.67days respectively in pure stand whereas, vetch*Vicia vilosa 6792* was flowered late in pure stand (132 days)in comparison to the other varieties studied. This might be due to vetch(*Vicia vilosa 6792)* varieties have higher N fixation ability that enhanced availability of nutrients which easily self-catered.

In oats-vetch mixture 50% flowering was accomplished between 114.67 and 123.67 days after sowing (DAS) for both species (Table4). The currentresult revealed that differences in 50% flowering between the species might be due to varietal differences and mixture.In all mixed cropped plots 50% flowering tooka long timecompared to sole cropped plot except *Vicia vilosa 6792* plots.The possible explanation for the delay in heading of oats in mixture might be attributed to the transfer of a higher proportion of N fixed by vetch, which in turn delayed the maturity of oats by keeping the leaves green for a longer time than those plots with pure stand oats.

The current result revealed that there wascomparatively longer days to forageharvestin vetchescompared to the findings of Gezahagn*et al*. (2013) who reported that vetch species such as *Vicia sativa,Vicia narbonensis* and *Vicia villosa* on average require99.25 and 109.32 days after emergence for forage harvest at Holetta and Ginchi respectively.The resultof present finding also comparatively shorter days to forage harvest in oats than the finding ofGetnet and Ledin (2001)who reported that oat varieties such as oats 2291 was early dough stage at 95 days on the black soil and at 105 days on the red soil, while oats 8237 and 2806 varieties dough stage were at 105 and 115 days respectively. The author suggested that difference in maturity period is an important agronomic trait to select companion crops in mixed fodder systems for maximum production. The current result indicated that late maturing species *Vicia vilosa 6792*mixedwith late maturing *Avenasativa* 5431A accessionsstay green and increased days to forage harvest and compatibility was good compared with early maturing *Avena sativa 15153A*varieties.Late maturing varieties stay green for longer period of time so farmers get green feed for their livestock for longer period. On the other hand, early maturing varieties *Avena sativa 15153A*and *Vicia sativa*could be raised in short rains to feed the livestock during the critical period of feed shortage.

4.2.3. Days to forage seed harvest

Days to seed maturity of species also showed similar trendwith days to 50% flowering for forage varieties under study (Table 4).Analysis of variance showed significant difference ($P<0.05$) in day to seed maturity between varieties and no significant different betweenmixtures(Table 4).The oats accessions,*Avena sativa* 15153Aand *Avena sativa* 5431A were early matured in 135 and 142.33days after forage sowing in pure stand whereas, vetch variety*Vicia sativa*was matured early 150.67 days after forage sowing.Vetch (*Vicia vilosa* 6792)waslate maturedunder sole170.67and when mixed with oats 154 to 158.33 DAS.Days toseed harvesting for oats was shorter compared to vetch and hence the growth rate of oats was also faster than the vetch while *Vicia sativa* grew very slowly at the beginning and fast at end of the growing period, which reduced compatibility. The growth rate of vetch in pure stands was very similar to vetches in the mixtures until 40 days. After this the vetch in the mixture could not compete and catch up on the oats and the suppression of oats became evident as the development of the plants progressed.

The result of this study showed that days to forage seed harvestin oatsaccessions was significantly longer ($p<0.05$) in *Vicia vilosa* 6792+ *Avena sativa* 5431A (158.33 days)mixed treatment compared to*Avena sativa 5431A*(142.33 days) in pure stand.Generally, vetch-oat mixture increased the number of days to seed maturity for oats accessions.This could be as a result of moisture conservation due to the reduced soil water evaporation provided by the vetches in the mixed treatments and reduced the severity of moisture stress.The result of present findingis comparable with the result of Gezahagn*et al.*,(2013) who reported that mean daysto forage seed harvest (140.81 days)for pure stand*Vicia sativa,Vicia narbonensis* and *Vicia villosa* foragesatHoleta and Ginchi locations.

Table 4.Days to emergence,50%flowering and seed harvest of vetch and oat accessions

Treatments	Days to 90 % emergence	Days to headingstage for oats and 50%flowering vetch	Days to seed harvest

T1	9.66±0.33[b]	132.00±0.57[a]	170.67±1.20[a]
T2	11.00±0.57[a]	106.67±0.88[e]	150.67±0.88[d]
T3	8.00±0.57[b]	97.00±0.57[f]	142.33±0.57[e]
T4	7.33±0.33[b]	90.00±1.15[g]	135.00±0.33[f]
T5	9.66±0.33[a]	123.67±0.88[b]	158.33±0.88[b]
T6	9.66±0.33[a]	115.33±0.88[d]	154.00±0.57[c]
T7	11.00±0.57[a]	121.00±0.57[c]	156.00±0.57[c]
T8	11.00±0.57[a]	114.67±0.33[d]	155.00±0.57[c]
Mean ± SEM	9.67±0.30	112.54±2.73	152.75±2.85
P-Value	0.0006	0.0001	0.0001
CV	8.88	1.00	0.58

[a-f,] means followed by different superscripts in a column are significantly different (P< 0.05); T1= *Vicia vilosa 6792*; T2= *Vicia sativa; T3=* Avena *sativa 5431A; T4 =Avena sativa 15153A; T5= Vicia vilosa 6792 + Avena sativa 5431A; T6= Vicia vilosa 6792 + Avena sativa 15153A T7=Vicia sativa +Avena sativa 5431A; T8=Vicia sativa + Avena sativa 15153A;*SEM = standard error mean, CV = Coefficient of variance.

4.3. Growth Parameters

4.3.1. Seedling count

The seedling counts after two weeks of emergency for both forage species showed significant variation (P<0.05) among the treatmentsas shown in table 5. The highest seedling counts at emergence for both specieswere obtained under pure stand and the lowest seedling count at emergence wereobtained from mixture of *Vicia sativa* + *Avena sativa* 5431A with grand mean values of 22.33 and 64.94 seedlings per m^2 for oats and vetch respectively.The possible reason for differences in seedling count might be due to the seed rate used at planting and germination percentage of the seed.

The current result is in line withthe finding of Fantahun*et al.*, (2017) who reported that the difference from the highest and lowest seedling counts at emergence for vetch varieties was 8 seedlings per m^2 and oats varieties126 seedlings per m^2.The current result was also supportedby Solomon *et al* (2008) who reported that the highest seedling counts at emergence were observed for the sole plots of both oats and vetch species than mixture.In contrary, the current result is lower than the finding of Getnet and Ledin (2001) who reportedthatthe mean seedling count at emergence 237 and 63 seedlings per m^2in pure stand oat and vetch whereas, in the mixture 191 and 63 seedlings per $m^2$for oats and vetchrespectively atHoleta, Ethiopia.

4.3.2. Plant height

Plant height recorded for vetches at flowering and oats at heading stages showed significant difference ($P < 0.05$) among the treatments (Table 5). The tallest vetch plants (118.46 cm) in pure stand and(114 cm) in mixturewere registered in *Vicia vilosa* 6792while,*Vicia sativa*recorded the shortest plant height70.60 cm and 87 cm under pure stand and mixture respectively. In oats accessions,the highestmean plant height116.26 cmand 133.53 cm wereobtainedin*Avena sativa* 15153Aunder pure stand and mixture treatment respectively.In mixed treatment, maximum plant height 133.53 cm was obtained from*Avena sativa 15153A* + *Vicia vilosa* 6792 followed by *Avena sativa* 5431A + *Vicia vilosa* 6792mixture124.60 cm and lowest height obtained from*Avena sativa* 5431A + *Vicia sativa*(113.46 cm). The results revealed that except in *Vicia vilosa* 6792 plant height in mixed plot is higher thanthat of pure stand plots. The mixtures of *Avena sativa 15153A* + *Vicia vilosa* 6792and*Avena sativa* 5431A + *Vicia vilosa* 6792crops obtained 17.27 cmand 15.2cm more plant height than their respective pure stand *Avena sativa* 15153A and *Avena sativa*5431A which could be a result of moisture conservation by the legumes and competitionfor sunlight between the plants of two species.

The current findings were in accordance with that of Khan *et al.*, (2005) who reported that legumes intercropping significantly increased the height of wheat when it was intercropped with lentils, canola and chickpea at the same ratio inPakistan. The current result also agrees with the finding of Gezahagn *et al*., (2016) who reported taller plant height for *Vicia vilosa* followed by *Vicia sativa*. Similarly, Desalegn and Hassen, (2015) reported that *Vicia sativa* wasthe shortest vetch species having an average height of 81 cm and *Vicia vilosa* was the tallest 126 cm. The result of the current study was in contrast with the findings of Canaan and Orak (2002) who reported the highest plant height from *Vicia sativa* under pure stand in Bulgaria. The higher variation in plant height might be attributed to factors such as season and soil type which can positively affect this character. Therefore, the variation in plant height between two studies could be attributed to variation in genetic make-up, soil type, season and adaptability of the varieties to different environmental conditions.

