EFFECT OF VARIETY AND SEED PROPORTIONS ON YIELD AND NUTRITIONAL QUALITY OF OATS-VETCH MIXTURES GROWN ON ACIDIC SOILS AT ASSOSA, BENISHANGUL-GUMUZ REGION

M.Sc. THESIS

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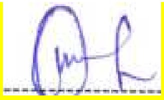
Gezahagn Kebede (PhD candidate)		------------------
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As members of the Board of Examiners of the final Master's degree open defense, we certify that we have read and evaluated the thesis prepared by **Kedija Ahmed Seid** under the title **"Effect of variety and seed proportions on yield and nutritional quality of oats-vetch mixtures grown on acidic soils at Assosa, Benishangul-Gumuz Region"** and recommend that it can be accepted for fulfilling the requirement for the degree of Masters of Science in Animal and Range Sciences with specialization in **Animal Production.**

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I hereby certify that all the corrections and recommendation suggested by the Board of Examiners are incorporated into the final thesis entitled **"Effect of variety and seed proportions on yield and nutritional quality of oats-vetch mixtures grown on acidic soils at Assosa, Benishangul-Gumuz Region"** by

Kedija Ahmed Seid

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DEDICATION

I dedicate this thesis manuscript to my beloved mother Lubaba Hussen and my father Ahmed Seid as well as my husband Mohammed Ali for nursing me with great affection and for their dedicated partnership in the success of my life.

STATEMENT OF AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of materials used for thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirement for M.Sc. degree at Hawassa University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Kedija Ahmed Seid Signature --------------- Date------------

Place: College of Agriculture, Hawassa University, Hawassa

Date of Submission: --------------/--------/-----------

LIST OF ABREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AI	Aggressivity Index
AOAC	Association of Official Analytical Chemists
AsARC	Assosa Agricultural Research Center
CP	Crude Protein
CPY	Crude Protein Yield
CR	Competitive Ratio
DM	Dry Matter
DMD	Dry Matter Digestibility
DMY	Dry Matter Yield
EIAR	Ethiopian Institute of Agricultural Research
GLM	General Liner Model
ha	Hectare
HARC	Holetta Agricultural Research Center
IVDMD	*In Vitro* Dry Matter Digestibility
Kg	Kilogram
m^2	Meter Square
m.a.s.l	Meters above sea level
ME	Metabolizable Energy
MJ kg^{-1}	Mega Joule per Kilogram
N	Nitrogen
NDF	Neutral Detergent Fiber
NPS	Nitrogen-Phosphors -Sulfur
pH	Power of Hydrogen
RCBD	Randomized Complete Block Design
RCC	Relative Crowding Coefficient
RY	Relative Yield
RYT	Relative Yield Total

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDICES

Effect of variety and seed proportions on yield and nutritional quality of oats-vetch mixtures grown on acidic soils at Assosa, Benishangule-Gumuz Region

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ABSTRACT

*The study was conducted during the main cropping season of 2019/2020 at Assosa in Benishangul-Gumuz regional state. The aim of the study was to evaluate herbage dry matter yield, nutritional quality and biological compatibility of oats-vetch mixtures. The treatments included two oat varieties (*SRCP X 80 Ab *2291 and* SRCP X 80 Ab *2806), two vetch species (Vicia sativa"ICARDA*61509" and *Vicia dasycarpa "Lana") and four levels of seed proportions (100%, 75%, 50% and 25%) of the recommended seeding rates of the two forages. Randomized complete block design was used with factorial arrangement and 3 replications. The results revealed that seedling count at emergence, stand count at tillering, plant height, leaf to stem ratio of oat and vetch were significantly ($P<0.05$) differed among oat varieties, vetch species and seed proportions. The interaction effect of oat by vetch, oat by seed proportions, vetch by seed proportions and oat by vetch by seed proportions had significant ($P<0.05$) effect on plot cover and vigor score percentage, dry matter yield (DMY) tha^{-1},and the quality parameters such as, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent Lignin (ADL), In-vitro Dry matter Digestibility (IVDMD) and crude protein yield (CPY) tha^{-1}. The mixtures of 75% SRCP X 80 Ab 2806 + 25% Vicia sativa "ICARDA-61509"(12.35) gave in the higher DMY (tha^{-1}). On the other hand Vicia dasycarpa sown in pure stands had lower DMY compared to oats-vetch mixtures (7.45). In terms of quality, increasing the seed proportions of both vetch species in the mixture resulted in higher CP%, CPY (tha^{-1}) and IVDMD% and lower NDF%, ADF% and ADL% contents. Relative yield total of oats-vetch mixtures at 25% SRCP X 80 Ab 2291 + 75% Vicia dasycarpa "Lana" (1.35), 25% SRCP X 80 Ab 2806 + 75% Vicia dasycarpa "Lana" (1.32), 75% SRCP X 80 Ab 2806 + 25% Vicia sativa"ICARDA-61509" (1.20) and 75% SRCP X 80 Ab 2291 + 25% Vicia dasycarpa "Lana" (1.12) were better compared to the other mixtures and pure stands. Generally, mixing of oat varieties with vetch species at different seed proportions of 75% oats: 25% vetch and 25% oats: 75% vetch produced better dry matter yield, nutritional quality and compatibility in the study area. However, the experiment should be conducted for more years at different locations to recommend the best oats-vetch mixtures for Assosa area of Benishangul-Gumuz Regional State.*

Keywords: *acidic soils, biological compatibility, dry matter yield, grass-legume mixture nutritive value, seed proportion, variety*

1. INTRODUCTION

Ethiopia has diverse agro-ecological zones suitable for livestock production. However, livestock production has mostly been subsistence-oriented and characterized by low reproductive and production performance (Malede, 2013b). One of the major problems to low production and productivity in the country is associated with shortage of livestock feeds both in quantity and quality, especially during the dry season (Zewdie, 2010). In Ethiopia, livestock are mainly dependent on naturally available feed resources (Alemayehu *et al*., 2017b) such as natural pasture which is often poor in quality. The role of natural pasture is diminishing from time to time due to shrinking grazing land size and the use of native hay is limited in coverage (Yayneshet, 2010). This resulted in keeping large number of livestock on limited grazing areas which results in a decrease in production and productivity of feed in the area. As a result, livestock are forced to graze on marginal areas, which combined with the use of low quality crop residues as feeds, could result in poor livestock performance.

Therefore, the use of grass-legume mixtures will help to increase productivity of land and livestock through improving the nutritive values of feeds. Forage grasses are commonly grown with legumes in a mixture because of their ability to increase the herbage yield and to produce forage with more balanced nutrient for livestock feeding (Koc *et al*., 2013).

In Ethiopia oats and vetches when grown by intercropping, provide high biomass yield of good nutritional quality (Gebrehiwot *et al.*, 2017). Oats-vetches mixtures could serve as a source of energy and protein content. It has very high feed value for animals as green fodder and hay. Vetches can offer substantial improvements in soil fertility, structure and organic matter as well as offering a weed and disease break for cereals in a crop rotation (Gebrehiwot *et al*., 2017). Oats and vetches have performed well across a wide range of agro-ecological zones with oats showing good tolerance to relatively low fertility and poor drainage soils in Ethiopia (Alemayehu *et al*., 2016).

In oats-vetches mixtures, the seed proportions and varieties affect yield and nutritional quality. Alemu *et al*. (2007) reported that reduced seed proportion of oats is associated with increased tillering, which contributed to comparable dry matter yield with seed proportions containing higher proportions of oats. A higher proportion of vetches in the forage mixtures delayed the physiological maturity and increased the leaf to stem ratio of oats, thus resulting in better nutritive value for animals (Alemu *et al.,* 2007). According to Fantahun (2016), planting of oats variety and vetches species mixtures at 75%: 25% and 50%: 50% seed proportions resulted in better relative yield which has been tested in the light (alfisols/holisols) soil. Vetches are rich in protein than oats and the NDF, ADF and ADL contents of the sole and mixed forages of oats and vetches is affected by seeding rate (Negash *et al.*, 2017). When vetches are increased in the mixture, it increases the CP content and decrease in ADF and NDF content of oats are indicators of good quality. The mixtures benefit the associating oats by improving the CP and reducing the fiber content which in turn improves the digestibility (Negash *et al.*, 2017).

1.1. Statement of the problem

Benishangul-Gumuz Region has large livestock resources. However, the production and productivity of the livestock are very low due to some technical and non-technical factors. Technical factors limiting livestock production and productivity include animal disease, poor genetic potential of the animal and shortage of feed in both quality and quantity. Among the technical factors, shortage of feed in both quality and quantity is the major factor that affects the production and productivity of livestock in the Region.

According to Beyene *et al*. (2011) natural pasture and crop residues are the most commonly utilized feed resource in both shifting cultivation and permanent farming systems in Assosa district. Although, natural pasture is providing significant amount of feed, nowadays the contribution and productivity of this feed resource is deteriorating from time to time mainly due to the expansion of crop production at the expense of grazing land. Low feed supply both in terms of quality and quantity results in retarded reproductive and growth performance of animals (Sisay, 2006).

Improved forage species and agro-industrial by-products are less available in Assosa district (Beyene *et al.*, 2011). So, to alleviate this problem, introducing improved grass and legume forages in the region has paramount importance. Most studies on production, productivity and compatibility of oats-vetch mixtures were done at high land vertisols and nitisols areas of Ethiopia (Fantahun, 2016: Gezahagn *et al.*, 2017). However, there is limited information on herbage dry matter yield, nutritional quality and biological compatibility of oat and vetch varieties grown using different seed proportions under acidic soil of Assosa district. Hence, this study was conducted with the following objectives:

1.2 Objectives of the study

- To evaluate the effect of variety and seed proportions of oats-vetch mixtures on herbage dry matter yield, nutritional quality and biological compatibility on acidic soils under rain fed conditions in Assosa district.

2. LITERATURE REVIEW

2.1. Livestock feed resources in Ethiopia

Livestock feed resources in Ethiopia both in terms of quantity and quality is a major bottleneck for livestock production. Feed resources can be classified as natural pasture, crop residue, improved forage and agro-industrial byproducts (Alemayehu *et al.,* 2017b). Those feed resources vary with the type of agricultural activities (mode and intensity of crop production), population pressure, agro-ecology, the season of the year and environmental conditions such as rainfall distribution (Seyoum *et al.*, 2001; Ahmed *et al*., 2010).

Natural pasture is the major livestock feed resource in Ethiopia. However, the quality and productivity of natural pastures are very poor to meet the nutrient requirement of animals (Malede and Takele, 2014); particularly in the dry season, due to poor management and their inherent low productivity and poor quality. Crop residues are providing a considerable quantity of dry season feed in most farming areas of the country. However, crop residues are the fibrous byproducts and their feeding value are limited by their poor voluntary intake, low digestibility and low nitrogen, energy, mineral and vitamin contents (Alemayehu *et al.*, 2017b).

Agro-industrial by-products are used for animal feeds and which are rich in energy and protein contents. They have low fiber content, high digestibility, and energy values compared with the other class of feeds (Lentes *et al*., 2010).Thus, the use of agro-industrial by-product is restricted to the emerging private dairy and fattening farms (Yayneshet, 2010). Even though, there is limited accessibility of agro-industrial by-products farmers supply agro-industrial by-products to their animal. And also, contribution of the by-products is proportionally low, due to their growing prices and low accessibility (Lemecha *et al*., 2013).

Improved forages play a varying role in different livestock production systems. The use of cultivated forages is an untapped resource in Ethiopia (Tesfaye *et al*., 2010). There are a lot of improved forages varieties of both grass and legumes species suitable for various agro ecologies in Ethiopia. Among these, desho grass, elephant grass, phalaris, oats and vetches forage species are widely known and distributed (Getnet and Ledin, 2001).

2.2. Improved forages and pasture crops

Improved forage varieties of both grass and legume species are available in Ethiopia and they are suitable for various agro ecologies (ESGPIP, 2008). Annual and perennial forage species have been tested in the mid-altitude under rain-fed conditions in Ethiopia that helped to identify many improved herbage species for the ecology. *Chloris gayana, Panicum coloratum, Panicum maximum, Desmodium uncbinatum, Staylosanthes guanensis, Leucanea leucocephala*, *Dolichos lablab*, *(Lablab purpureus) and Vicia atropurpurea* are the most promising pasture and fodder species. And those are tested species, which are adaptable for mid-altitude areas ranging in altitude from 1,000-1,800 m.a.s.l (Gebrehiwot and Tadesse, 1985). Moreover, improved forage species, including elephant grass (*Pennisetum purpureum*), oats (*Avena sativa*), Rhodes grass (*Chloris gayana*), pigeon pea (*Cajanus cajan*), vetches and *Sesbania* species have been introduced in an endeavor to increase the amount of feed resources and they have been promoted in the region by Assosa Agricultural Research Center for the last decade(Alemayehu *et al*., 2018).