4.3.3. Number of branches per plant

A number of branches per plant in vetch were significantly affected (P<0.05) by both cropping systemand varietaldifferences as shown in Table 5. The higher number of branches per plant was recorded in *Vicia vilosa* 6792compared to *Vicia sativa*both underpure standand mixture. The average mean value (7.73 and 3.90) was obtained from *Vicia vilosa* 6792and*Vicia sativa* under pure stand cropped plots whereas, average mean value 3.8 to 5.93 were obtained under mixture of two vetch varieties with oats accession plots.The result showed*Vicia villosa 6792*had higherbranching abilities observed compared to*Vicia sativa* in both pure stand and mixture with oats accessions.

The possible reason for variation in number of branching abilities between vetch species might be due to species difference and adaptability of the varieties to experimental site. The current result is lower than the finding of Molla *et al.,* (2018) who reported that the mean number of bran ches per plant of *Vicia villosa* (14.57) and *Vicia dasycarpa* (11.43) at Fogera district North West Ethiopia. Similarly, Gezahagn *et al.*, (2013) reported that *Vicia dasycarpa* and *Vicia villosa* gave the highest branches per plant during forage harvest at Holetta and Ginchi.

4.3.4. Number of tillers per plant of oats varieties

Number of tillers per plant was significantly higher(P<0.05) between accessions and cropping system at heading stage of oats (Table 5). The highestnumber of tiller per plant was found in *Avena sativa 15153A*accessionmixed with*Vicia vilosa 6792*(8.20) followed by *Avena sativa 5431A*mixed with *Vicia vilosa 6792*(7.26)whereas, the lowest average mean number of tiller(4.10) was recorded under pure stand *Avena sativa 15153A*accession.Number of tiller per plant oats was greater in the mixed plot than in the sole oat plots. The variation in number of tillers could be attributed to variation in cropping system, varieties difference and adaptability of varieties to the study site.The present result is lower than the finding ofAmanuel*et al.*, (2019) who reported thatat 50% heading stage CV-SRCP X 80Ab 2806 produced the highest number of tillers per plant (12.0) followed by lampton (11.0), CI-8235 (10.7) and CV-SRCP X 80Ab 2291 (10.7) and the lowest was recorded for the variety CI-8237 (10.3)grown under irrigation condition in Soddozuriya district, Wolaita Zone, Ethiopia

Table 5. Effects of species on seedling counts at emergence, plant height at forage harvest, number of tillers per plant and number of branches per plants in the study area

Treatment	SC (per m^2)		PH (cm)		NTPPO	NBPPV
	Vetch	Oats	Vetch	Oats		
T1	27.66±0.88[a]	-	118.46±0.74[a]	-	-	7.73±0.35[a]
T2	24.33±0.33[b]	-	70.60±0.41[f]	-	-	3.90±0.32[c]
T3	-	88.00±5.13[b]	-	109.4±2.41[d]	5.76±0.23[b]	-
T4	-	103.33±4.84[a]	-	116.26±1.50[c]	4.10±0.47[c]	-
T5	22.33±0.88[bc]	48.00±3.21[c]	97.93±0.37[c]	124.60±1.22[b]	7.26±0.24[ab]	5.93±0.35[b]
T6	19.33±0.88[de]	53.00±7.57[c]	114±0.11[b]	133.53±3.46[a]	8.20±0.63[a]	5.53±0.40[b]
T7	18.66±0.88[e]	42.66±3.48[c]	84.33±1.09[e]	113.46±1.20[cd]	7.13±0.73[ab]	4.33±0.46[c]
T8	21.66±0.88[cd]	54.66±4.63[c]	87±1.02[d]	118.73±1.07[bc]	5.70±0.35[bc]	3.80±0.36[c]
Mean±SEM	22.33±0.78	64.94±5.72	95.38±4.08	119.33±2.03	6.36±0.36	5.20±0.35
P-Value	0.0001	0.0001	0.0001	0.0002	0.0034	0.0001
CV	5.95	10.37	1.10	3.08	14.39	12

[a-f,] means followed by different superscripts in a column are significantly different (P< 0.05); SC =seedling count, PH= plant height (cm), NTPPO= number of tiller per plant oat, NBPPV= number of branches per plant vetch T1= *Vicia vilosa* 6792, T2= *Vicia sativa*, T3= Avena *sativa* 5431A, T4 =*Avena sativa* 15153A, T5= *Vicia vilosa* 6792 + *Avena sativa* 5431A, T6=*Vicia vilosa* 6792 + *Avena sativa* 15153A T7=*Vicia sativa* + *Avena sativa* 5431A, T8=*Vicia sativa* +*Avena sativa* 15153A;SEM = standard error mean; CV = Coefficient of variance.

4.4. Nodulation of vetch species

Number of nodules weresignificantly affected (P<0.05) by varietydifferences andmixture(Table6). The highest nodule score(1.33)in the crown-root zone with 9 nodules on elsewhere on the root system were recorded at 30 DAS in pure stand *Vicia vilosa* 6792whereas, the lowest nodule score(0.55)in the crown-root zonewith 4 nodules on elsewhere on the root systemwere recorded from mixed plot *Vicia sativa* + *Avena sativa 15153A.*The results showed that, *Vicia vilosa* 6792 havea significantlyhigher number of nodules at 30 DAS than *Vicia sativa.* Due to higher numberof nodules*Vicia vilosa* 6792 which had a good potential for N2 fixation than *Vicia sativa.*The lowest mean number of nodule was obtained from *Vicia sativa* + *Avena sativa 15153A* which indicates there was probably little or no N_2 fixation in *Vicia sativa* varieties at 30 DAS (Appendix Table 5 and 6).

At 70 DAS the highest nodule score(4.78)in the crown-root zone with 78 nodules on elsewhere on the root system were recorded in pure stand *Vicia vilosa* 6792whereas, the lowest nodule score(3.00)in the crown-root zone with 28.33 nodules on elsewhere on the root systemwere recorded in mixed plot *Vicia sativa* + *Avena sativa* 15153A.The result (Table 6) after 70 DAS showed that the highest nodule score obtained from *Vicia vilosa* 6792that indicates excellent nodulation or excellent potential for N2 fixation whereas, the lowest nodule score was obtained from*Vicia sativa + Avena sativa 15153A*after 70 DASwhich indicates there was a good nodulation and good potential for N2 fixation.

Thedifferences in number of nodules between study varieties attributed due togrowth stage, existence of sufficient nutrients, soilacidity and varietal differences.The current study supported by Pimratch *et al.,* (2008) whoreportedthatlegumes nodulation and nitrogen fixation depends up onsome of climatic factors like excessive soil moisture and moisture stress and edaphic factors such as soil acidity,existence of minerals nitrogen and deficiencies of phosphorus. Similarly, legumes normally require more phosphorus than none nitrogen fixing crops (Serraj*et al.,* 2004) as phosphorus is important in ATP synthesis for nitrogen fixation (Muhammad *et al.,* 2004; and Qiao *et al.,* 2007). The current study also in line with Rasmussen *et al*., (2007) who reported that N accumulated in legume roots could be transferred to the associated crops in mixed cropping and intercropping systems through decomposition of debris of legume roots including root nodules and/or exudation of nitrogenous compounds from the roots.

Table 6. Nodulation of Vetch grown in pure stand and in mixturewith oats

Treatments	Mean nodule score	
	30 (DAS)	70 (DAS)
Vicia vilosa 6792	1.33±0.10[a]	4.78±0.11[a]
Vicia sativa	0.89±0.10[bc]	4.33±0.19[ab]
Vicia vilosa 6792+ *Avena sativa* 5431A	0.99±0.10[ab]	3.66±0.33[bc]
Vicia vilosa 6792+ *Avena sativa* 15153A	1.11±.10[ab]	4.22±0.11[ab]
Vicia sativa +*Avena sativa* 5431A	0.66±0.10[cd]	3.33±0.33[c]

Vicia sativa + Avena sativa 15153A	$0.55{\pm}0.10^{d}$	$3.00{\pm}0.19^{c}$
Mean±SEM	0.926±0.10	3.88±0.16
P-Value	0.0032	0.0016
CV	19.26	9.77

^{abcd,} = means followed by different superscripts in a column are significantly different (P< 0.05); DAS =Days after forage sowing; SEM = standard error mean; CV = Coefficient of variance

4.5. Yield and Yield Related Components

4.5.1. Forage dry matter yield

The results from analysis of variance for DM yield of sole vetch and oats accessions and their mixtures werepresented in Table 7. Significant differences were observed in forage DM yield(p<0.05) among the treatment groups. The highestmean forageDM yield wasobtained in *Vicia vilosa 6792 +Avena sativa 15153A*mixture (8.49 t/ha) whereas, the lowest mean forageDM yield (3.8 t/ ha) was obtainedfrom pure *Vicia sativa*.The current result indicated that from vetch varieties,*Vicia vilosa6792*performed better in herbage DM yieldthan*Vicia sativa*in both pure stand and in mixture.Similarly, from oat accessions, *Avena sativa 15153A* had highest herbagedry matter yield compared to *Avena sativa 5431A* in both pure stands and in mixture.

The result from analysis of variance revealed that the herbage DM yields of oat accessions under mixture treatments weresignificantly higher (P<0.05) DM yield than their respective of pure stand. The possible reason for higher DM yield for oat-vetch mixturethan pure stand might be due to the higher number of tillers and maximum plant vegetative growth were observed in mixed plotscompared to pure stand oat plots.The possible reason for higher DM yield for *Vicia vilosa6792*species in both pure stand and mixture compared to *Vicia sativa* might be due to the higher branching abilities, varietal differences and maximum plant vegetative growth were observed compared to *Vicia sativa* species.

Generally in this study, forage DM yield of oats-vetch mixed treatments were superior compared to their counterpart treatments. The present resultis in line withthat of Getnet and Lendin,(2001) andAlemu *et al.*(2007) who reportedthat yields for vetch-oats mixtures were higher compared to either of the pure stands at Holetta research Centre.This study was also supported byMalede

(2013)who reported that dry matter production in oats-vetch mixture had been more than pure cropping at North Gondar zone, Ethiopia.

In contrary, the current result is lower than the finding of Fantahun *et al.*,(2017)who obtained higher meanherbageDM yield and lowest meanherbageDM (17.61 t/ha and 6.48 t/ha)from 75% oats +25% vetch and 100% vetch seed proportion respectivelyat Debre Zeit agricultural research Centre.However,present findingis higher thanMolla *et al.*,(2018)who reported higher mean DM (5.09 t/ha) in the mixture of *CI-8237 + V.vilosa*and the lowest mean DMY (3.22 t/ha)in mixture of *CI-8251 + V. dasycarpa*at Fogera district North West Ethiopia.

4.5.2. Seed yield and thousand seed weight

The seed yield in tone per hectare was significantly affected ($P < 0.05$) due to species variability and mixed cropping (Table 7). The highest seed yields were obtained from*Avena sativa* 5431A with 3.73 t/ha followed by *Avena sativa 15153A* with an average yield of 3.65t/ha under pure stand. The lowest mean seed yields (1.19 t/ha and 1.92 t/ha)were recorded from*Vicia vilosa* 6792and *Vicia sativa* respectively.

The sole cropping was significantly different from the mixed treatments and produced the highest seed yield obtained which was by far greater than any of the mixed situation in present study. The yield differences between varieties and accessions might be due to in vetch species which have erected growth habit and effective branch whereas in oats effective tiller and varietal variability attributed the differences.

The current result is higher than the finding of Gezahagn*et al*., (2013) who reported that the highest seed yield was obtained from *Vicia sativa* 0.8 t/ha at Holetta and *Vicia narbonensis* 2.9 t/ha at Ginchi, whereas the lowest seed yield was obtained from *Vicia narbonensis* 0.4 t/ha at Holetta and *Vicia atropurpurea* 2.0 t/ha at Ginchi.

Thousand seed weight (TSW) of both vetch and oats varieties showed significant ($P<0.05$) difference among the treatment combination (Table 7). The highest thousand seed weight 89.38 gm was recorded from vetch varieties *Vicia sativa* whereas the lowest thousand seed weight 37.61gm was recorded for oat *Avena sativa 15153A* accession. This agronomic trait is important for seed rate determination for both oat and vetch varieties. The difference in thousand seed weight could be due to the species variability complemented with the mixed cropping and seed size. The current result is lower than the finding of Gezahagn *et al.*, (2013) who reported that the thousands of seed yield for vetch varieties (*Vicia dasycarpa*, *atropupura, vilosa, sativa,* and *narbonensis*) with a mean of 81.7 gm at Holetta and mean of 86.3 gm at Ginchi. Fekede (2004) also suggested that thousand seed weight has got practical significance in estimating seeding rate for each oat variety in order to ensure that equal number of seeds could be sown per unit area.

Table 7. The effect of variety ontotal DM yield (t/ha), seed yield (t/ha)and thousand seed weight of oats - vetch mixtures

Treatments	TDMY (t/ha)	SY (t/ha)	TSW (g)	
			Vetch	Oat
T1	5.47±0.49[d]	1.19±0.04[d]	71.62±3.56[bc]	-
T2	3.8±0.42[e]	1.92±0.06[c]	89.38±2.42[a]	-
T3	4.87±0.26[d]	3.73±0.14[a]	-	47.33±3.36[a]
T4	7.55±0.45[bc]	3.65±0.19[a]	-	45.60±2.07[a]
T5	6.83±0.33[bc]	2.95±0.04[b]	64.13±2.35[cd]	39.86±0.57[b]
T6	8.49±0.41[a]	3.09±0.02[b]	62.06±1.84[d]	39.80±0.57[b]
T7	6.48±0.67[cd]	2.84±0.09[b]	77.14±2.21[b]	40.18±0.80[b]
T8	6.89±0.13[ab]	3.09±0.06[b]	73.56±4.47[b]	37.61±1.02[b]
Mean±SEM	6.30±0.33	2.81±0.17	69.14±4.47	41.73±0.74
P-value	0.0008	0.0001	0.0002	0.005
CV%	9.55	6.09	5.99	6.04

[abc,] = means followed by different superscripts in a column are significantly different (P< 0.05); TDMY = dry matter yield;SY = seed yield; TSY= thousands seed yield; T1= *Vicia vilosa* 6792; T2= *Vicia sativa;*T3= Avena *sativa* 5431A; T4 =*Avena sativa* 15153A; T5= *Vicia vilosa* 6792 + *Avena sativa* 5431A;T6= *Vicia vilosa* 6792+ *Avena sativa* 15153A; T7=*Vicia sativa* +*Avena sativa* 5431A; T8=*Vicia sativa* + *Avena sativa* 15153A; SEM = standard error mean, CV = Coefficient of variance

4.6. Chemical Compositions of Oats and Vetch Varieties

4.6.1. Dry matter (%DM)

The dry matter percentage of the treatments was presented in Table 8. There was no significant difference (P>0.05) between vetch and oat varieties under both mixture and pure standin DM content. However, numerically, the DM percentwas ranged from 91.80% to 93.78% with over all mean of 92.70% for both oat and vetch varieties under pure stand and mixture.Thecurrent result agrees with the result of Fantahun *et al*., (2017) who reported thatDM % of vetch and oatranged between 91.15%and 93.76% in bothmixture and pure stand respectively.

4.6.2. Crude protein contents

The mean crude protein content was significantly ($P < 0.05$ affected by bothcropping system and species differences (Table 8).In current study themean higher CP content (20.14 %) and (19.40 %) was obtainedforvetch species*Vicia vilosa* 6792and *Vicia sativa* whereas, the lowest CP content (14.04 %) and (14.45 %) obtainedfor *Avena sativa 5431A* and *Avena sativa* 15153Ain pure stand respectively. Under mixed cropping, percent of CP contentranged from 15.45 to 17.87for oats at heading stage and vetch at flowering stage. However,the CP content of two oat accessions were notsignificantly different under pure stand butsignificantly lower CP content than the respective pure vetch varieties and oat-vetch mixtures. Though the CP content of mixtures were below the CP content of their respective pure vetch varieties, mixtures showed greater than CP content of their respective pure oats accessions.

The variability in CP content between the treatments might be due to species differences and the symbiosis process;vetches associated with rhizobia symbiotically fix atmospheric N_2 and increase available N in the soil and in return they receive nitrogen assimilated by them, which they use to produce high percent of protein. Possible reason for the variability in CP content of oats growing in the vicinity of vetch use the nitrogen assimilated by nodule bacteria, as it is transferred to the soil whichenhance soil fertility and species differences being the basis for variation in CP content of oats in mixture compared to the respective pure stand oats.Making use of improved forage varieties has several advantages.The most important contribution of CP is their direct effect on livestock production. It has good feeding value related to nutrient contents and digestibility. Better animal performance can be obtained from high protein and energy because milk and other products increase their nutrients flourish for the neonate and human nutrition.Thecurrent result is in line with the finding of Molla*et al*. (2018) who obtained the highest mean CP % of 19.55 % from mixtures of oats CI-8251 + *Vicia villosa* at first cutting stagewhich was higher than their counter part purely sown oat plots in Fogera district, North West Ethiopia.SimilarlyGezahagn*et al*., (2016)who reported 18% CP in oats–vetch mixture, and Starks *et al.*,(2006) reported 26% CP obtained in case of pure stand vetch at dough stage.