Improved forages mainly legumes can improve the productivity of natural pastures by improving the fertility status of the soil and the feed value of the native pastures since they have more protein content than naturally occurring grasses (Yeshitila *et al.*, 2008). Among the introduced improved forages, legumes have high feeding value which provides a sustainable source of cheaper protein compared to concentrates (Seyoum, 1994). Legumes increase digestibility and intake of the conserved forage (Alemayehu *et al*., 2017a).

2.3. Grass-legume mixtures in agriculture

2.3.1. Advantages of grass-legume mixtures

The main advantage of grass-legume mixtures is for more efficient utilization of the available resources and to increase production and productivity compared with each sole crops of the mixture (Getachew *et al*., 2008; Mucheru-Muna *et al*., 2010). Mixed planting of grasses and legumes also indicated to control weeds, diseases and pests (Erla, 2011). As components of mixed grass–legume swards, forage legumes offer important opportunities for tackling future agricultural challenges (Luscher *et al*., 2014). All forage crops need nitrogen (N) for maximum productivity, but legumes are valued for their ability to grow in a symbiotic relationship with certain nitrogen (N)-fixing bacteria (*Rhizobia*). These form a nodule on the roots and convert atmospheric nitrogen (N) into a form the plant can use which is cheaper to farmers, avoiding the use of chemical fertilizers. Legumes are rich in terms of protein concentration, whereas grass has higher carbohydrate contents and grasses benefit from the nitrogen fixed by legumes when they are grown together. Grasses do not have this capability and their nitrogen (N) requirements must have met by other means (Lauriault *et al*., 2005). In grass-legume mixtures, nitrogen (N) can be transferred from the legume into the soil and grasses can use it during their growth (Lauk and Lauk, 2009).

The legume-grass combination has been used in several mixed cropping systems including forage and cover crops (Rauber *et al.*, 2001; Ramos *et al*., 2011). Mixed cropping is an important element of self-sustaining, low input agricultural systems (Adesogan *et al*., 2002), while components of a mixture use limited resources more efficiently than pure stands, thus showing resource complementarities (Atis *et al*., 2012). These multiple advantages benefit the whole grassland husbandry system through reduced dependency on fossil energy and industrial nitrogen fertilizer, lower nitrate and greenhouse gas emissions into the environment, lower production costs, higher productivity and protein self-sufficiency (Luscher *et al*., 2014).

2.3.2. Advantage of grass-legume mixtures for acidic soil

The grass-legume mixtures have a positive impact on soil productivity and fertility resilience, which eventually can improve soil health in long-term (Dhakal and Islam, 2018).Legumes improve the productivity of low fertile acidic soils by increasing the amount of plant-available nitrogen in the soil, which is an advantageous feature for associated grasses (Rao *et al*., 1994).The benefits to the soil emanating from biological nitrogen fixation by legumes include the improvement of soil organic matter content, soil porosity, soil nutrients, soil structure, soil pH, biological diversity and pest cycle (Malik, 2010; Mohammadi *et al*., 2012).

2.3.3. Role of grass-legume mixtures for improving forage yield and quality

The development of grass-legume mixed pasture is an alternative strategy to improve feed resource availability both in quantity and quality. Quality forage and seasonal distribution of dry matter (DM) production of grass-legume mixed sward was higher compared to those grasses or forage legumes grown in pure-stands (Ibrahim *et al*., 2012; Diriba and Diriba, 2013; Tessema and Feleke, 2018). Grass-legume mixture has been advocated for numerous advantages ranging from increased dry matter yield (DMY), increase forage quality, reduce production costs and improve soil health to the farmers up to sustainability of the agricultural system (Jabbar *et al.*, 2011; Sturludottir *et al*., 2014).

Grass-legume mixture has been higher feed quality owing to the higher crude protein (CP) concentration of legumes increase biomass yield and improve livestock production (Garridoand López-Bellido, 2001; Lithourgidis *et al.,* 2006).The effect of this functional diversity can substantially contribute to improve the productivity and the efficiency of resource use in agricultural grassland systems (Nyfeler *et al.,* 2009). This suggests that forage legumes have been the potential to improve the diets of ruminants and must be used to supplement the nutritive value of natural grasses. The improvement of forage quantity and quality was crucial for improved animal performance which has been a goal of all livestock farmers (Gulwa *et al*., 2018). The grass-legume mixtures decreases the ADF and NDF content as well as increases the CP content of grass as legume increased in the mixture (Sani *et al*., 2020). Intercropping legumes with grasses benefit the associating grasses by improving the CP content, reducing the fiber content which in turn improves the digestibility (Njoka-Njiru *et al*., 2006).

2.4. Biological compatibility and yield advantages of grass-legume mixtures

The biological compatibility of forage legumes with grasses depends on the morphology and physiological characteristics of the legume and grass. It also depends with the response of each to management imposed and the climate, soil and biotic conditions under which the crop is growing (Gezahagn *et al*., 2016). The choice of compatible crops for an intercropping system depends on plant growth habit, land, light, water and fertilizer utilization (Brintha and Seran, 2009).

Yield advantages of grass-legume mixture productivity measured with several indices such as land equivalent ratio (LER), competitive ratio (CR), relative crowding coefficient (K), aggressivity and actual yield loss have been developed to measure competition indices and to compare mixtures with pure stands (Nassab *et al.*, 2011; Atis *et al.,* 2012).

The land equivalent ratio is closely related to the earlier relative yield total (RYT). It is also introduced as an index for comparing mixtures and sole crop performance (de Wit and Van den Bergh, 1965). The relative yield describes the response of a particular species to the competition imposed by another species in a mixed stand. The sum of the relative yields of species has been defined by De Wit and Vander Bergh (1965), as a relative yield total (RYT). The relative yield total describes the resource complementarities between species in a binary mixture; the value assumed by this index indicates whether the species are performing better in a mixture than in monoculture. In the relative yield total (RYT), two species are equal, less or greater than one, which means that the mixtures system has no yield advantage, disadvantage or advantage, respectively.

The relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. According to Willey (1979), in an intercropping system, each crop has its RCC (K). The component crop with a higher “K” value is the dominant and that with low “K” value is dominated. To determine if there is a yield advantage in intercropping, the product of the coefficient of both component crops is obtained and that is usually designated as “K”. If the product of RCC of the two species is equal, less or greater than one it means that the intercropping system has no advantage, disadvantage or advantage, respectively.

Aggressivity (A): is an important tool for determining the competitive ability of mixtures when they are grown in association with each other. If the aggressivity is zero, then it indicates that the components mixtures are equally competitive. In any other conditions, if the mixtures have the same numerical value, then the dominant species are signed positive and the dominated species are signed with negative (McGilchrist, 1965; Ehsanullah and Zahir, 2014).

Competitive ratio (CR): is some of the competition indexes frequently used to compare mixtures and pure stands (Atis *et al.*, 2012). Competitive ratio (CR) gives a better measure of competitive ability of the crops and can prove a better index as compared with RCC and Aggressivity (Willey and Rao, 1980; Dhima *et al*., 2007). Competitive ratio (CR) over one indicated that a good competitor in mixtures while a value less than one indicated that a poor competitor (Jedel *et al*., 1998).

2.5. Oats (*Avena sativa L.*) varieties and adaptations

Oats (*Avena sativa L*.) are the most cultivated forage varieties and probably more than 80% of the total average is devoted to these varieties (Coffman, 1977). Oats (*Avena sativa L*.) are one of the annual forage grasses. It has been adapted to a wide range of soil types and climatic conditions (Ecoport, 2013). Fodder oats (*Avena sativa L*.) is an important winter season cereal fodder crop which can be successfully grown under both irrigated and rain-fed conditions with a rainfall of 400 mm and an optimum temperature range of 16-32°C (Bhatti *et al*.,1992). It is an important forage/grain crop grown as a pasture, hay, silage and poultry feed in the world. Further, oats perform better in loam soils but tolerate acidic and low fertile soils with pH ranging from 4.5 to 8.6 (Heuz *et al*., 2016).

Oats are an erect annual grass with a fairly good tillering habit that attains a height of 1-2 m. The panicles are lax, effuse and the inflorescence may be equilateral or unilateral. The main axis and lateral branches end in a single apical spikelet. Oats are the preferred feed of all animals and grain is also valuable feed for dairy cows, poultry and young breeding animals. It is a fodder crop used as energy source for livestock (Mengistu, 2008). It is an important fodder, mostly fed as green but excess is converted into silage or hay for animal feeding during fodder deficit periods (Suttie and Reynolds, 2004). To increase productivity per unit area, there is a need to develop promising cultivars having high forage yield potential and quality (Ahmad *et al.,* 2014).

Oats, barley and wheat are important fodders grown under rain fed conditions for the sustenance of livestock. It is a quick growing, palatable, succulent and nutritious fodders with sufficient amount of carbohydrate, but deficient in protein (Getnet and Ledin, 2001). The seed rate of oats 75–100 kg is required for a hectare of land and can have 10-52 ton/ha of fresh herbage and can be used either as fresh or in the form of hay. The crude protein content, of oats ranges from 70 to 150 g/kg DM (McDonald *et al*., 2010). Oats forage yields are very variable, depending on year and location. Average DM yields range from 4 to 15 t/ha, but much higher yields have been obtained (Getnet, 2006). The stages of growth at cutting and environmental conditions play an important role in determining 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% (Kellems and Church, 2002). Oats form an excellent combination, when fed along with other legumes like Lucerne (alfalfa), senji (*Indian clover*), shaftal (*Persian clover*) and vetches (*Vicia sativa*) (Zaman *et al*., 2006). Suitable fodder combinations, grass-legume combinations such as (oats + vetches and oats + peas), commercial dairy farmers and resource poor farmers have greatly reduced the feed shortage problem and reduced the cost of feed to a great extent (Pariyar, 2004).

2.6. Vetch (*Vicia species*) and their adaptations

Vetch (Vicia species) is one of annual forage legume adapted to a wide range of soil types, altitudes and rainfall conditions. It has been grown successfully in areas with acidic soil with a pH of 5.5-6. Vetch is rich sources of nitrogen for livestock with cheaper prices compared to concentrates especially in developing countries (Seyoum, 1994). It is found to be with high herbage yield under low input condition such as fertilizer and can be used for livestock feeding in the form of green or conserved for dry season use. It is also a highly efficient nitrogen fixer and can replace much of the nitrogen fertilizer.

Vetch in the cropping system provide an environmentally friendly solution to reducing use of nitrogen fertilizer while improving soil fertility and enhancing crop yield (Alemayehu, 1997). One attraction of vetch is its versatility, which permits diverse utilization as either ruminant feed. The vetch (*Vicia*) species were being productive regarding the biomass yield and seed yield of each species, which is hopeful to fill the gap of low quantity ruminant feed supply of the country (Kassahun and Wasihun, 2015).

Vetch species has different characteristics in terms of growth habit, days to maturity, morphological fractions, and climatic adaptation. In general, growth habit of vetches species can be broadly grouped as erect, creeping or climbing. For instance, *Vicia dasycarpa*, *Vicia villosa* and *Vicia atropurpurea* have creeping or climbing growth habit, whereas *Vicia narbonensis* and *Vicia sativa* have erect growth habit. These differences in genetic characteristics are the basis for variation in nutritive values and also determine the production, utilization and the various management practices (Gezahagn *et al.,* 2013).The vetches species used as a protein supplement for tropical ruminants which are suffering from poor quality tropical grasses, low protein and poor digestible crop residues which are the major ruminant feed sources particularly in Ethiopia (Kassahun and Wasihun, 2015). According to Getnet and Ledin (2001), vetches have a higher crude protein content compared to many other tropical herbaceous legumes. Vetches apart from being able to stay green in the dry season, they are high in protein content and have considerable potential for increasing forage quality (Semman *et al*., 2018).

The nutritional values of vetches were promising particularly, the CP content of *Vicia dasycarpa.* It has higher CP and digestibility but lower fiber contents (Kassahun and Wasihun, 2015). This shows that the different vetches species and their accessions need to be assessed for the nutritional quality differences under the different soil types and climatic conditions (Gezahegn *et al.,* 2013). Vetch species is a very good source of protein especially *Vicia dasycarpa* with higher CP content (25-26%) than other species (Gezahegn *et al*., 2014). The seed rate may range from 20-30 kg per hectare depending on different factors including seed quality and soil condition. Generally, vetches species have different phenology, forage and seed productivity and forage quality (Gezahegn, 2016).