4.6.3.Total ash content.

Total ash content was significantly affected ($P < 0.05$) byvarietal differences (Table 8). The highest ash percentage was recorded from *Avena sativa 5431A* (12.30%) and the lowestwas obtained from *Vicia sativa* (9.68%) under pure stand.Inmixed croppingthe highestash percentage was recorded in*Vicia sativa + Avena sativa 15153A* (11.40%) andthelowest was obtained from *Vicia vilosa 6792* + *Avena sativa 15153A* (10.97 %), but mixture gave statistically similar values. The variability in %ash content between treatments might be due to varietal differences.The present result agrees with Fantahun*et al*. (2017) who reported that the ash content of both varieties of vetch was low compared to the mixture and sole oats varieties. In general, variation in concentration of minerals in forages can be induced by factors like varieties and morphological fractions,plant developmental stage, climatic conditions, soil characteristics and fertilization regime has been reported(Jukenvicius and Sabiene, 2007; Gezahagn *et al.*, 2016).

4.6.4. Neutral detergent fiber (%NDF)

The analysis of varianceshowed that Neutral detergent fiber (NDF) was significantlyaffected(P<0.05) byboth varieties and cropping system (Table 8). The highest NDF content (55.90 % DM) and(55.52 % DM)were recorded for pure stand *Avena sativa* 5431Aand*Avena sativa* 15153Arespectively whereasthe lowest NDF content(40.35% DM)was recorded for pure stand*Vicia vilosa* 6792.In present study,the two vetch varieties exhibited the lower mean values of NDF content than the two accessions of oats and vetch-oats mixture except in*Vicia vilosa* 6792 + *Avena sativa* 15153Amixed treatment which has the value of NDF content less than from*Vicia sativa*NDFcontent. The NDF content of treatments wasvariedamong the testedspecies but thetwo oats varietiesnot significantly different under pure stand.In vetch, early maturing and erect growing type *Vicia sativa*had comparatively higher NDF content than intermediate to late maturing and creeping type of *Vicia villosa 6792*.

Generally,the mean NDF value of 50.54% DM obtained in present study wascomparable with the mean NDF values of56 % reported by Singh *etal*., (2010) and 61 % by Anele *et al*., (2011a). The current finding is similar with Molla*et al*.,(2018) who reported that the mean NDF value of 50.49% was recorded inoats CI-8237 + *Vicia dasycarpa* and oats CI-8237 + *Vicia villosa* mixture at Fogera district, Ethiopia.Similarly, the current finding was in line with the finding of Kassahun and Wasihun(2015) who reported that 47.1% and 49.4% NDF content were obtained in pure stand *Vicia dasycarpa* and *Viciavilosa* respectively at the agricultural research site of Jimma University.Jung and Engles (2002)suggested that as stems mature, protein content decreases and carbohydrate content increases and at maturity, stems make up as much as 80% of the total DM and NDF, which generally estimates the percentage of total fiber (cellulose, hemi cellulose and lignin) increases due to increases in xylem tissue.

4.6.5. Acid detergent fiber content (%ADF)

Acid detergent fiber was significantly (P<0.05) affected by both cropping system and species difference (Table 8).This fraction contains cellulose, lignin and pectin. ADF has positive relationship with the age of the plant (NRC, 1981). In present study, the highest ADF content of (41.33 %)was obtainedin purestand *Avena sativa* 15153Aandthe lowest (29.84%) ADFwas recorded from *Vicia vilosa* 6792.The lower ADF content indicates that it is more digestible and more desirable.ADF content recorded in sole oat plot was higher than ADF % obtained in pure stand vetch and vetch - oat mixed treatments. The variability in ADF content between the vetch and oat species might be attributed to species differencesbetween tested varietiesand cropping system.

The grand mean of ADF content35.70 % found in present study wasslightly comparable withKezemi*et al.,(*2012) who reported that ADF value falling within value less than 40% were rated first grade quality standard and above 40% low quality. Hence, current varieties were comparatively lower value of ADF content, this could be indicative of its better digestibility at 50% flowering stage for vetches and heading stage for oatsin all treatmentsexcept for *Avena sativa 15153A*(41.33 %).Thisresult islower than the finding of Berhanu*et al.,*(2007)who reportedthat the mean ADF content 40.68% andADF value rangingfrom 33.09 to 44.97 at different harvesting stage in case of oat and vetch mixturesat Adet agricultural research center, Northwestern Ethiopia. The author suggested that highest ADFconcentration produced at late harvesting stage mightbe due to the decrease in leaf to stem proportion andan increase in cell wall lignification which may leadto raised ADF concentration at an advanced growthstage.

4.6.6. Acid detergent lignin content (ADL)

Acid detergent lignin (ADL) was significantly ($P < 0.05$) affected by variety differences, but their mixture did not show significant effect on this parameter(Table 8). The highest ADL content 10.93% DM and lowest ADL content 7.76% were recorded frompure stand *Avena sativa* 15153A and*Vicia vilosa* 6792 respectively.The grand mean of 9.37 % ADL content in current study were recorded from both pure stand and mixed treatments. Thus, the lignin contents of feeds in this study in line with the finding of Molla *et al.,*(2018) who reported thatthe highest (11.87%) and lowest (7.92%) mean ADL contents were recorded at third cutting and first cutting , respectively. The current result also agreeswith the result of Kassahun and Wasihun,2015 who reported that the maximum level of ADL content 10.76% DM and minimum ADL content 6.3% DMwas obtained from pure stand *Vicia dasycarpa* and*Vicia vilosa* respectivelyat the agricultural research Centre of Jimma University.This could be due to rapid lignification as the result of concentration of structural carbohydrates at advanced age of plant growth.

6.6.7. Ether extract (%EE)

The ether extract content was significantly different ($P<0.05$) between species and varieties(Table 8). The highest crude fatcontent was obtained from pure stand vetch varieties compared withoat and oat-vetch mixed treatments. The highest 1.06% of ether extract content was obtained from *Vicia vilosa* 6792and lowest 0.79% of ether extract was obtained from*Avena sativa* 5431Aoat accessions.The result revealed that the highestcrude fat and protein content were obtained in pure stand vetch and vetch associated treatments while the pure stand oat had the lowest amount of these components.

6.6.8. Cellulose and Hemicellulose content

The analysis of variance showed that cellulose content significantly different ($P<0.05$) among the treatments (Table 8). The cellulose content of the treatments also showed the highest value when compared with lignin and hemicellulos. The result also revealed that hemicellulose content significantly different ($P<0.05$) among the species.In this study cellulose content ranged from 21.53 to 30.40 the overall mean of 26.32 and hemicellulose ranged 10.50 to 18.42 the overall mean value 14.83 was obtained (Table 8). Result revealed that among the plant tissue constitutes cellulose was highest followed by hemicelluloses and lignin which is similar to the finding of Gezahagn *et al., (*2014) and Fantahun *et al.,* (2017).

Table 8.The effect of varieties on qualities ofvetch and oats grown in pure stand and mixture in the study area.

Treatments	%DM	%Ash	% Cp	% EE	% NDF	% ADF	%ADL	%Cel	%Hem.cel
T1	93.37±0.90[ab]	10.58±0.23[bc]	20.14±0.32[a]	1.06±0.00[a]	40.35±0.19[e]	29.84±0.75[d]	7.76±0.61[c]	22.08±1.08[b]	10.50±0.95[d]
T2	92.97±0.58[ab]	9.68±0.14[c]	19.4±0.61[b]	1.02±0.01[ab]	49.39±0.79[cd]	30.96±0.89[d]	9.43±0.54[b]	21.53±1.44[b]	18.42±0.16[a]
T3	93.78±0.15[a]	12.30±0.28[a]	14.04±0.24[f]	0.79±0.06[d]	55.90±1.49[a]	39.35±0.60[abc]	9.73±0.23[ab]	29.61±0.63[a]	16.55±1.79[ab]
T4	91.80±0.39[b]	12.08±0.48[b]	14.45±0.42[f]	0.93±0.05[bc]	55.52±0.75[a]	41.33±1.27[a]	10.93±0.37[a]	30.40±1.31[a]	14.18±1.52[abcd]
T5	92.48±0.40[ab]	10.99±0.63[abc]	17.12±0.23[d]	0.86±0.05[cd]	50.47±1.48[bcd]	36.62±0.64[c]	9.10±0.20[bc]	27.52±0.45[a]	13.85±0.92[bcd]
T6	91.96±0.15[b]	10.97±0.57[abc]	17.87±0.21[c]	0.97±0.01[abc]	47.66±0.43[d]	30.66±1.74[d]	8.70±0.58[bc]	21.96±1.81[b]	17.00±1.39[ab]
T7	92.39±0.72[ab]	11.38±0.25[ab]	15.93±0.19[e]	0.92±0.04[bc]	51.82±1.21[bc]	39.76±1.12[ab]	9.76±0.34[ab]	30.00±1.40[a]	12.05±2.30[cd]
T8	92.82±0.24[ab]	11.40±0.85[ab]	15.45±0.15[e]	0.93±0.00[bc]	53.20±0.94[ab]	37.06±0.99[bc]	9.60±0.47[ab]	27.46±1.44[a]	16.13±1.92[abc]
Mean±SEM	92.70±0.2	11.17±0.21	16.80±0.44	0.94±0.02	50.54±1.02	35.70±0.94	9.37±0.22	26.32±0.83	14.83±0.68
P-value	0.22	0.020	0.0001	0.0069	0.0001	0.0001	0.018	0.0002	0.025
CV	1.01	6.82	2.51	7.10	3.52	4.62	8.81	8.03	17

[a-f,]= means followed by different superscripts in a column are significantly different (P< 0.05); T1= *Vicia vilosa* 6792, T2= *Vicia sativa*, T3= *Avena sativa* 5431A, T4 =*Avena sativa* 15153A, T5= *Vicia vilosa* 6792 + *Avena sativa* 5431A, T6= *Vicia vilosa 6792* + *Avena sativa* 15153A;T7=*Vicia sativa* +*Avena sativa* 5431A; T8=*Vicia sativa* + *Avena sativa* 15153A; SEM = standard error mean, CV = Coefficient of variance

4.7. Crude Protein Yield (CPY) and Neutral Detergent Fiber Yield (NDFY) t/ha

The calculated CPY and NDFY from the total DMY of the pure oats and vetch and their mixtures showed significant differences (P<0.05).The highest CPY 1.51 t/ha was calculated from *Vicia vilosa 6792 + Avena sativa 15153A*in mixtureand the least 0.68 t/ha was calculated from *Avena sativa 5431A* under pure stand whereas, the highest NDFY 4.20 t/ha was obtained from *Avena sativa 15153A*and the least 1.87 t/ha was calculated from *Vicia sativa*under pure stand (Table 9).

The significant differences in nutrient yield between the treatments might be due to the total dry matter yield obtained per hectareand the concentration of nutrient obtained from each component.The result ofthis study is supported by Geleti (2014) who reported that CPY is the product of total dry matter yield and CP concentration in the plant which can be substantiated by the values obtained from CP percent and the dry mater yield obtained from each treatment in Bako and Nekemte Peri-urban areas, Oromia, Ethiopia. Because of this fact, in present study, the highest amount of CPY was obtained from the high DMY recorded *Vicia vilosa 6792 + Avena sativa 15153A* mixed treatment and low CPY (t/ha) was obtained from the low CP concentrated *Avena sativa 5431A*pure stand treatment.

Table 9. The effect of variety on nutrient yield (t/ha) of oats - vetch grown on pure stand and mixture

Treatments	CPY (t/ha)	NDFY (t/ha)
T1	$1.25{\pm}0.22^{ab}$	$2.20{\pm}0.37^{de}$
T2	$0.79{\pm}0.09^{cd}$	$1.87{\pm}0.20^{e}$
T3	$0.68{\pm}0.03^{d}$	$2.73{\pm}0.20^{cd}$
T4	$1.08{\pm}0.02^{bc}$	$4.20{\pm}0.30^{a}$
T5	$1.12{\pm}0.01^{b}$	$3.44{\pm}0.10^{abc}$
T6	$1.51{\pm}0.06^{a}$	$4.04{\pm}0.20^{ab}$
T7	$1.03{\pm}0.12^{bc}$	$3.34{\pm}0.26^{bc}$
T8	$1.06{\pm}0.01^{bc}$	$3.66{\pm}0.09^{ab}$
Mean ± SEM	1.066±0.05	3.18±0.17
P-value	0.0024	0.0001
CV	17.12	13.85

[abcd]=means followed by different superscripts in a column are significantly different (P< 0.05); CPY = crude protein yield ton per hectare; NDFY (t/ha) = Neutral detergent fiber yield ton per hectare.T1= *Vicia vilosa* 6792; T2= *Vicia sativa;* T3=Avena *sativa* 5431A; T4 =*Avena sativa* 15153A; T5= *Vicia vilosa* 6792 + *Avena sativa* 5431A; T6= *Vicia vilosa 6792* + *Avena sativa* 15153A; T7= *Vicia sativa* + *Avena sativa* 5431A; T8=*Vicia sativa* + *Avena sativa* 15153A; SEM = standard error mean, CV = Coefficient of variance

4.8. Nitrogen percent and N uptake in Oat and Vetch Plants

The finding revealedthat nitrogenpercent and nitrogen uptake showed significant differences(P<0.05) among the treatments. Accordingly, the maximum nitrogen content(3.22%) and nitrogen uptake(0.18 t/ha)on DM basis was attained by sole *Vicia vilosa 6792*and mixture of *Vicia vilosa 6792 + Avena sativa 5431A*respectively whereas the minimum nitrogen content (2.24 %) and nitrogen uptake (0.10 t/ha) onDM basis wererecorded by sole oat *Avena sativa 5431A* accession. The possible reason for variations of nitrogen content as well as nitrogen uptake might be due to the fact that in legume there is high nitrogen fixation ability that enhanced the CP content in legume and legume-grass mixed treatments.

The current result is in line with the finding of Mueller & Thorup-Kristensen (2001) who reported that above-ground plant material of common vetch may contain more than 100 kg N /ha originating from N2-fixation.The current result was also in line with the finding of Ansarul*et al.*(2018)who reported that the highest nitrogen content 3.34 %was attained by sole sown vetch and the highest nitrogen up take 0.18t/ha attained from oat + vetch mixture inMountain livestock research institute (MLRI), Manasbal of Kashmir University in India.Similarly, nitrogen fixation reported by Haque and Jutizi; (1984) shows that between oat-vetch mixture 62-290 kg N/ha per year have been recorded in sub-Saharan Africa for a wide range of tropical forage legumes.Seyoum, (1994) suggested that legumes in general and vetches in particular were excellent sources of N for livestock.According to NRC, (1985) reported thatnitrogen requirements of ruminant livestock had been reported to range from 1.2-2.7%. The current result (Appendix Table 3)revealed that the %N ranged between 2.24 to 3.22% were observed from both two tested species hence, this study could satisfactorily supply the required nitrogen for ruminant livestock.

4.9. Relationshipsbetween Agronomic and Morphological Traits in Oat-Vetch Cropping

Person correlation coefficient was used to identify the association between yield and yield related components of oat-vetch grown in pure stand and in mixture (Table 10). Number of tillers per plant in oats showed a strong (P<0.01) positive correlation with plant height at forage harvest (r= 0.926), dry matter yield of oat (r = 0.706), total DM yield (r= 0.642),seed yield (0.702), and thousand seed weight of oats (r = 0.85)but non-significant (P>0.05) negative correlations with days to forage harvest (r= -0.018) and days to seed harvest(r = -0.097).This would imply that a number of tillers might have contributed to the differences in dry matter yield of oat, total dry matter yield, and seed yield.

Number of branches per plant in vetch showed a strong (P<0.01) positive correlation with plant height of vetch at forage harvest (r= 0.798), days to forage harvest (r = 0.924), days to forage seed harvest (r = 0.951), dry matter yield of vetch (r = 0.866), and thousand seed weight of vetch (r = 0.781).It had a significant (P<0.01) negative correlation with seed yield (r= - 0.733) and non-significant (P>0.05) positive correlation with TDMY (r= 0.068). Highly correlation of number of branches per plant withdry matter yield of vetch indicate that number of branches contribute to higher dry matter yield in vetch species. This agrees with the study conducted byGezahagn *et al*. 2013 who reported thathighly branching *Vicia villosa*gave relatively higher dry matter yield than *Vicia dasycarpa*, *Vicia sativa* and *Vicia narbonensis* at Holeta.

Plant height of vetch at forage harvest showed a significant (P<0.01) positive correlation with days to forage harvest (r= 0.699) and days to seed harvest (r= 0.761) whereas plant height of oats at forage harvest have positive correlation with dry matter yield of oats (r = 0.867), total dry matter yield (r = 0.652), seed yield (r = 0.858) and thousand seed weight of oat (r = 0.960).This would imply that increase in plant height might have contributed to the differences in days to forage harvest and seed harvest in vetch whereas dry matter yield of oats, seed yield of oats, thousand seed weightof oat and total dry matter yield of oats and vetch. Similar to the current finding,Fekede (2004) and Gezahagn *et al*. (2013)reported that plant height at forage harvest was positively and significantly correlated with herbage yield, but in contrary to the current result it was negatively correlated with seed yield and thousand seed weight of oats varieties. Getnet *et al*., (2003) also reported that taller and late maturing oats varieties had higher forage yield but lower seed yield.