2.7. Mixtures of oats and vetches

Oats and vetches are suitable for intercropping. To get balanced mixed biomass of oats and vetches, it is important to maintain appropriate seeding rate taking into account germination percentages of each seed type (Bezabih *et al*., 2016). In vetches mixtures with grasses, it is necessary to know the ratios of the vetches and grass species (Albayrak *et al*., 2004; Balabanli and Turk, 2006), because it affects the growth rate of the individual species in the mixtures as well as the forage yield and quality (Lithourgidis *et al.,* 2006; Lauk and Lauk, 2009). Oat and vetch mixtures production potential and utilization under arid conditions to provide low cost fodder to animal particularly during the dry season, and the potential ease of agronomic practices to produce these forage species make them of higher choice and priority (Getu *et al*., 2012). Productivity of oats and vetches mixtures are also known to be superior to pure stands in yield and quality (Getent and Ledin, 2001; Erol *et al*., 2009). Vetches (*Vacia sativa*) are reputed for their beneficial compatibility with grass when they grow in mixture *(*Alemu *et al*., 2007). Forage species such as vetches (*Vacia sativa)* and oats grass *(Avena sativa*) are high potential feed sources to fill the gap of feed shortage. They are promising due to their high quality feeding value (Getu *et al*., 2012).

2.8. Effects of variety and seed proportions of oats-vetch mixtures on herbage dry matter yield

The oat and vetch mixtures were found to be advantageous which can increase forage yield. The best results in terms of herbage and dry matter yields from mixture 25% vetch + 75% oat being followed by 50% vetch + 50% oat, 75% vetch + 25% oat mixtures. Herbage and dry matter yield of mixtures increased when the proportion of vetches declined (Tuna and Orak, 2007). The vetch-oat seeding ratio of 30%: 70% produced higher forage yield under rain fed condition while the vetch-grass seeding ratio of 25%: 75% performed better in terms of green as well as dry matter production (Ansar *et al*., 2013).

Forage mixture containing 25%-50% legume produces more quality forage and yield per unit area than those of pure sowings (Alemu *et al*., 2007). Increasing the seed proportion of an intercrop in mixture delays its maturity and increases the dry matter percentage (Juskiw *et al*., 2000; Alemu *et al*., 2007). Pure vetch was generally lower yielding than oat. Adding oat to vetch increased the total forage yield. Planting of CV-SRCP X 80 Ab 2806 variety followed by CV-SRCP X 80 Ab 2291 produced higher grain and straw yield than other varieties (Amanuel *et al.*, 2019).

2.8.1 Effects of variety and seed proportions on leaf to stem ratio of oats-vetch mixtures

Leaf to stem ratio is an important determinant of feed intake in grazing livestock due to modulating ingestion, yield, distribution and density of biomass (Whiteman, 1980). The leaf to stem ratio was affected by species performance and age of harvesting (Alemu *et al*., 2007). The leaf fraction has significant implications on the nutritive quality of the forage as leaves contain higher levels of nutrients and less fiber than stems (Denbela *et al.,* 2015).

2.9. Effects of variety and seed proportions of oats-vetch mixtures on nutritive values

The CP content of oat-vetch mixtures were higher than the oat grown alone, while it is lower than legume mono crop of vetch (Haq *et al*., 2018). All the pure legume forages produced relatively high digestibility values compared to oats. Oats-vetch mixtures generally had higher digestibility values than pure oats. The CP content increased with increasing rate of vetch in the forage mixture, as vetch is rich in protein than oats (Lithourgidis *et al*., 2006; Negash *et al.*, 2017). The contents of NDF, ADF and ADL appeared to increase with increasing proportion of oats in the mixture (Negash *et al*., 2017). Increasing the legume proportion resulted in decreased ADF and NDF concentrations for the legume-grass mixtures (Vern *et al*., 2004).

3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted at Assosa Agricultural Research Center (AsARC), in Benishangul-Gumuz Regional State. The center is located at 675 km from Addis Ababa to the Western part of Ethiopia. Geographically, it is located at 10^{0} 02ˈ47” N latitude and 34^{0} 34ˈ 27" E longitude with an altitude of 1560 meters above sea level (Fig. 1). Agro-climatically; it has been characterized by hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts towards the end of October with maximum rainfall from June to October. The mean annual rainfall of the area (during 2004-2020) was 1165.6 mm. The mean annual minimum and maximum temperatures of the area for the same years were 14.63 and 28.61^{0}C, respectively. The predominant soil type of the area was reddish-brown nitisols (Alemayehu and Woldegabriel, 2016), and it has a pH value less than 6, which range from very strongly to moderately acidic (AsARC, 2006).

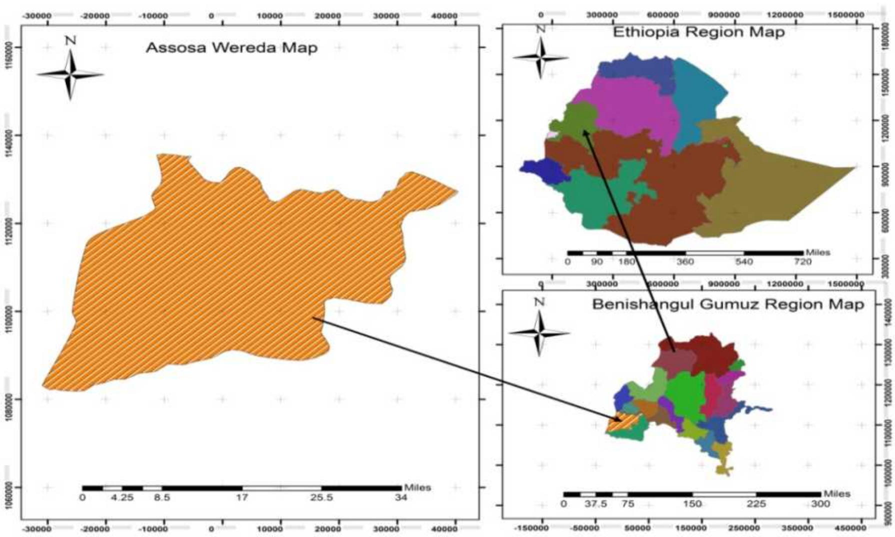

Figure 1: Map of the study area (AsARC, 2006)

3.2. Source of planting materials

The oat varieties and vetch species used in the experiment were SRCP X 80 Ab 2806 and SRCP X 80 Ab 2291 for oat varieties and *Vicia dasycarpa* 'Lana' and *Vicia sativa* “ICARDA-61509” for vetch species. They were obtained from Holetta Agricultural Research Center. The oat varieties were chosen since they were recently released by Holetta Agricultural Research Center (HARC) and vetch species were chosen because they had better compatibility with oat varieties from previous studies in the highlands.

3.3. Soil sampling and analysis

Soil samples were collected with the aid of soil-auger before sowing. Fifteen samples were taken from fifteen sampling spots in total, five from each block of experimental field with X-pattern of sampling within the depth of 0-20 cm. They were then bulked together to get a representative composite soil sample. Then, the composite soil samples were placed in sealed labeled bags and transferred to the Assosa Agricultural Research Center soil laboratory for analysis of the selected parameters. The determined parameters were soil textural class (sand, silt and clay), soil pH, total nitrogen (N), organic carbon(OC), organic matter (OM), available phosphorous (P), cation exchangeable capacity (CEC) and exchangeable base (Ca, Mg, Na and K).

Soil pH was determined from 1:2.5 soils to deionized (distilled water) ratio suspension (Page *et al.,* 1982), and soil pH was recorded using a glass electrode attached to a digital pH meter (potentiometer) after a thorough stirring. Total organic carbon content was measured by Walkley and wet oxidation method as described by Jackson (1958).Total N was determined by Kjeldahl method as described by Dewis and Freitas, (1975). Organic matter was calculated by multiplying the percent organic carbon by 1.724 assuming that organic matter is composed of 58 % carbon (Kerven *et al.,* 2000). Extractable phosphorous was determined by following Olsen's sodium bicarbonate extraction method (Olsen, 1954).

Potassium was determined after extracting the sample using the ammonium acetate extractable method and analyzed by a flame photometer (Jackson, 1973). Soil texture analysis was performed by Bouyoucous hydrometer method (Day, 1965).

3.4. Land preparation and management

The land was plowed and harrowed twice by a tractor to make the soil fine-tilth before planting. A total area of the experimental site was 9m*63m (567m^2). The plot size was 2m*3m (6m^2) with 1.5m, 1m and 0.3m spacing between blocks, plots and rows, respectively. The plots that were assigned randomly for the oats and vetch were divided into seven rows. Blended NPS fertilizer was applied at sowing time at a rate of 121.05 kg/ha, because 121.05kg NPS fertilizer was equivalent in phosphorus (P) nutrients content with 100kg DAP (Ethiosis, 2019)

3.5. Experimental treatments and design

The experiment was laid down in factorial arrangements using a randomized complete block design (RCBD) with three replications. Treatment was arranged in a 2*2*4 factorial arrangement with two levels of oat varieties, two levels of vetch species and four levels of oats and vetch seed proportions. The oat varieties and vetch species were sown in rows and they were mixed at four seed rate proportions: 75% (oats, O) + 25% (vetch, V), 50% O + 50% V, and 25% O + 75% V of the mixed species and sole of the two forage types. Thus, the experiment consisted of sixteen (16) treatments (Table 1), replicated three times with a total of forty eight plots. The amount of seed used for sole and mixture were determined based on the recommended seeding rate of 30 kg/ha for pure vetch (Gezahagn, 2016) and 100 kg/ha for pure oats (Fekede *et al*., 2008). Plots within a block were randomly assigned for each treatment. The seeds were planted by drilling in rows.

Table 1: Treatments arrangement

Trt No	Oat Varieties	Vetch Species	Seed Proportions %	Varieties name and their combinations	Amount of seed/plot (g)
1	Oat V1	Vetch V1	100	100% SRCP X 80 Ab 2291	60 (Oat)
2	Oat V1	Vetch V1	75/25	75% SRCP X 80 Ab 2291 + 25% *Viciasativa* “ICARDA 61509”	45 (Oat) + 4.5 (Vetch)
3	Oat V1	Vetch V1	50/50	50% SRCP X 80 Ab 2291 + 50% *Vicia sativa* “ICARDA 61509”	30 (Oat) + 9 (Vetch)
4	Oat V1	Vetch V1	25/75	25% SRCP X 80 Ab 2291 + 75% *Vicia sativa* “ICARDA 61509”	15 (Oat) + 13.5 (Vetch)
5	Oat V1	Vetch V2	100	100% *Vicia dasycarpa* ‘Lana’	18 (Vetch)
6	Oat V1	Vetch V2	75/25	75% SRCP X 80 Ab 2291 + 25% *Vicia dasycarpa* ‘Lana’	45 (Oat) + 4.5 (Vetch)
7	Oat V1	Vetch V2	50/50	50% SRCP X 80 Ab 2291 + 50% *Vicia dasycarpa* ‘Lana’	30 (Oat) + 9 (Vetch)
8	Oat V1	Vetch V2	25/75	25% SRCP X 80 Ab 2291 + 75% *Vicia dasycarpa* ‘Lana’	15 (Oat) + 13.5 (Vetch)
9	Oat V2	Vetch V1	100	100% *Vicia sativa* “ICARDA 61509”	18 (Vetch)
10	Oat V2	Vetch V1	75/25	75% SRCP X 80 Ab 2806 + 25%*Vicia sativa* “ICARDA 61509”	45 (Oat) + 4.5 (Vetch)
11	Oat V2	Vetch V1	50/50	50% SRCP X 80 Ab 2806 + 50% *Vicia sativa* “ICARDA 61509”	30 (Oat) + 9 (Vetch)
12	Oat V2	Vetch V1	25/75	25% SRCP X 80 Ab 2806 + 75% *Vicia sativa* “ICARDA 61509”	15 (Oat) + 13.5 (Vetch)
13	Oat V2	Vetch V2	100	100% SRCP X 80 Ab 2806	60 (Oat)
14	Oat V2	Vetch V2	75/25	75% SRCP X 80 Ab 2806 + 25% *Vicia dasycarpa* ‘Lana’	45 (Oat) + 4.5 (Vetch)
15	Oat V2	Vetch V2	50/50	50% SRCP X 80 Ab 2806 + 50% *Vicia dasycarpa* ‘Lana’	30 (Oat) + 9 (Vetch)
16	Oat V2	Vetch V2	25/75	25% SRCP X 80 Ab 2806 + 75% *Vicia dasycarpa* ‘Lana’	15 (Oat) + 13.5 (Vetch)

Note: oat V1=oat variety one, oatV2= oat variety two, vetch V1=vetch variety one and vetch V2=vetch variety two

3.6. Data collected

3.6.1. Morphological parameters

Morphological parameters measured were seedling count and stand count at tillering. Close observation was made starting from the 5^{th} day of sowing to assess the rate of germination and early establishment performance of the varieties. In order to support the visual assessment of the establishment performance of the varieties, seedling count were made using randomly placed $1m^2$ quadrates in each plot at two weeks after emergence. In order to assess tillering performance of the varieties, plant stand was counted on the 45^{th} day of sowing as described above for seedling count (Akililu and Alemayehu, 2007).