Days to forage harvest showed a strong(P<0.01) positive correlation with days to seed harvest (r= 0.983), forage DM yield of vetch (r= 0.766) and thousand seed weight of vetch (r = 0.746) but negatively correlated (P<0.01) with forage DM yield of oats (r= -0.544), seed yield (r = -0.655)and thousand seed weight of oat (r = -0.411).Days to seed harvest also showed similar trend as days to forage harvest (Table 10).Similar to the current finding,Fekede (2004) also reported that days to maturity of forage was correlated positively with plant height, herbage yield, but negatively correlated with seed yield and thousand seed weight of oats varieties. Generally, early maturing vetch species (*Vicia sativa*) had shorter plant height, higher seed yield, thousand seed weight and lower DM yield than latematuring accessions.

Table 10. Pearson's correlation coefficients between agronomic and morphological traits of oats accessions and vetch species

Parameters	NTPP	NBPP	PHV	PHO	DFH	DFSH	DMYV	DMYO	TDMY	SY	TSWV	TSWO
NTPP	1.00	-0.120^{NS}	0.122^{NS}	0.926**	-0.018^{NS}	-0.097^{NS}	-0.393^{NS}	0.706**	0.642**	0.702**	-0.189^{NS}	0.850**
NBPP		1.00	0.798**	-0.343^{NS}	0.924**	0.951**	0.866**	-0.605**	0.068^{NS}	-0.733**	0.781**	-0.535**
PHV			1.00	0.094^{NS}	0.699**	0.761**	0.450^{NS}	0.056^{NS}	0.457^{NS}	-0.172^{NS}	-0.692**	0.044^{NS}
PHO				1.00	-0.248^{NS}	-0.332^{NS}	-0.598**	0.867**	0.652**	0.858**	-0.396^{NS}	0.960**
DFH					1.00	0.983**	0.766**	-0.544**	0.047^{NS}	-0.655**	0.746**	-0.411*
DFSH						1.00	0.840**	-0.616**	0.021^{NS}	-0.726**	0.784**	-0.496*
DMYV							1.00	-0.768**	-0.028^{NS}	-0.838**	0.722**	-0.744**
DMYO								1.00	0.662**	0.882**	-0.636**	0.901**
TDMY									1.00	0.396^{NS}	-0.147^{NS}	0.535**
GY										1.00	-0.682**	0.910**
TSWV											1.00	-0.582**
TSWO												1.00

**,* = highly significant and significant, NS=non-significant, NTPP=number of tillers per plant, NBPP= number of branches per plant, PHV = plant height of vetch, PHO= plant height of oats, DFH = days to forage harvest, DFSH = days to forage seed harvest, DMYV = dry matter yield of vetch, DMYO = dry matter yield of oats, TDMY= total dry matter yield of vetch and oats, SY = seed yield of vetch and oats, TSWV = thousands of seed weight of vetch, TSWO = thousands of seed weight of oats

4.10. Relationships between Morphological Traits and Nutritional Quality of Oat-Vetch Cropping

The linear correlation coefficients between morphological traits and nutritional charactersare shown in Table 11.Number of tillers per plant oat was significant ($p<0.05$) positive correlation with ash (r= 0.40),NDF (r= 0.40), ADF(r = 0.44) and cellulose (r = 0.45) whereas highly significant ($p<0.01$) negative correlation with CP (r= -0.54) and EE (r= -0.51) in oat-vetch mixed treatment.Number of branch per plant vetch was significant ($p<0.01$) positive correlation withCP (r=0.80) and ether extract (r=0.47) whereas highly significant ($p<0.01$) negative correlation with NDF(r= -0.83), ADF (r= -0.65), ADL (r= -0.72) and cellulose (r= -0.54) in pure stand and in mixture.This would imply that increase in number of tillers in oat plant might have contributed to the increases in NDF, Ash, ADF, and cellulose content but decrease in CP and EE contents in both pure stand and oat-vetch mixed cropping.Similarly,increasing number of branch in vetch speciesmight have contributed to the increases in CP, and EE content but decrease in NDF, ADF, ADL and cellulose contentin pure stand and oat-vetch mixed cropping.

Days to forage harvest (DFH)showed highly significant ($P<0.01$) positive correlation with CP(r= 0. 63) and significant ($p<0.05$) positive correlation with ether extract (r= 0.34). On the other hand, Days to forage harvest was highly significant ($p<0.01$) negative correlation with NDF (r = -0.73), ADF (r = -0.51) and ADL (r = -0.66) in oat-vetch mixed treatments. Generally, late maturing species had comparatively higher CP content than intermediate to late maturing ones.The current result is in line with Gezahagn, (2013) who reported thatearly maturing accessions had comparatively lower CP yield than intermediate to late maturing ones.

Table 11. Pearson's correlation coefficients between morphological traits and nutritional parameters of oats and vetch species

Agronomic	Nutritional qualities								
Parameters	%DM	ASH	CP	EE	NDF	ADF	ADL	CEL	HEM
NTPP	-0.319^{NS}	0.405*	-0.547**	-0.518**	0.404*	0.443*	0.174^{NS}	0.454*	-0.010^{NS}
NBPP	-0.001^{NS}	-0.482**	0.800**	0.474**	-0.829**	-0.655**	-0.720**	-0.547**	-0.333^{NS}
PHV	-0.053^{NS}	-0.485**	0.726**	0.459*	-0.746**	-0.664**	-0.641**	-0.578**	-0.196^{NS}
PHO	-0.317^{NS}	0.525**	-0.732**	-0.576**	0.604**	0.591**	0.363*	0.570**	0.084^{NS}
DFH	0.084^{NS}	-0.379*	0.628**	0.345*	-0.734**	-0.510**	-0.658**	-0.400*	-0.390*

**,* = highly significant and significant, NS=non-significant, NTPP=number of tillers per plant, NBPP= number of branches per plant, PHV = plant height of vetch, PHO= plant height of oats, DFH = days to forage harvest, DMYV = dry matter yield of vetch, DMYO = dry matter yield of oats, TDMY= total dry matter yield of vetch and oats

4.11. Relationships between Nutritional Parametersof Oat-Vetch Mixtures

The linear correlation coefficients between nutritional characters are shown in Table 12. The CP content showed a significant (P<0.01) negative correlations with NDFcontent (r= -0.861),NDFY (r = -0.554)and non-significant negative correlation with DMY (r = -0.284) but non-significant positive correlation with CP yield (r= 0.29). The NDF content showed a non-significant positive correlations with NDFY (r= 0.391) and DMY (r = 0.053).It had a significant(P<0.05) negative correlation with CPY (r= -0.486).The CPY and NDFYshowed a significant (P<0.01)positive correlation with DMY (r= 0.808) and (r = 0.936).The current result indicates that CP content had a significant (P<0.01) negative correlations with NDF,NDFY and DMY.This would imply that CP content might have reverse contribution to NDF, NDFY and DMY.

DMY showed a strong (P<0.01) positive correlation with CPY and NDFY.The result of this study is supported by Geleti (2014) who reported that CPY and NDFY were the product of total dry matter yield and concentration of cell well component in the plant which can be substantiated by the values obtained from nutrient content and the dry mater yield obtained from each plant species in Bako and Nekemte Peri-urban areas, Oromia, Ethiopia.However, the current result disagrees with the finding of Tessema*et al.* (2002), who reported significant but negative correlations between DMY and cell wall components, and DMY and CP were significantly and positively correlated in Napier grass. Tessema *et al*., (2002) also reported that CP showed high positive correlations with DMY, whereas NDF showed negative correlations with DMY in Napier grass harvested at different heights.

Table 12. Pearson's correlation coefficients between nutritional parameters of oats and vetch mixtures

Parameters	CP	NDF	CPY	NDFY	DMY
CP	1.00				
NDF	-0.861**	1.00			
CPY	0.290 NS	-0.486*	1.00		
NDFY	-0.554**	0.391NS	0.568**	1.00	
DMY	-0.284 NS	0.053 NS	0.808**	0.936**	1.00

**,* = highly significant and significant, NS = non-significant, CP = crude protein, NDF = neutral detergent fiber, CPY = crude protein yield, NDFY = neutral detergent fiber yield, DMY = total dry matter yield

4.12. Biological Efficiency of Oats-Vetch Mixture

4.12.1. Relative yield and relative yield total of vetch- oats mixture

The result of biological efficiency of both species was indicated in Table 13. Accordingly,the present study showed, that relative yield (RY) of the component variety in the mixtures with the respective to pure stand varieties; as indicated it was less than one. The RY values less than one means that the yields obtained in mixed stand is less than those obtained in pure stands. The highest RYof oat (1.08)was obtained in *Avena sativa* 15153A at mixture of *Vicia vilosa 6792*speciesand the lowest RY of oat(0.63) was calculated in *Avena sativa* 15153A mixed with*Vicia sativa* species. Similarly, the highestRY of vetch (0.67) was calculated in*Vicia vilosa* 6792mixed with*Avena sativa* 5431A and the lowest RY of vetch(o.46) was calculated in*Vicia sativa* mixed with*Avena sativa* 5431A verity.The RY > 0.5 indicates positive effect on yields in the mixed cropping plots and RY<0.5 indicates negative effect on yields in mixed cropping plots compared to pure stand.