Plant height was determined by measuring the length of sampled plants from the ground level to the top of the plants at milk stage of oats which is the recommended stage (Gezahagn *et al.,* 2017) for harvesting of oats-vetch mixtures. Ten plants (5 oats and 5 vetch species) were randomly selected from each plot and their heights were measured in centimeters (cm), then the average value was recorded. The ground (plot) cover and vigor percentage was scored at harvesting time by observing the existing performance of the forage of each plot on a five scale score from 50- 100%. According to Tarawali (1995) ground (plot) cover and vigor score percentage was described as excellent (91-100%), very good (81-90%), good (71- 80%), fair (61- 70%) and poor (50 - 60%).

3.6.2. Herbage dry matter yield

Oats-vetch mixtures were harvested from the interior rows of each plot at milk stage of oats which is the recommended stage (Gezahagn *et.al,* 2017) for harvesting of oats-vetch mixture. The plants were harvested five centimeters above the ground level by hand using sickles. Weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 600g (two paper bags each containing about 300 g sample) of their representative samples were taken for further processing in the laboratory. The first estimated 300 g sample taken from each plot was weighed to know the sample fresh weight using sensitive balance and oven dried at 105°C for 24 hours for dry matter determination to estimate herbage dry matter yield. The second estimated 300 g sample taken from each plots were weighed and oven dried at 65°C for 48 hours for chemical composition analysis and *in-vitro* dry matter digestibility analysis, which were done at animal nutrition laboratory of Holetta Agricultural Research Center.

The leaf to stem ratio (LSR) of oats and vetch were determined by taking 300 g sample from each plot and then partitioned into leaf and stem. The fresh leaves and stems were weighed separately and dried in forced air draft oven at105°C for 24 hours and their weight determined. Then the leaf weight was divided by stem weight to determine LSR.

3.7. Chemical analysis and yield determination

The partially dried forage samples were ground using a cyclone mill to pass through a 1 mm screen for laboratory analysis and *in-vitro* dry matter digestibility determination. Total ash and CP contents were determined using standard procedures of AOAC (1995). Accordingly, ash was determined upon complete burning of the feed samples in a muffle furnace at 500ºC for 6 hours. The total N content was determined by Kjeldahl wet digestion method. Crude protein content was calculated as 6.25 X N assuming that protein contains 16% N. The Neutral Detergent Fiber (NDF), Acid Detergent Lignin (ADL) and Acid Detergent Fiber (ADF) were determined according to the procedures of Van Soest and Robertson (1985). Crude protein yield (CPY) was determined as the product of CP contents and herbage DM yields (Starks *et al*., 2006). The CP yield (t/ha) was calculated by multiplying CP% with total dry matter yield.

3.7.1. In vitro dry matter digestibility

The two stage Tilley and Terry (1963) method was used to determine IVDMD. Rumen liquor was collected from three fistulated steers and transported to the laboratory using thermos flasks that had been pre-warmed to 39^{0}C. Steers were fed natural pasture hay adlibitum and 2 kg concentrate mixture per day. The chemical composition of concentrate mixture was 18 % CP and 10 MJ/kg DM of ME. Rumen liquor was taken in the morning before steers were offered with feed. A duplicate sample of 0.5 g was incubated with 10 ml of rumen liquor and a buffer in 50 ml test tube in incubator at 39^{0}C for a period of 48 hour for microbial digestion followed by another 48 hour for enzymatic digestion with acid pepsin solution. Blank samples containing buffered rumen fluid were incubated in duplicates for adjustment.

$$IVDMD = \frac{(\text{Sample weight} * \%\ DM) - (\text{Residue weight} - \text{blank weight}) \times 100}{\text{Sample weight} * \%\ DM}$$

Where: IVDMD = In vitro Dry Matter Digestibility

3.8. Biological compatibility

3.8.1. Relative yield (RY)

The relative yields (RY) for grass and legume were assessed using the equation of De Wit and Vander Bergh (1965).

$RY_G = (DMY_{GL} / DMY_{GG})$; $RY_L = (DMY_{LG} / DMY_{LL})$

Where: DMY_{GG} is the dry matter yield of grass ‘G’ as a monoculture; DMY_{LL} is the dry matter yield of legume ‘L’ as a monoculture; DMY_{GL} is the dry matter yield of grass component ‘G’ grown in mixture with legume ‘L’ and DMY_{LG} is the dry matter yield of legume component ‘L’ grown in mixture with grass ‘G’.

3.8.2. Relative yield total (RYT)

Relative yield total (RYT) or Land equivalent ratio (LER) was calculated according to the formula of De W it (1960):

$RYT_{GL} = (DMY_{GL}/DMY_{GG}) + (DMY_{LG}/DMY_{LL})$

Where: DMY_{GG} is the DMY of grass as monoculture, DMY_{LL} is the DMY of legume as a monoculture, DMY_{GL} is the DMY of grass component grown in mixture with legume, and DMY_{LG} is the DMY of legume component grown in mixture with grass. It shows that if $RYT_{GL}>1$, there is yield advantage of mixtures compared to the pure stands.

3.8.3. Competitive ratio (CR)

The competitive ratio (CR) is another way to assess competitive ability between the different species. Competitive ratio (CR) is the ratio of the individual RYT's of the component crops and it indicates the number of times by which one component crop is more competitive than the other (Willey and Rao, 1980).

$CR_{GL} = (RY_{GL} / RY_{LG})* (Z_{LG} / Z_{GL})$ and

$CR_{LG} = (RY_{LG} / RY_{GL})* (Z_{GL} / Z_{LG})$

Where; $CR_{GL =}$ Competitive ratio of grass in combination with legume

CR_{LG} = Competitive ratio of Legume in combination with grass

Z_{GL} = Sown proportion of grass in mixture with legume

Z_{LG} = Sown proportion of legume in mixture with grass

3.8.4. Relative crowding coefficient (RCC)

This parameter was calculated to determine the competitive ability of grass and legume in the mixture (De Wit and Vander Bergh, 1965).

For 50:50 seed proportion:

$RCC_{GL}= DMY_{GL} / (DMY_{GG} - DMY_{GL})$

$RCC_{LG} = DMY_{LG} / (DMY_{LL} - DMY_{LG})$

For mixtures different from 50:50, the RCC was calculated as:

$RCC_{GL} = DMY_{GL} \times Z_{LG} / (DMY_{GG} - DMY_{GL})\ Z_{GL}$

$RCC_{LG} = DMY_{LG} \times Z_{GL} / (DMY_{LL} - DMY_{LG})\ Z_{LG}$

Where, RCC = DMY_{GG} = Dry matter yield of pure stand of Grass, DMY_{LL} = Dry matter yield of pure stand of Legume, DMY_{GL} = Mixture yield of Grass in combination with Legume, DMY_{LG} = Mixture yield of Legume in combination with Grass, Z_{GL} = Sown proportion of Grass in mixture with Legumes, Z_{LG} = Sown proportion of Legume in mixture with Grass, RCC_{GL} = Values indicate the following conclusions: RCC<1, there is yield disadvantage ,RCC = 1, there is no difference and RCC > 1, there is yield advantage in mixing.

3.8.5. Aggressivity index (AI)

The dominance or aggressive ability of the grass against the legume in a mixture was described by calculating aggressivity Index (AI) as indicated by McGilchrist and Trenbath (1971):

For 50:50 seed proportion:

$AI_{GL} = (DMY_{GL} / DMY_{GG}) - (DMY_{LG} / DMY_{LL})$

$AI_{LG} = (DMY_{LG} / DMY_{LL}) - (DMY_{GL} / DMY_{GG})$

For mixtures different from 50:50 seed proportion:

$AI_{GL} = DMY_{GL} / (DMY_{GG} \times Z_{GL}) - DMY_{LG} / (DMY_{LL} \times Z_{LG})$

$AI_{LG} = DMY_{LG} / (DMY_{LL} \times Z_{LG}) - DMY_{GL} / (DMY_{GG} \times Z_{GL})$

Where; AI_{GL} =Aggressivity index of grass component grown in mixture with legume, AI_{LG} = Aggressivity index of legume component grown in mixture with grass, DMY_{GL}= DMY of grass component grown in mixture with legume, $DMY_{LG=}$ DMY of legume component grown in mixture with grass. Z_{GL} and Z_{LG} = are the sown proportion of ‘Grass’ and ‘Legume’ in the mixtures, respectively. If DM of species ‘Grass’ and ‘Legume’ is calculated on per unit area basis, where both 'Grass' and 'Legume' have the same competitive ability, the value of Aggressivity index (AI) is zero. AI value greater than zero, indicates greater competitive ability of 'Grass' compared to 'Legume'. If the numerical value of AI of both species is the same, the sign of the dominant species is positive and that of the dominated is negative. Moreover, the greater the numerical value, the bigger is the difference in competitive ability; and the bigger is the difference between the actual and expected yields.

3.9. Statistical analysis

Data was subjected to analysis of variance using the general linear model procedures of the statistical analysis system (SAS, 2002). Differences among treatment means were separated using Duncan's multiple range tests, when treatment effects are significant ($P<0.05$). The statistical model used was:

$Y_{ijpk} = \mu + O_i + Vj + S_p + B_K + (OV)\ ij + (OS)\ ip + (VS)jp + (OVS)_{ijp} + e_{ijpk}$

Where: Y_{ijpk} = Measurable variable, μ = Overall mean, O_i = Effect of oat variety (Oat), I = (1, 2),Vj = Effect of vetch species (Vetch), j= (1, 2), S_p = Effect of seed proportion, p= (1, 2, 3, 4), B_K= Block effect, k = (1, 2, 3), (OV)ij = the ijth interaction effect (Oat * Vetch), (OS)ip = the ipth interaction effect (Oat * seed proportion), (VS)jp = the jpth interaction effect (Vetch * Seed proportion), (OVS)ijp = the ijpth interaction effect (Oat * Vetch * Seed proportion), e_{ijpk} = Random error term.

4. RESULTS

4.1. Soil Physico-Chemical Properties of the Study Area

Composite soil samples were collected and analyzed prior to conducting the experiment. The analysis of the soil physical properties showed that the soil contains 32% sand, 11.2% silt, 56.8% clay and the textural class of the soil was clay. Chemically, the soil had a pH of 5.58, and contained 1.75% organic carbon,2.95% organic matters , 0.22%total nitrogen 5.7 *mg* kg^{-1}available phosphorus , 4.6 cmol kg^{-1}exchangeable acid , 2.56 cmol kg^{-1}calcium , 0.57cmol kg^{-1}magnesium , 0.22 cmol kg^{-1}sodium and 1.1cmol kg^{-1}available potassium (Table 2).

Table 2: Physico-chemical properties of the experimental soil before planting

Soil Physical properties	**Values**
Sand %	32
Silt%	11.2
Clay%	56.8
Textural class	**Clay**
Soil chemical properties	
pH (H2O) (1:12.5)	5.58
Organic carbon (%)	1.75
Organic matter (%)	2.95
Total nitrogen (%)	0.22
Available P (mg kg^{-1})	5.7
Exchangeable acid (cmol kg^{-1})	4.6
Exchangeable base (cmol kg^{-1})	
Ca	2.56
Mg	0.57
Na	0.22
K	1.1

Note: N: Nitrogen, P: Phosphorus, Ca: Calcium, Mg: Magnesium, mg: Milligram, Na: Sodium, K: Potassium.