The current study revealed that the RY of mixed treatments were greater than 0.5 except when *Vicia sativa + Avena sativa 5431A* mixed treatment the relative yield of *Vicia sativa* was recorded less than 0.5indicates lower yield in the mixture than sole.The highest RY value 1.08 was calculated in *Avena sativa* 15153A indicates that the *Avena sativa* 15153A component at mixture had 58% yield advantage than those obtained in pure stand.

Similarly, in present study the RYT of all oat-vetch mixed treatments were greater than one, there was yield advantage of mixtures compared to the pure stand.The present study also showed that relative yield total of oats-vetch mixture was greater than one and ranged between (1.10) or 10% to (1.70) or 70% dry matter yield advantage were recorded between the treatments (Table 13). Therefore evaluation of oats-vetch mixtures indicated that mixtures improved total dry matter (DM) yield compared to pure stand. This showed that mixed cropping tested varieties of vetch and oats was superior to sole cropping in terms of resource use efficiency and this could be attributed to the mutual complementary resource utilization relationship by the species in the mixtures. The present finding agree with the finding of Getnet(1999) who obtained similar result from oat-vetch mixture the biomass yield was higher by 70% on red soil compared to black soil at Selale, Sheno and Adaberga areas central high land of Ethiopia.The result of present studyshowed highest RYT than the finding of Fantahun (2016) who revealed the greatest RYT (1.48) or 48% yield advantage was calculated in the oats-vetch variety (SRCP X 80 Ab 2291 and *Vicia sativa* ICARDA 61509) mixed at the seed proportion of 50:50.

4.12.2. Relative crowding coefficient (RCC)

The competition function of the mixtures of two component species in relation to relative crowding coefficient was indicated in Table 13. In sowing mixture the higher RCC of the component species indicates that it is more competent.The present result revealed that the calculated RCC value of *Vicia vilosa*6792 was greater than the RCC value of oatsvarietieswhereas oatsvarieties had greater RCC values whengrownin mixture of *Vicia sativa*.The possible reason for*Vicia vilosa* 6792 varieties more competent than oats it might be due to *Vicia vilosa* 6792 have longest plant height, branching ability and climbing behavior that make*Vicia vilosa* 6792 more competent with oat plants. This result is in line with the result of Fantahun *et al.*, (2017) who reported that in mixture*Vicia sativa* ICARDA 61509 with both varieties of oats the RCC of oat varieties was higher at the 50%:50% seed proportion with oats variety (SRCP × 80 Ab 2806).

4.12.3. The dominance or Aggressivity index

The Aggressivity index of vetch-oat mixture indicates the dominance of certain species in the mixture (Table 13). In present study, the Aggressivity index ofboth oats varieties had negative valuewhenmixed with*Vicia vilosa* 6792whereas, positive value when mixed with *Vicia sativa*.The result showed thatboth oats varieties were dominated by *Vicia vilosa* 6792 at 50:50 mixtures. This vetch dominance over oatsmight be due to *Vicia vilosa* 6792 had better plant height, climbing behavior andhigh branching ability that make aggressive over oats varieties.

The current result is disagreewith the report ofAgegnehu *et al*., (2006)who reported that cereals may not always be the dominant crops when grown in mixture of legumes.However, in present studytwo oatsaccessions dominance over *Vicia sativa* speciesthis might be due to *Vicia sativa*short plant height, erecting behaviorand less branching ability might be attributed oats aggressive over*Vicia sativa* species.

Table 13. Relative yield, relative yield total, relative crowding coefficient and Aggressivity index of oats and vetch mixtures

Treatments	RY		RYT	RCC		AI	
	Vetch	Oats		Vetch	Oats	Vetch	Oats
Vicia vilosa 6792 + *Avena sativa* 5431A	0.67	0.69	1.37	4.84	2.62	2.21	-2.21
Vicia vilosa 6792 + *Avena sativa*15153A	0.62	1.08	1.70	2.14	-0.51	2.66	-2.66
Vicia sativa + *Avena sativa 5431A*	0.46	0.64	1.10	0.95	2.40	-1.44	1.44
Vicia sativa + *Avena sativa 15153A*	0.55	0.63	1.19	1.35	1.81	-0.46	0.46

RY=Relative yield. RYT= Relative yield total. RCC = relative crowding coefficient. AI = Aggressivity index.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Forage legumes cultivation not only provide high quality and quantity feed for livestock but by fixing nitrogen they could maintain and improve soil fertility and reduce the cost of chemical fertilizers, in which prices are increased rapidly in recent years. Compatibility of forage legumes with grasses depends on the morphology and physiological characteristics of the legume and grass, in combination with the response of each to management imposed and the climate and soil and biotic conditions under which the crop is growing. Considerable variations exist among the tested varieties indicating the potential for selecting superior varieties for both forage and seed yield.The highest forage yieldin both pure stand and oats-vetch mixture was obtained from *Vicia vilosa 6792* andfrom *Avena sativa 15153A* varieties.However the highest seed yield was obtained from *Avena sativa 5431A*and*Avena sativa 15153A* in pure stand.The analysis of variance also showed a great variation in chemical composition(DM%, Ash%, EE%, CP%, NDF%, ADF% and ADL %) of the tested vetch and oats accessions.

The CP content and Ether extract contents in the pure stand vetch plot were significantly higher than those in pure stand oat and oat- vetch mixed plots.However, the crude protein content of the vetch varieties and mixtures were ranged between the reported thresh hold levelfor optimal production or growth. The NDF content of all treatments was observed to be belowthe critical level (55%) of NDF which indicates higher digestibility and intake except forpure stand oat varieties.The crude protein and neutraldetergent fiber were the most important nutrient that determines the quality of forages due to thisthe highest total nutrient yield of CPY and NDFYwere obtained in mixed treatments compared to pure stands.

The relative yield total of present study oat-vetch mixtures were greater than 1 which indicates the yield advantages of mixtures.Generally,in present study vetch-oat mixture increased relative yield total oftwo species which were ranged between (1.10) or 10 % to (1.70) or 70% dry matter yield advantage obtained frommixture compered to their respective pure stand.

5.2. Recommendations

Based on the finding of this study and the above conclusion, the following recommendations are forwarded:

- The mixture of*Vicia vilosa 6792 + Avena sativa 15153A*was the best performed in most agronomicand nutritional parameters at harvesting stage (50 % flowering) and it is recommended for fodder production inMareka district and relatedagro-ecology to fillthe dry season feed shortage (through conserved forage)and improve livestock productivity and enhance foodsecurity.
- When growing oats for seed purpose it is preferable to use *Avena sativa 5431A*in pure stand as it gave comparatively higher seed yield.
- However, this study was conducted in only one location over a single seasontherefore it is recommended that the experiment should be conducted over different locations and years in order to draw more concrete recommendation
- In addition, the effect of oats and vetch varieties and their mixtures should be tested onanimal performance.

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7. APPENDICES

APPENDICES

Appendix Table 1. The calculated emergency percentage (%) of vetch and oats

varieties	Emergency percentage (%) of two forages before planting
Vetch Lalisa (*Vicia vilosa 6792*)	94
VetchGebisa (*Vicia sativa)*	90
Oats *(Avena sativa 5431A)*	92
Oats *(Avena sativa 15153A)*	91

Appendix Table 2. Mean square ANOVA for days to emergence, days to forage harvest and days to forage seed harvest of vetch and oats

Source	DF	Mean square		
		Days to 90% emergence	Days to 50% heading for Oats and flowering Vetch	Days to seed harvest
TRT.	7	5.80**	587.32**	638.75**
Rep.	2	0.16^{NS}	5.29*	8.04*
Error	14	0.73	1.29	0.75
Total	23			
CV (%)		8.88	1.00	0.58

**,*,^{NS}, =highly significant, significantand non-significant level at5%; DF = degree of freedom; TRT = treatments; Rep = replications; CV = coefficient of variance.

Appendix Table 3. Important nutrients %N and N uptake of experiment treatments

Treatments	%N	N up take (t/ha)

Vicia vilosa 6792	3.22	0.17
Vicia sativa	3.1	0.11
Avena sativa 5431A	2.24	0.10
Avena sativa 15153A	2.30	0.17
Vicia vilosa 6792 + Avena sativa 5431A	2.73	0.18
Vicia vilosa 6792 + Avena sativa 15153A	2.85	0.24
Vicia sativa +Avena sativa 5431A	2.54	0.16
Vicia sativa + Avena sativa 15153A	2.47	0.17
Mean	2.68	0.16
SEM	0.07	0.009

% N=nitrogen percentage of forage,N uptake = nitrogen up take in dry matter of forage.