4.2. Effect of variety and seed proportions on morphological growth parameters of oats-vetch mixtures

4.2.1. Seedling count, stand count at tillering and plant height of oats and vetch

The effect of oat varieties, vetch species and seed proportions on seedling count, stand count at tillering and plant height of oats-vetch mixture are shown in Table 3. Oat varieties sown with different vetch species using different seed proportions and their interaction effects had no significant (P>0.05) effect on seedling count of oats at emergence. However, oat varieties sown under different seed proportions had a significant effect (P<0.05) on oats seedling count at emergence. The highest and lowest mean seedling counts of oats at emergence were obtained from oat varieties sown in pure stands and oat varieties sown with vetch species at seed proportions of 25% oats and 75% of vetch , respectively.

On the other hand, oat varieties sown with different vetch species under different seed proportions and their interaction effects had no significant effect (P>0.05) on vetch seedling count at emergence. However, vetch species sown with different oat varieties and seed proportions had a significant effect (P<0.05) on vetch seedling count at emergence. The highest and lowest mean seedling counts at emergence were obtained from *Vicia dasycarpa* and *Vicia sativa* sown with different oat varieties, respectively. On the other hand, the highest and lowest seedling counts at emergence of vetch were obtained from vetch species sown in pure stand and vetch species sown with oats at seed proportions of 25% vetch and 75% of oats, respectively.

Vetch species sown with different oat varieties under different seed proportions and their interactions had no significant effect (P>0.05) on oats stand count at tillering. However, oat varieties sown with different vetch species and seed proportions had significant effect (P<0.05) on oats stand count at tillering .The highest and lowest mean stand counts at tillering of oats were obtained from oat variety, SRCP X 80 Ab 2291 (493.7) and SRCP X 80 Ab 2806 (458.1), respectively. On the other hand, the highest and lowest stand counts at tillering of oats were obtained from oat varieties sown in pure stands and oat varieties sown with vetch species at seed proportions of 25% oats and 75% of vetch, respectively.

Oat varieties sown with different vetch species and their interaction had no significant effect ($P>0.05$) on vetch stand count at tillering. However, vetch species sown with different oat varieties and seed proportions had a significant effect ($P<0.05$) on vetch stand count at tillering .The highest and lowest mean stand counts at tillering were obtained from *Vicia dasycarpa* and *Vicia sativa* sown with different oat varieties. On the other hand, the highest and lowest mean stand counts at tillering of vetch were obtained from vetch species sown in pure stand and vetch species sown with oats at seed proportions of 25% vetch and 75% oat, respectively.

Vetch species sown with different oat varieties using different seed proportions and their interaction had no significant effect ($P>0.05$) on plant height (cm) of oats. However, oat varieties sown with different vetch species had a significant effect ($P<0.05$) on plant height .The longest and shortest mean values of plant height were obtained from oat varieties, SRCP X 80 Ab 2806 and SRCP X 80 Ab 2291, respectively.

On the other hand, oat varieties sown with different vetch species using different seed proportions and their interaction had no significant effect ($P>0.05$) on plant height of vetch. However, vetch species sown with different oat varieties had significant effect ($P<0.05$) on plant height .The longest and shortest mean values of plant height were recorded for vetch species, *Vicia dasycarpa* and *Vicia sativa*, respectively.

Table 3: Effects of oat varieties, vetch species and seed proportions on seedling count, stand count at tillering and plant height of oats-vetch mixtures

Factors	Seedling count (m^2)		Stand count (m^2)		Plant height (cm)	
	Oat	Vetch	Oat	Vetch	Oat	Vetch
Oat variety (O)						
SRCP X 80 Ab 2291	94.50	75.90	493.70^{a}	191.10	104.90^{b}	111.30
SRCP X 80 Ab 2806	92.80	72.81	458.10^{b}	172.80	116.20^{a}	111.40
P-value	**0.7237**	**0.5110**	**0.0310**	**0.0600**	**<0.001**	**0.5833**
Vetch species (V)						
Vicia sativa	94.09	69.00^{b}	471.84	166.80^{b}	110.80	78.50^{b}
Vicia dasycarpa	93.33	79.71^{a}	480.04	197.18^{a}	110.40	144.20^{a}
P-value	**0.8136**	**0.0003**	**0.5753**	**0.0005**	**0.3585**	**<0.001**
Seed proportion (SP)						
100	134.70^{a}	107.20^{a}	716.20^{a}	265.00^{a}	113.20	97.60
75/25	113.50^{b}	42.50^{d}	547.50^{b}	104.30^{d}	111.10	112.20
50/50	86.80^{c}	73.80^{c}	431.80^{c}	175.90^{c}	110.70	111.40
25/75	60.30^{d}	90.30^{b}	328.40^{d}	224.30^{b}	108.80	117.60
P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.4399**	**0.5645**
Interaction						
O * V	NS	NS	NS	NS	NS	NS
O * SP	NS	NS	NS	NS	NS	NS
V * SP	NS	NS	NS	NS	NS	NS
O * V * SP	NS	NS	NS	NS	NS	NS
Mean	**93.71**	**74.35**	**475.93**	**182.00**	**110.62**	**111.40**
CV	**5.97**	**10.09**	**11.31**	**11.68**	**6.76**	**22.08**
R^2	**0.97**	**0.94**	**0.90**	**0.92**	**0.61**	**0.77**

*= P<0.05; ** = P<0.01; ***= P<0.001;NS= non-significant (P>0.05); O * V= interaction of oat and vetch; O * SP= interaction of oat and seed proportion; V * SP= interaction of vetch and seed proportion; O * V * SP= interaction of oat, vetch and seed proportion; CV = Coefficient of variation and R^2=R-Square; means followed by a common superscript letter/s within a column are not significantly different (P>0.05).

4.2.2. Plot cover and vigor score of oats-vetch mixtures

Interaction effects of oats by vetch, oats by seed proportions and oats by vetch by seed proportions on plot cover and vigor score of oats-vetch mixtures are shown in Table 4 and 5. The interaction effects of oats by vetch was significant effect ($P<0.05$) for plot cover of the oats-vetch mixtures. The highest plot cover was recorded from oat variety SRCP X 80 Ab 2291 sown with *Vicia dasycarpa*, oat variety SRCP X 80 Ab 2806 sown with *Vicia dasycarpa* and *Vicia sativa* compared with the oat variety SRCP X 80 Ab 2291 grown with *Vicia sativa*. The interaction of oat varieties and seed proportions had also significant ($P<0.05$) effect on plot cover of oats-vetch mixtures. Higher plot cover was recorded from oat variety, SRCP X 80 Ab 2291 at 100% and 25% seed proportions, and SRCP X 80 Ab 2806 at 75% and 25% than oat variety, SRCP X 80 Ab 2291 at 50% but intermediate plot cover was recorded from SRCP X 80 Ab 2291 at 75% and SRCP X 80 Ab 2806 at 100% and 50% seed proportions.

The interaction of oat varieties, vetch species and seed proportions had significant ($P<0.05$) effect on vigor score (**Table 5**). Higher vigor score of oats-vetch mixtures was obtained from 75% SRCP X 80 Ab 2806 + 25% *Vicia sativa*, 25% SRCP X 80 Ab 2806 + 75% *Vicia dasycarpa*, *Vicia dasycarpa* sown in pure stand and 25% SRCP X 80 Ab 2291 + 75% *Vicia dasycarpa* and the lower vigor score of oats-vetch mixtures was obtained from 50% SRCP X 80Ab 2291 + 50% *Vicia sativa*.

Table 4: Interaction effects of oats by vetch and oats by seed proportions on plot cover of oats-vetch mixtures

Oat varieties	**Vetch species**	**Plot cover (%)**
SRCP X 80 Ab 2291	*Vicia sativa*	82.83[b]
	Vicia dasycarpa	92.83[a]
SRCP X 80 Ab 2806	*Vicia sativa*	89.83[a]
	Vicia dasycarpa	91.50[a]
	Mean	**89.25**
	CV	**9.18**
	P-value	**0.0225**
Oat varieties	**Seed proportion**	**Plot cover**
	100 (O)	95.00[a]
	75/25 (O/V)	86.66[ab]
SRCP X 80 Ab 2291	50/50 (O/V)	79.00[b]
	25/75 (O/V)	90.66[a]
	100 (O)	88.00[ab]
SRCP X 80 Ab 2806	75/25 (O/V)	94.00[a]
	50/50 (O/V)	86.66[ab]
	25/75 (O/V)	94.00[a]
	CV	8.77
	P-value	0.0190
	Interaction	**Significance**
	O * V	*
	O * SP	*
	V * SP	NS
	O * V * SP	NS

*= P<0.05; ** = P<0.01; ***= P<0.001;NS = non-significant (P>0.05); O * V = interaction of oat and vetch; O * SP = interaction of oat and seed proportion; V * SP = interaction of vetch and seed proportion; O * V * SP = interaction of oat, vetch and seed proportion; CV = Coefficient of variation; Means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

Table 5: Interaction effect of oat varieties, vetch species and seed proportions on vigor score of oats-vetch mixtures

Oat variety	Vetch species	Seed proportion	Vigor score (%)
		100 (O)	92.67[ab]
	Vicia sativa	75/25 (O/V)	79.33[de]
		50/50 (O/V)	74.00[e]
SRCP X 80 Ab 2291		25/75 (O/V)	82.67[cd]
		100 (V)	96.00[a]
	Vicia dasycarpa	75/25 (O/V)	92.67[ab]
		50/50 (O/V)	82.67[cd]
		25/75 (O/V)	96.67[a]
		100 (V)	84.00[cd]
	Vicia sativa	75/25 (O/V)	97.33[a]
		50/50 (O/V)	86.00[bcd]
SRCP X 80 Ab 2806		25/75 (O/V)	89.33[abc]
		100 (O)	90.67[abc]
	Vicia dasycarpa	75/25 (O/V)	90.00[abc]
		50/50 (O/V)	86.00[bcd]
		25/75 (O/V)	97.33[a]
		Mean	**88.58**
		CV	**4.83**
		P-value	**<0.001**
		Interaction	**Significance**
		O * V	**
		O * SP	***
		V * SP	NS
		O * V * SP	***

*= P<0.05; ** = P<0.01; ***= P<0.001;NS = non-significant (P>0.05); O * V = interaction of oat and vetch; O * SP = interaction of oat and seed proportion; V * SP = interaction of vetch and seed proportion; O * V * SP = interaction of oat, vetch and seed proportion; CV = Coefficient of variation; Means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

4.3. Leaf to stem ratio and dry matter yield of oats-vetch mixtures

Effects of oat varieties, vetch species and seed proportions on leaf to stem ratio and dry matter yield of oats and vetch grown in pure stand and mixtures are given in Table 6 and 7. The main factors and their interactions had not significant ($P>0.05$) effect on leaf to stem ratio of oats. Moreover, oat varieties sown with vetch species using different seed proportions and their interaction had no significant effect ($P>0.05$) on leaf to stem ratio of vetch. However, vetch species sown with different oat varieties had a significant effect ($P<0.05$) on leaf to stem ratio (**Table 6**). The highest and lowest mean leaf to stem ratio was obtained from vetch species *Vicia sativa* and *Vicia dasycarpa*, respectively.

The interactions of oat varieties, vetch species and seed proportion had a significant effect ($P<0.05$) on DMY of oats-vetch mixtures (**Table 7**). Higher DMY was obtained from 75% SRCP X 80 Ab 2806 sown with 25% *Vicia sativa.* On the other hand the lower DMY was obtained from *Vicia dasycarpa* sown in pure stands.

Table 6: Effects of oat varieties, vetch species and seed proportions on leaf to stem ratio of oats and vetch grown in pure stand and mixtures

	Leaf to stem ratio	
Factors	Oats	Vetch
Oat variety (O)		
SRCP X 80 Ab 2291	0.65	0.79
SRCP X 80 Ab 2806	0.69	0.78
P-value	**0.4129**	**0.1426**
Vetch species (V)		
Vicia sativa	0.66	0.92[a]
Vicia dasycarpa	0.69	0.66[b]
P-value	**0.5599**	**<0.001**
Seed proportion (SP)		
100	0.68	0.81
75/25	0.70	0.76
50/50	0.65	0.78
25/75	0.66	0.80
P-value	**0.8002**	**0.7162**
Interaction		
O * V	NS	NS
O * SP	NS	NS
V * SP	NS	NS
O * V * SP	NS	NS
Mean	**0.67**	**0.79**
CV	**18.34**	**12.68**
R^2	**0.35**	**0.75**

*= P<0.05; ** = P<0.01; ***= P<0.001; NS= Non-significant (P>0.05); O * V= interaction of oat and vetch; O * SP= interaction of oat and seed proportion; V * SP= interaction of vetch and seed proportion; O * V * SP= interaction of oat, vetch and seed proportion; CV = Coefficient of variation and R^2= R-Square; DMY = dry matter yield; Means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

Table 7: The interaction effect of oat varieties, vetch species and seed proportions on dry matter yield (t ha^{-1}) of oats-vetch mixtures

Oat variety	Vetch species	Seed proportion	DMY
		100 (O)	10.20^{a-f}
	Vicia sativa	75/25 (O/V)	8.90^{c-g}
		50/50 (O/V)	7.66^{fg}
SRCP X 80 Ab 2291		25/75 (O/V)	8.14^{d-g}
		100 (V)	7.45^{g}
	Vicia dasycarpa	75/25 (O/V)	10.28^{a-e}
		50/50 (O/V)	9.69^{b-g}
		25/75 (O/V)	11.60^{ab}
		100 (V)	7.99^{e-g}
	Vicia sativa	75/25 (O/V)	12.35^{a}
		50/50 (O/V)	10.64^{a-d}
SRCP X 80 Ab 2806		25/75 (O/V)	9.04^{b-g}
		100 (O)	10.94^{a-c}
	Vicia dasycarpa	75/25 (O/V)	9.93^{a-g}
		50/50 (O/V)	10.03^{a-g}
		25/75 (O/V)	11.50^{a-c}
		Mean	**9.77**
		CV	**13.73**
		P-value	**0.0013**
		Interaction	**Significance**
		O * V	NS
		O * SP	NS
		V * SP	*
		O * V * SP	**
		R^2	0.66

DMY = Dry matter yield; *= P<0.05; ** = P<0.01; ***= P<0.001; NS= Non-significant (P>0.05); O * V= interaction of oat and vetch; O * SP= interaction of oat and seed proportion; V * SP= interaction of vetch and seed proportion; O * V * SP= interaction of oat, vetch and seed proportion; CV = Coefficient of variation and R^2= R-Square; DMY = dry matter yield; Means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

4.4. Chemical Composition and In vitro dry matter digestibility of mixed and pure stands of oats and vetch

Interaction effects of oat varieties, vetch species and seed proportions on chemical compositions of oats-vetch mixtures are shown on Table 8 and 9. The interaction of oat varieties, vetch species and seed proportions had significant (P<0.05) effect on CP content of oats-vetch mixtures. Higher CP content was obtained from vetch species, *Vicia sativa* and *Vicia dasycarpa* sown in pure stands while oat variety, SRCP X 80 Ab 2806 and SRCP X 80 Ab 2291 sown in pure stand had lower CP content than other mixtures.

The interaction of oat varieties, vetch species and seed proportions had significant (P<0.05) effect on NDF content of oats-vetch mixtures. Higher NDF content was obtained from oat varieties, SRCP X 80 Ab 2291 and SRCP X 80 Ab 2806 sown in pure stands while vetch species, *Vicia sativa* and *Vicia dasycarpa* sown in pure stands had lower NDF content than other mixtures.

The interaction of oat varieties, vetch species and seed proportions had significant effect (P<0.05) on ADF content of oats-vetch mixtures. Higher ADF content was obtained from oat variety, SRCP X 80 Ab 2291 sown in pure stands while vetch species, *Vicia sativa* and *Vicia dasycarpa* sown in pure stands had lower ADF content than other mixtures.

The interaction of oat varieties, vetch species and seed proportions had a significant (P<0.05) effect on ADL content of oats-vetch mixtures. Higher ADL content was obtained from oat variety, SRCP X 80 Ab 2291 and SRCP X 80 Ab 2806 sown in pure stands than other mixtures.

The interaction of oat varieties, vetch species and seed proportions had significant effect (P<0.05) on IVDMD content of oats-vetch mixtures. Higher IVDMD content was obtained from *Vicia sativa* sown in pure stands than others mixtures. On the other hand, SRCP X 80 Ab 2806 sown in pure stands had lower IVDMD content than other mixtures.

The interaction of oat varieties and vetch species had a significant (P<0.05) effect on ash content of oats-vetch mixtures (**Table 9**). The highest ash content was obtained from SRCP X 80 Ab 2291sown with (*Vicia sativa*, Vicia *dasycarpa)* and SRCP X 80 Ab 2806 sown with *Vicia dasycarpa* while the lowest was obtained from SRCP X 80 Ab 2806 sown with *Vicia sativa*. On the other hand, the interaction of oat varieties and seed proportions had significant (P<0.05) effect on ash content of oats-vetch mixtures. Higher ash content was obtained from SRCP X 80 Ab 2291 at 100% and 50% seed proportions while the lower value was obtained from SRCP X 80 Ab 2806 at 100% seed proportions.

The interaction oat varieties and vetch species had significant effect (P<0.05) on CP yield (t/ha^{-1}) of oats-vetch mixtures. The highest CP yield was obtained from SRCP X 80 Ab 2291 sown with *Vicia dasycarpa*, SRCP X 80 Ab 2806 sown with *Vicia sativa* and *Vicia dasycarpa* while the lowest CP yield was obtained from SRCP X 80 Ab 2291 sown with *Vicia sativa*. On the other hand, the interaction of vetch species and seed proportions had significant effect (P<0.05) on CP yield (t/ha^{-1}) of oats-vetch mixtures. The highest CP yield was obtained from 25% oat varieties sown with 75% *Vicia dasycarpa* than other seed proportions.

Table 8: Interaction effects of oat varieties, vetch species and seed proportions on chemical compositions and In vitro dry matter digestibility (%) of oats-vetch mixtures

Oat variety	**Vetch species**	**Seed proportion**	**CP**	**NDF**	**ADF**	**ADL**	**IVDMD**
		100 (O)	12.83^{fg}	59.83^{a}	40.37^{a}	8.60^{a}	65.17^{cd}
	Vicia sativa	75/25 (O/V)	14.90^{ef}	53.13^{cd}	30.37^{b}	5.45^{cd}	66.22^{cd}
		50/50 (O/V)	14.66^{ef}	53.26^{bcd}	29.16^{b}	6.78^{b}	65.91^{cd}
SRCP X 80 Ab 2291		25/75 (O/V)	15.85^{de}	49.68^{cd}	30.23^{b}	6.04^{bcd}	67.40^{bc}
		100 (V)	22.50^{a}	43.62^{e}	23.89^{c}	6.17^{bcd}	67.44^{bc}
	Vicia dasycarpa	75/25 (O/V)	14.79^{ef}	54.26^{bc}	33.39^{b}	6.71^{b}	65.23^{cd}
		50/50 (O/V)	16.12^{cde}	54.62^{abc}	31.69^{b}	6.52^{cb}	66.11^{cd}
		25/75 (O/V)	17.68^{bcd}	50.04^{cd}	30.66^{b}	5.06^{d}	66.31^{cd}
		100 (V)	24.40^{a}	35.44^{f}	20.89^{c}	5.12^{d}	73.29^{a}
	Vicia sativa	75/25 (O/V)	13.58^{efg}	54.81^{abc}	31.49^{b}	5.77^{bcd}	65.27^{cd}
		50/50 (O/V)	13.54^{efg}	53.48^{bcd}	31.32^{b}	6.31^{bc}	65.10^{cd}
SRCP X 80 Ab 2806		25/75 (O/V)	18.34^{bc}	48.45^{de}	30.31^{b}	5.09^{d}	69.56^{b}
		100 (O)	11.67^{g}	58.81^{ab}	33.49^{b}	8.15^{a}	63.34^{d}
	Vicia dasycarpa	75/25 (O/V)	15.39^{def}	54.99^{abc}	33.29^{b}	6.03^{bcd}	66.20^{cd}
		50/50 (O/V)	14.96^{ef}	55.12^{abc}	30.53^{b}	6.83^{b}	64.95^{cd}
		25/75 (O/V)	18.83^{b}	50.58^{cd}	29.84^{b}	5.53^{cd}	67.87^{bc}
		Mean	**16.25**	**51.88**	**30.68**	**6.26**	**66.58**
		CV	**8.34**	**5.62**	**8.22**	**9.76**	**2.37**
		P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
		Interaction			**Significance**		
		O * V	***	***	NS	***	**
		O * SP	NS	NS	NS	NS	NS
		V * SP	NS	NS	NS	NS	*
		O * V * SP	***	***	***	***	***
		R^2	0.90	0.86	0.81	0.80	0.75

CP = Crud protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL= Acid detergent lignin; IVDMD = in-vitro dry matter digestibility; CV = Coefficient of variation; *= P<0.05; ** = P<0.01; ***= P<0.001; NS = Non-significant (P>0.05); O * V = interaction of oat and vetch; O * SP = interaction of oat and seed proportion; V * SP = interaction of vetch and seed proportion; O * V * SP = interaction of oat, vetch and seed proportion; means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

Table 9: Interaction effects of oats by vetch on ash content (%) and crude protein yield (t ha^{-1}), oats by seed proportions on ash content and vetch by seed proportions on crude protein yield of oats-vetch mixtures

Oat variety	Vetch species	Ash	CPY
SRCP X 80 Ab 2291	*Vicia sativa*	11.07^{a}	1.26^{b}
	Vicia dasycarpa	11.64^{a}	1.70^{a}
SRCP X 80 Ab 2806	*Vicia sativa*	9.21^{b}	1.67^{a}
	Vicia dasycarpa	10.98^{a}	1.61^{a}
	Mean	**10.72**	**1.56**
	CV	**9.56**	**19.66**
	P-value	**<0.001**	**0.0036**
Oat variety	**Seed proportions**	**Ash**	-
SRCP X 80 Ab 2291	100 (O)	11.66^{a}	-
	75/25 (O/V)	11.31^{ab}	-
	50/50 (O/V)	11.70^{a}	-
	25/75 (O/V)	10.73^{ab}	-
SRCP X 80 Ab 2806	100 (O)	9.21^{c}	-
	75/25 (O/V)	10.29^{abc}	-
	50/50 (O/V)	9.86^{bc}	-
	25/75 (O/V)	11.02^{ab}	-
	CV	**10.80**	**-**
	P-value	**0.0054**	**-**
Vetch species	**Seed proportions**	**-**	**CPY**
Vicia sativa	100 (O)	-	1.63^{b}
	75/25 (O/V)	-	1.48^{b}
	50/50 (O/V)	-	1.28^{b}
	25/75 (O/V)	-	1.48^{b}
Vicia dasycarpa	100 (O)	-	1.48^{b}
	75/25 (O/V)	-	1.52^{b}
	50/50 (O/V)	-	1.53^{b}
	25/75 (O/V)	-	2.10^{a}
	CV	**-**	**18.28**
	P-value	**-**	**0.0019**
	Interaction	**Significance**	
	O * V	***	**
	O * SP	**	NS
	V * SP	NS	**
	O * V * SP	NS	NS
	R^2	**0.70**	**0.69**

CPY = Crude protein yield; *= P<0.05; ** = P<0.01; ***= P<0.001; NS = Non-significant (P>0.05); O * V = interaction of oat and vetch; O * SP = interaction of oat and seed proportion; V * SP = interaction of vetch and seed proportion; O * V * SP = interaction of oat, vetch and seed proportion; CV = Coefficient of variation; means followed by a common superscript letter/s within a column are not significantly different (P>0.05)

4.5. Biological competition and yield advantages of oats-vetch mixtures

Effect of oat varieties, vetch species and seed proportions on relative yield, relative yield total, relative crowding coefficient, aggressivity index and competitive ratio of oats-vetch mixtures are shown in Table 10. Higher RY of the oats component was observed at 75% SRCP X 80 Ab 2806 sown with 25% *Vicia sativa* 50% SRCP X 80 Ab 2806 sown with 50% *Vicia sativa* and 75% SRCP X 80 Ab 2291 sown with 25 % *Vicia dasycarpa* than other mixtures. Similarly, the RY of vetch at 25% SRCP X 80 Ab 2806 sown with75% *Vicia dasycarpa* and 25% SRCP X 80 Ab 2291sown with75% *Vicia dasycarpa was* higher than other mixtures.

Greater RYTs were obtained from 25% SRCP X 80 Ab 2291sown with 75% *Vicia dasycarpa*, 25% SRCP X 80 Ab 2806 sown with 75% *Vicia dasycarpa*,75% SRCP X 80 Ab 2806 mixed with 25% *Vicia sativa*, 75% SRCP X 80 Ab 2291 sown with 25% *Vicia dasycarpa*, 50% SRCP X 80 Ab 2291mixed with 50% *Vicia dasycarpa*, 50% SRCP X 80 Ab 2806 mixed with 50% *Vicia dasycarpa*,50% SRCP X 80 Ab 2806 sown with 50% *Vicia sativa* and 75% SRCP X 80 Ab 2806 sown with 25% *Vicia dasycarpa*. These mixtures had a RYT values of 1.02 -1.35, which had 2- 35% yield advantages.