Appendix Table 4.ANOVA table for %N and N uptake on oats and vetch and their mixture

Source	DF	Mean square	
		%N (mg/gm.)	N uptake (q/ha)
TRT	7	0.38**	0.0051**
Rep	2	0.017^{NS}	0.00002^{NS}
Error	14	0.004	0.00068
Total	23		
CV		2.49	15.60

**, ^{NS} = significant and non-significant 5%; DF = degree of freedom; % N = nitrogen content of forage in dry matter milligram per a gram; N uptake = nitrogen up take in Dry matter of forage quintals per hectare;TRT = treatments; Rep = replications; CV = coefficient of variance.

Appendix Table 5. Rating key for nodule assessment(Corbin *et al.*, 1977) invetch species

Field assessment key	Mean score and indication

Score	Visual observation on field	Mean nodule score	Indication
0	No nodulation	0	No nodulation and no N2 fixation
1	<5 in the crown-root zone (regarded as the region up to 5 cm below the first lateral roots) with no nodules on elsewhere on the root system	0-1	Very poor nodulation and probably little or no N2 fixation
2	5-10 in the crown-root zone with <5 nodules on elsewhere on the root system	1-2	Poor nodulation and probably little N2 fixation
3	>10 in the crown-root zone with <5 nodules on elsewhere on the root system	2-3	Fair nodulation; N2 fixation may not be sufficient to supply the N demand of the crop
4	>10 in the crown-root zone with 5-10 nodules on elsewhere on the root system	3-4	Good nodulation and good potential for N2 fixation
5	>10 in the crown-root zone with >10 nodules on elsewhere on the root system	4-5	Excellent nodulation; excellent potential for N2 fixation

Appendix Table 6. Number of nodele per plant out of crown- root zone at 30 DAS and 70 DAS

Treatments	Number of nodele perplant out of crown- root zone (30 DAS)	Number of nodele perplant out of crown-root zone (70 DAS)
Vicia vilosa 6792	9±0.57	78±8.66
Vicia sativa	8±0.66	60±6.17
Vicia vilosa 6792 + Avena sativa 5431A	7±0.57	56.33±4.70
Vicia vilosa 6792 + Avena sativa 15153A	5±0.57	45.33±12.28
Vicia sativa +Avena sativa 5431A	4.33±0.57	43.33±13.61
Vicia sativa + Avena sativa 15153A	4±0.33	28.33±8.51

Appendix Table 7. Fresh biomass yield (FBY kg/m^2) of oats and vetch in pure stand and mixture

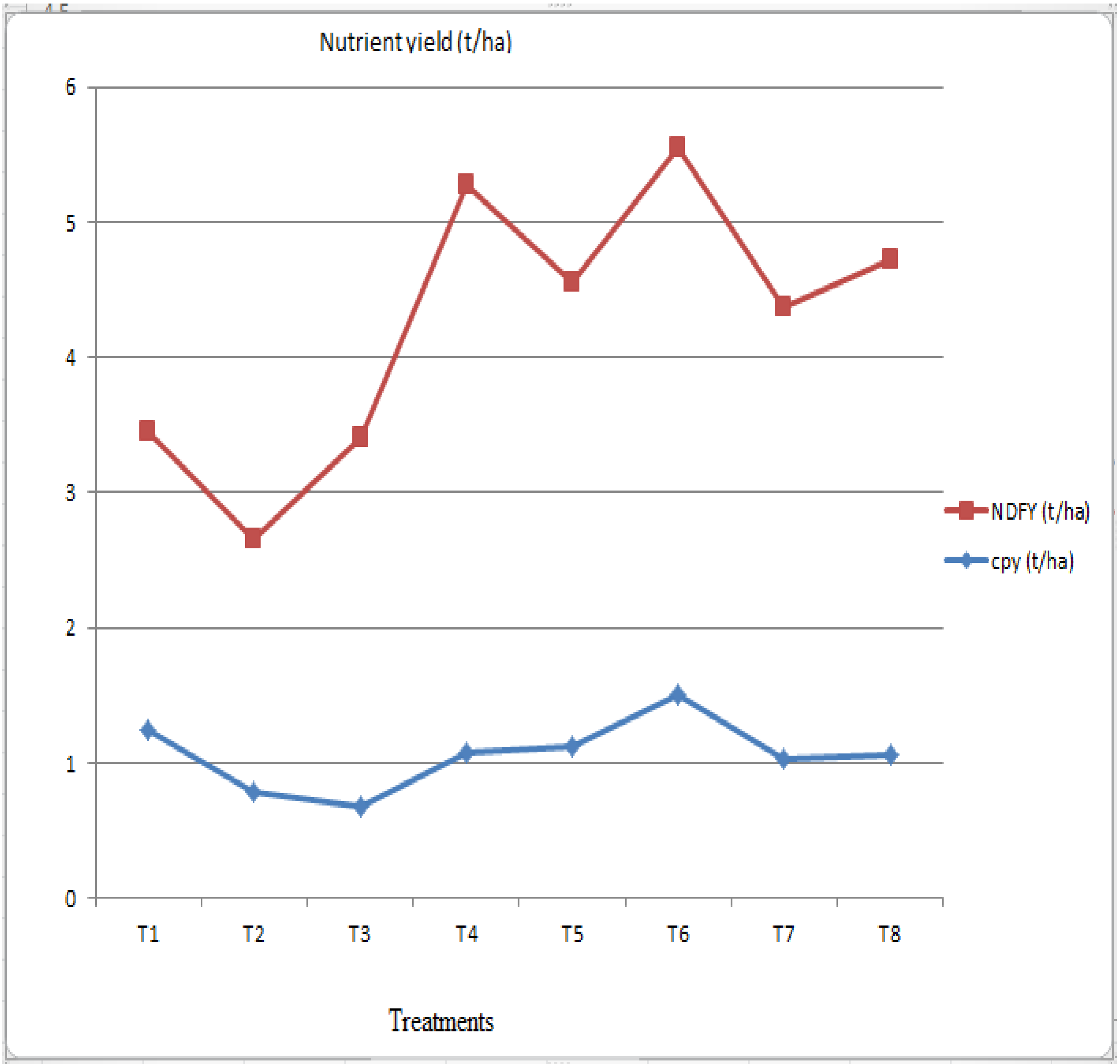
Treatments	FBY(kg/m^2) of vetch	FBY (kg/m^2) of oats	TFBY (kg/m^2) oat and vetch
T1	8.18±0.46	-	8.18±0.46

T2	5.39±0.23	-	5.39±0.23
T3	-	7.83±0.22	7.83±0.22
T4	-	9.21±0.17	9.21±0.17
T5	4.64±0.34	4.49±0.31	9.13±0.65
T6	4.01±0.29	6.55±0.11	10.56±0.38
T7	2.26±0.11	6.26±0.18	8.53±0.30
T8	2.92±0.23	6.72±0.3	9.64±0.53
Mean + SEM	4.56±0.47	6.84±0.35	8.56±0.32
CV	12.14	5.20	8.21
p-value	0.0001	0.0001	0.0001

Appendix Table 8. Mean square ANOVA for vetch and oat chemical composition

Source	DF	Mean square								
		DM%	Ash	CP	EE	NDF	ADF	ADL	CEL.	Hem.Cel
TRT	7	1.375^{ns}	2.08*	14.97**	0.02**	75.27**	62.73**	2.52**	44.44**	21.44*
REP	2	0.19^{NS}	1.69^{NS}	0.70*	0.006^{NS}	2.53^{NS}	7.89^{NS}	0.007^{NS}	7.51^{NS}	10.23^{NS}
Error	14	0.79	0.58	0.17	0.0044	3.166	2.75	0.68	4.47	6.36
Total	23									
CV		1.01	6.82	2.51	7.1	3.52	4.65	8.81	8.03	17.00

****, *, NS**= highly significant, significant and non-significant level at 5%;DF = degree of freedom; TRT = treatments; Rep = replications; CV = coefficient of variance.



Appendix Figure 1. Crud Protein Yield (t/ha) and Neutral Detergent Fiber Yield (t/ha) of the treatments

Appendix Figure 2. Partial view of land preparation and agronomic characteristics in experimental site.

Appendix Figure 3. Evaluation of nodules in vetch and counting tillers in oats in experiment site.

Appendix Figure 4. Partial view during fodder harvesting and yield recording.

Appendix Figure 5. Partial view during soil laboratory analysis and proximity analysis of studied forages.