The highest RCC of oats were obtained from 50% SRCP X 80 Ab 2806 sown with 50% *Vicia sativa* (5.52). The result indicates that SRCP X 80 Ab 2806 appeared to be highly dominant (superior in competitive ability over *Vicia sativa*). On the other hand, the highest RCC of vetch was obtained from 25% SRCP X 80 Ab 2806 sown with 75% *Vicia dasycarpa* (1.37). This indicates that *Vicia dasycarpa* appeared to be highly dominant (superior in competitive ability over SRCP X 80 Ab 2806).

The aggresivity index, oat varieties were more aggressive or dominant on 25% SRCP X 80 Ab 2291 sown with 75% *Vicia dasycarpa*, 25% SRCP X 80 Ab 2291 sown with 75% *Vicia* *sativa* and 25% SRCP X 80 Ab 2806 sown with 75% *Vicia sativa* as indicated by their positive sign (+). However, vetch species was more aggressive or dominant on 75% SRCP X 80 Ab 2806 sown with 25% *Vicia dasycarpa*, 75% SRCP X 80 Ab 2291 sown with 25% *Vicia dasycarpa* and 75% SRCP X 80 Ab 2291 sown with 25% *Vicia sativa* as indicated by their positive sign (+).

The CR of oats-vetch mixtures indicated that vetch was more competitor than oat when sown with75% SRCP X 80 Ab 2291 + 25% *Vicia dasycarpa.* However, both oat varieties sown in vetch species mixtures at 25:75%, 50:50% and 75:25% seed proportions were more competitor than vetch.

Table 10: Effect of oat varieties, vetch species and seed proportions on relative yield (RY), relative yield total (RYT), relative crowding coefficient (RCC), aggressivity index (AI) and competitive ratio (CR) of oats-vetch mixtures

Oat variety	**Vetch species**	**Seed proportion**	**RY**		**RYT**	**RCC**		**AI**		**CR**	
			Oats	**Vetch**	**Oats-vetch**	**Oats**	**Vetch**	**Oats**	**Vetch**	**Oats**	**Vetch**
SRCP X 80 Ab 2291	*Vicia sativa*	75/25 (O/V)	0.68^{bcd}	0.28^{cd}	0.96^{cde}	0.53^{bc}	0.07^{c}	-0.21^{efg}	0.21^{abc}	0.82	1.26^{b}
		50/50 (O/V)	0.54^{bcd}	0.29^{cd}	0.83^{e}	1.22^{bc}	0.42^{bc}	0.24^{def}	-0.24^{bcd}	1.82	0.57^{b}
		25/75 (O/V)	0.50^{cd}	0.39^{bcd}	0.90^{de}	0.20^{bc}	0.12^{c}	1.48^{ab}	-1.48^{fg}	3.84	0.26^{b}
	Vicia dasycarpa	75/25 (O/V)	0.76^{abc}	0.36^{bcd}	1.12^{abcd}	0.73^{bc}	0.11^{c}	-0.44^{fg}	0.44^{ab}	0.72	3.69^{a}
		50/50 (O/V)	0.65^{bcd}	0.41^{bcd}	1.07^{bcde}	2.20^{b}	0.70^{b}	0.24^{def}	-0.24^{bcd}	1.60	0.66^{b}
		25/75 (O/V)	0.64^{bcd}	0.70^{a}	1.35^{a}	0.42^{bc}	0.46^{bc}	1.64^{a}	-1.64^{g}	2.79	0.39^{b}
SRCP X 80 Ab 2806	*Vicia sativa*	75/25 (O/V)	0.96^{a}	0.24^{d}	1.20^{abc}	1.32^{bc}	0.06^{c}	0.34^{cde}	-0.34^{cde}	1.44	0.80^{b}
		50/50 (O/V)	0.79^{ab}	0.27^{cd}	1.06^{bcde}	5.52^{a}	0.40^{bc}	0.52^{cde}	-0.52^{cde}	3.55	0.36^{b}
		25/75 (O/V)	0.44^{d}	0.53^{b}	0.97^{cde}	0.16^{bc}	0.31^{bc}	1.05^{abc}	-1.05^{efg}	2.75	0.41^{b}
	Vicia dasycarpa	75/25 (O/V)	0.66^{bcd}	0.35^{cd}	1.02^{cde}	0.40^{bc}	0.10^{c}	-0.53^{g}	0.53^{a}	3.12	1.64^{b}
		50/50 (O/V)	0.63^{bcd}	0.44^{bc}	1.07^{bcde}	1.95^{b}	0.79^{b}	0.19^{defg}	-0.19^{abcd}	1.46	0.72^{b}
		25/75 (O/V)	0.48^{d}	0.84^{a}	1.32^{ab}	0.18^{bc}	1.37^{a}	0.80^{bcd}	-0.80^{def}	1.73	0.59^{b}
		P-value	**0.0078**	**0.001**	**0.0053**	**0.0021**	**0.0004**	**0.001**	**0.001**	**0.2625**	**0.0372**

5. DISCUSSION

5.1. Soil Physico-chemical properties of the study area

The result of pre-planting soil analysis revealed that the soil of the study area is clay in texture with the value of 56.8%. Soil texture is a fundamental physical soil property of soil. Soil texture is closely related to the water-holding capacity of soils since clay soils hold more water than do sandy soils (Brady and Weil, 2002). Thus, the soil of the study area has good water holding capacity, which creates a good growing media for plant growth. The soil pH ranged from very strongly to moderately acidic in reaction with the pH (H_2O 1:2.5) value of 5.58, which is within the range of optimum soil pH for legume production (Walelign, 2015).

5.2. Morphological growth parameters of oats-vetch mixtures

5.2.1. Seedling count, stand count at tillering and plant height of oats and vetch

The highest seedling counts at emergence and stand counts at tillering from the sole plots of both oat varieties and vetch species, and the decline with reduction of the respective variety in the seed proportions of the mixtures is in agreement with the study of Alemu *et al.* (2007) and Fantahun (2016) who reported that seedling counts increased with increasing seed proportions of both oat and vetch varieties. The higher seedling counts at the emergence of vetch in *Vicia dasycarpa* than *Vicia sativa* could be attributed to variation in variety and seed size. These results agree with the finding of Zareian *et al*. (2013) who reported that species and seed size were significantly affected on seedling counts. The variation in stand counts at tillering of oat variety and vetch species could be attributed to genetic variations. Similarly Ahmad *et al*. (2008) and Gebremdhn *et al.* (2015) observed variation in tiller number among varieties.

Plant height is one of the important agronomic traits which affects the production and productivity of all forage crops Gezahagn *al*. (2016). Higher plant height for SRCP X 80 Ab 2806 oat variety than SRCP X 80 Ab 2291 variety may be attributed to variation in genetic make-up and adaptability of the varieties to different environmental conditions. Zaman *et al*. (2006) indicated that plant height may differ among varieties due to environmental conditions which in turn cause variation in hormonal balance and cell division rate.

Higher plant height of *Vicia dasycarpa* compared with *Vicia sativa* in the present study could be attributed to genetic variability and environmental conditions as observed by Gezahagn *et al*. (2016).This implies that different species have different height. The result of this study is in agreement with the finding of Kassahun and Wasihun (2015) and Gezahagn *et al*. (2016) who reported that different vetch species varied in plant height.

5.2.2. Plot cover and vigor score of oats-vetch mixtures

The higher plot cover percentage of oat variety, SRCP X 80 Ab 2806 mixed with two vetch species and oat variety, SRCP X 80 Ab 2291 mixed with *Vicia dasycarpa* relative to oat variety, SRCP X 80 Ab 2291 mixed with vetch species, *Vicia sativa* might be attributed to less compatibility which could contribute to the difference in plot cover percentage.

The greater plot cover percentage of oat variety by seed proportion (except for oat variety, SRCP X 80 Ab 2291 by 50% seed proportion) might be attributed to genetic variability and seed proportions. The result of this study is in agreement with the finding of Malede (2018) who reported that the ground cover percentage increased with the increase in relative proportions of the seeds of triticale and vetch in the forage mixtures.

The varieties with better vigor and plot cover percentage resulted in good dry matter yield. Vigor score percentage increased with increasing seed proportions (100%, 75:25% and

25:75%) of the two oat varieties with two vetch species mixtures. These results agree with the finding of Fantahun (2016) who reported that vigor and plot cover percentage increased with the increasing seed proportions of oat in the mixture.

5.3. Leaf to stem ratio and dry matter yield of oats-vetch mixtures

The leaf to stem ratio was affected by species performance and age of harvesting (Alemu *et al*., 2007). The leaf fraction has significant implications on the nutritive quality of the forage as leaves contain higher levels of nutrients and less fiber than stems (Denbela *et. al.*, 2015). In the present study, leaf to stem ratio of the two vetch species was significantly varied among species; where *Vicia sativa* was higher than *Vicia dasycarpa* in leaf to stem ratio. In this finding, the observed difference in leaf to stem ratio among the vetch species might be attributed to genetic variability. The finding of leaf to stem ratio of vetch species from this study was higher than the report of Luis *et al.* (2019). This difference might be due to environmental conditions, altitude, soil fertility, soil type and management system.

The higher dry matter yield in the two oat varieties sown in pure stands, SRCP X 80 Ab2806 sown with *Vicia dasycarpa* at 75:25% indicates that vetch might have contributed more to the mixture through rhizobium nodulation during nitrogen fixation compared to other treatments. According to Tuna and Orak (2007), and Barsila (2018), dry matter yield in vetch mixtures with oat at seed proportion of 75% oats: 25% vetch combination was more productive than pure vetch. In general, oat varieties and vetch species at different seed proportion mixtures were observed to have high yield than the pure stand of vetch.

5.4. Chemical Composition and In vitro dry matter digestibility of mixed and pure stands of oats and vetch

The crude protein content of forage is one of the most important criteria for forage quality evaluation (Lithourgidis *et al*., 2006; Khan *et al*., 2014). Higher CP content was obtained in sole vetch species followed by 25% oats: 75% vetch seed proportions of both oat varieties and vetch species mixture which is in line with the finding of Haq *et al*. (2018) who reported that the CP content of the oats-vetch mixture was higher than the oat grown alone. The findings of this study also agree with the report of Sani *et al*. (2020) who reported that the CP content in the mixture of grass-legume at 25% Brachiaria: 75% *Centrosema pascuorum* (Centro) were higher than the pure grass.

The NDF content of oats-vetch mixtures was increased in the mixtures with increment of both oat varieties seed proportions, whereas it decreased as vetch species increased in the mixture. The result of this study agrees with the finding of Carita *et al.* (2016) who reported that legumes have less NDF than grasses. The content of NDF in the forage is an indicator of its digestibility and feed intake. Therefore, Meissner *et al.*(1991) and Diriba, (2000) reported that the NDF contents above the critical value of 60% results in decreased voluntary feed intake, feed conversion efficiency and longer rumination time. In the present study, the NDF content of all the treatments was observed to be below this threshold level.

The ADF content of oats-vetch mixtures was increased with increment in oats seed proportions, whereas it decreased as vetch species increased in the mixture. The study agrees with the finding of Vern *et al*. (2004) and Negash *et al*. (2017) who reported a decrease in ADF levels with increasing vetch proportions. It also agrees with the finding of Sani *et al*. (2020) who observed decrease in ADF content of *Brachiaria ruziziensis* (grass) as *Centrosema pascuorum* (legume) increased in the mixture. The content of ADF in the forage is an indicator of its digestibility and feed intake. Therefore, Kellems and Church (1998) reported that the characterized forage with less than 40% ADF content is high in quality and above 40% ADF content is low quality. Therefore, in the present study, the ADF content of all the treatments was observed to be below this threshold level except sole oat variety, SRCP X 80 Ab 2291 which indicates that the current ADF level does not affect digestibility and feed intake for animals.

The ADL content of both oat varieties, the sole plots were higher than sole vetch and mixtures which agrees with the finding of Demissie (2014) who reported a decrease in ADL levels with increasing vetch seed rate. The ADL content of the oats-vetch mixture in the present study (5.06-8.60) is similar with the finding of Nsahlai *et al*. (1996) who reported that high quality roughages have the ADL content of 3.20 to 11.00%.

The IVDMD content of oats-vetch mixtures was increased with an increase in both vetch species seed proportions. The highest IVDMD was obtained in 25% oat: 75% vetch seed proportions of both oat varieties and vetch species mixtures in the current study which agree with the finding of Diriba and Diriba (2013) who reported that the IVDMD content of legumes is higher than grass. The IVDMD in forage is an indicator of its feed intake and digestibility. According to McDowell (2003) the IVDMD greater than 55% indicates good feeding values and below this threshold level reduces feed intake due to lower digestibility. In the present study, the IVDMD content of all treatments was observed to be above this threshold level which is an indicator for its good nutritive value.

The ash content is the concentration of minerals in the forages. The lower ash content of oat variety, SRCP X 80 Ab 2806 with vetch species *Vicia sativa* compared with other oat variety and vetch species mixtures might be attributed to varietal differences. According to Juknevicius and Sabiene (2007) and Gezahagn *et al*. (2016), the concentration of minerals in forages varies according to the varieties, plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime. And also, the lower ash content of oat variety was SRCP X 80 Ab 2806 at 100% seed proportions. The finding of the present study agrees with Bakhashwain and Ahmed (2010) who reported that ash content is affected by different seed proportions of Rhodes and alfalfa mixtures.

Crude protein yield of forage is one of the main criteria for forage quality (Yilmaz *et al*., 2015). Oat varieties and vetch species interaction was significantly varied on CPY of oat - vetch mixtures. The observed difference might be attributed due to varietal difference. The current study is comparable with the finding of Albayrak *et al*. (2004) who reported that CPY is affected by different environments and genotypes. And also, the higher CPY for *Vicia dasycarpa* at 75% seed proportions than other vetch species and seed proportions agrees with Karagic *et al*. (2011) who reported that increase in the rate of vetch species resulted in higher crude protein yield. However, to the contrary Demissie (2014) reported that seeding rates have not affected CPY of oat and vetch mixtures. This difference might be due to species, environment conditions, harvesting stage, soil fertility and soil type.

5.5. Biological competition and yield advantages of oat and vetch mixtures

The mixtures of 75% oats: 25% vetch and 25% oats: 75% vetch both oat and vetch varieties had more a yield advantage of 2-35% than the other seed proportions and pure stands which indicates that N contribution to oat through nitrogen fixation by the vetch and its transfer from the vetch component to the oats. The results of the RY and RYT in the current study agree with the findings of Tessema and Baars (2006) for Chloris- Medicago and Panicum-Desmodium mixtures.

Relative crowding coefficient (RCC) indicates the competitive ability of the component species. In the mixtures, the higher RCC of the component species indicates that it is more competent. Oat varieties at 50% SRCP X 80 Ab 2806 sown with *Vicia sativa* seed proportions were more competent. However, vetch species at 25% oat SRCP X 80 Ab 2806 sown with 75% vetch *Vicia dasycarpa* seed proportions were more competent. This result is agree with the finding of Malede (2013a) reported that different seed proportion of grass was a dominant species over legume, at 25:75 or 50:50 and these patterns had produced products of crowding coefficient greater than one.

Vetch was slightly more competitive than oat in the 75% SRCP X 80 Ab 2291 sown with 25% vetch *Vicia dasycarpa but* oats was slightly more competitive than vetch in the 75:25% 50:50% and 25:75% seed proportions of both oat varieties which agrees with the finding of Erol *et al*. (2009) who reported that vetch was slightly more competitive than oat in the 75%:25% oat-vetch mixtures and also, they reported that oat was slightly more competitive than vetch in the 85%:15% and 55%:45% mixtures.

The competitive ability of the component crops in a mixture system is determined by its Aggressivity value (Rusdy, 2016; Khan *et al*., 2018). In the present study, the Aggressivity index of oats-vetch mixtures have a positive sign for vetch at a seed proportion of 75%:25% in both vetch species except at 75% oat SRCP X 80 Ab 2806 sown with 25% *Vicia sativa* which indicates that vetch was dominant (+ve) while oat appeared as a dominated crop (-ve). However, the Aggressivity index for the mixtures had a positive sign for both oat varieties at the seed proportions of 50%:50%, 25%:75% and 75% oat SRCP X 80 Ab 2806 sown with 25% vetch *Vicia sativa* which indicates that oat was dominant (+ ve) while vetch appeared as dominated (-ve)

6. CONCLUSION AND RECOMMENDATION

It could be deduced that the use of oat varieties and vetch species with the seed proportions of 75% SRCP X 80 Ab 2806 sown with 25% Vicia sativa resulted in high DMY. Increasing the seed proportions of both vetch species in the mixture resulted in higher CP%, CPY *(tha^{-1})* and IVDMD% and lower, NDF%, ADF% and ADL% contents. The use of both oat varieties and vetch species with the seed proportions of 75% oats: 25% vetch, 25% oats: 75% vetch resulted in best compatibility.

Both oats variety and vetch species at seed proportions of 75% oats: 25% vetch and 25% oats: 75% vetch could be recommended in Assosa, Benishangul-Gumuz Regional State of Western Ethiopia to get higher dry matter yield, best quality and better biological compatibility under condition of the current experiment. Furthermore, the experiment should be done in different agro ecology and season to come up with conclusive recommendation.

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8. APPENDICES

Appendix 1: Field sample recording data sheet for oats-vetch mixtures

Trt no.	Rep	Seedling count (m^2)	Stand count at tillering (m^2)	Average Ht (cm)	Plot cover %	Vigor score%	Fresh wt (kg/SA)	Fresh wt (kg/ha)	Fresh wt (t/ha)	Sample at oven drying	Dry sample wt (kg/SA)	dry sample wt (kg/ha)	dry sample wt (t/ha)	DMY(t/ha)	Leaf to stem ratio
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															

Rep=Replication, Trt=Treatment, Ht=Height, wt=weight, kg=kilogram, t/ha = tone per hectare, SA=sample

Appendix 2: Analysis of variance (ANOVA) for measured traits of oats-vetch mixtures sown with different seed proportions

SN	Traits	Mean square								Mean	CV	R^2
		O (1)	**V (1)**	**SP (3)**	**O*V**	**O*SP**	**V*SP**	**O*V*SP**	**Error**			
1	SECO	4.00^{ns}	1.78^{ns}	9014.07***	7.11^{ns}	1.00^{ns}	70.11^{ns}	14.11^{ns}	31.32	93.71	5.97	0.97
2	SECV	25.00^{ns}	1002.78***	7010.75***	21.78^{ns}	8.33^{ns}	134.78^{ns}	2.78^{ns}	56.3	74.357	10.09	0.94
3	STCO	15104.41*	934.32^{ns}	203894.89***	5461.21^{ns}	259.69^{ns}	3582.59^{ns}	2358.49^{ns}	2902.14	475.94	11.32	0.91
4	STCV	1750.03^{ns}	7084.03***	43126.38***	2.89^{ns}	18.30^{ns}	1212.13^{ns}	66.80^{ns}	452.56	182.00	11.69	0.93
5	PHO	1142.44***	49.00^{ns}	52.20^{ns}	170.74^{ns}	24.57^{ns}	61.81^{ns}	71.90^{ns}	56.08	110.63	6.77	0.62
6	PHV	186.78^{ns}	46886.68***	419.62^{ns}	64.00^{ns}	234.11^{ns}	919.10^{ns}	226.87^{ns}	605.36	111.40	22.09	0.77
7	LSRO	0.011^{ns}	0.005^{ns}	0.005^{ns}	0.03^{ns}	0.03^{ns}	0.0015^{ns}	0.003^{ns}	0.015	0.676	18.34	0.35
8	LSRV	0.023^{ns}	0.585***	0.0045^{ns}	0.002^{ns}	0.016^{ns}	0.0004^{ns}	0.0083^{ns}	0.01	0.79	12.68	0.76
9	PCOV	96.33^{ns}	408.33**	227.66**	208.33*	140.55*	43.22^{ns}	77.00^{ns}	45.17	89.25	7.53	0.62
10	VISOV	108.00*	408.33***	225.22***	192.00**	144.00***	37.66^{ns}	73.33***	18.316	88.58	4.83	0.80
11	DMYOV	13.50*	7.94*	3.61^{ns}	0.57^{ns}	1.21^{ns}	6.88*	13.52**	1.80	9.77	13.73	0.66
12	CPOV	0.36^{ns}	2.76^{ns}	36.56***	89.57***	4.75^{ns}	18.45^{ns}	96.94***	1.84	16.25	8.34	0.91
13	CPYOV	0.32*	0.43**	0.32**	0.75**	0.01^{ns}	0.32**	0.10^{ns}	0.06	1.57	15.26	0.69
14	AshOV	18.98***	16.40***	0.46^{ns}	4.33***	4.19**	0.47^{ns}	0.49^{ns}	0.91	10.73	8.91	0.71
15	NDFOV	8.61^{ns}	36.45^{ns}	86.74***	310.24***	20.02^{ns}	4.86^{ns}	289.13***	8.51	51.88	5.62	0.86
16	ADFOV	13.87^{ns}	1.31^{ns}	13.31^{ns}	39.986^{ns}	16.42^{ns}	9.86^{ns}	179.81***	6.37	30.68	8.22	0.81
17	ADLOV	1.163^{ns}	0.63^{ns}	5.78***	8.36***	0.27^{ns}	0.55^{ns}	5.58***	0.37	6.26	9.77	0.81
18	IVDMDOV	6.26^{ns}	20.61**	15.35**	23.70**	6.40^{ns}	9.86*	30.50***	2.50	66.59	2.38	0.76

*= P<0.05; ** = P<0.01; ***= P<0.001; ^{NS}= P>0.05; **O** = Oat; **V**= Vetch; **SP** = Seed Proportion; **SECO**=Seedling count oat; **SECV**= Seedling count vetch; **STCO**=Stand count oat ; **STCV**= Stand count vetch ; **PHO** = Plant Height of Oat; **PHV** = Plant Height of Vetch; **LSRO**= Leaf to steam ratio oat; **LSRV**= Leaf to steam ratio vetch; **PCOV**= Plot cover percentage of oats-vetch mixtures ;**VISOV**= Vigor score percentage of oats-vetch mixtures; **DMYOV**= Dry matter yield($t\ ha^{-1}$) of oats-vetch mixtures ; **CPOV**= Crude protein content of oats-vetch mixtures **CPYOV**= Crude protein content yield tone per hectare of oats-vetch mixtures; **Ash OV**= Ash content of oats-vetch mixtures **NDFOV**= Neutral detergent fiber content of oats-vetch mixtures ;**ADFOV** = Acid detergent fiber content of oats-vetch mixtures ;**ADLOV** = Acid detergent lignin content of oats-vetch mixtures; **IVDMDOV**=In vitro dry matter digestibility content of oats-vetch mixtures

Appendix 3: Different pictures during the study period




Legend: Soil sample collection

Legend: Land preparations

Legend :Sowing at experimental site




Legend: Emergency of vetch and oat varieties

Legend: Weeding

Legend: Plant height measurement




Legend: During harvesting time

Legend: Weight measurement for oat

Legend: Weight measurement for vetch

Legend: Sample chopping

Legend: fresh weight measurement before drying

Legend: Fresh sample arrangement in oven for drying

Legend: Sample in oven after drying

Legend: Sample preparation for submission for chemical analysis

BIOGRAPHICAL SKETCH

The author, Kedija Ahmed was born from her father Mr. Ahmed Seid and mother Mrs. Lubaba Hussen September, 1983 E.C in Assosa Woreda Benishangul-Gumuz Region, Ethiopia. As she got a chance to learn, she joined the Primary School in Assosa, Hoha number six up to grade 6, and from grade 7 up to 8 she continued Assosa elementary school and from grade 9 up to 10 she continued her education at Assosa General Seiner Secondary School. After she completed grade 10, she joined Assosa ATVET (Agricultural Technical Vocational Education Training) Collage in September 2001 E.C and graduated with Diploma in Animal Sciences in 2003 E.C. After completion of her Diploma education, she joined Assosa University in September 2005 E.C and graduated with Bachelor of Science (BSc.) in Animal Sciences in 2008 E.C. Then after graduation she employed Ethiopian Institute of Agricultural Research at Assosa Agricultural research center. The author joined the School of Graduate Studies of Hawassa University, College of Agriculture, School of Animal and Range science, in September, 2011 E.C within work experienced directly by sponsor of Ethiopian Institute of Agricultural Research to pursue M.Sc. degree in Animal and Range science (Specialization: Animal Production).