THE EFFECTS OF INTERCROPPING TWO VETCH SPECIES (*Vicia sativa and Vicia dasycarpa*) AT DIFFERENT ROW SPACING ON YIELD AND NUTRITIONAL VALUES OF *DESHO* GRASS (*Pennisetum glaucifolium*) IN SAYO DISTRICT, WESTERN ETHIOPIA

MSc. THESIS

BY

YEROSAN WEKGARI OLJIRA

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Yerosan Wekgari Oljira

A Thesis

Submitted to School of Graduate Studies, College of Agriculture and Veterinary Medicine, Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Nutrition

Major Advisor: Taye Tolemariam (PhD, Professor)

Co-Advisor: Zemene Worku (MSc, Assist. Professor)

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DEDICATION

I dedicate this thesis to my father Wekgari Oljira and my mother Chure Banti who have nursed me with care and affection, tirelessly laboured and forfeit whatever they had for my education to reach me on this stage of education,as well as my beloved wife Lalise Gadisa and my son Natoli Yerosan and all the rest families.

STATEMENT OF THE AUTHOR

I declare that this thesis is my real work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree at Jimma University and is deposited at the university library to be made available to borrowers under rules and regulations of the library. I 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: Yerosan Wekgari Signature: ____________

Place: Jimma University, Ethiopia

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BIOGRAPHICAL SKETCH

The author, Yerosan Wekgari was born on January 25, 1990, in Hababo Guduru District, Horro Guduru Wollega Zone, Oromia National Regional State. He attended his elementary education in 1997 – 2000 grades 1- 4 and in 2001 to 2004 grades 5-8 at Tarkanfata Gino and Kubsa Kidame elementary school, respectively. Thenafter he attended secondary school from 2005-2006 at Kombolcha secondary school and his preparatory school from 2007-2008 at Fincha preparatory school. After successful completion of University Entrance Examination, he then joined Hawassa University in 2009 and attended his degree in Animal and Range Scienceand Awarded Bachelor of Sciences degree on 3rd July 2011 with distinction.

After his completion, the author was employed by the Addis Ababa city, Bureau of Urban Agriculture and assigned as an expert in October, 2011. In February, 2014 he joined Oromia Agricultural Research Institute (IQQO) assigned to Bore Agricultural Research Center to work as junior researcher of Animal Feed and Nutrition research division. In 2015, he transferred to Haro Sabu Agricultural Research Center and worked as Assistant Researcher. Thereafter, in October, 2018 he joined Jimma University College of Agriculture and Veterinary Medicine, School of Graduate Studies to pursue his MSc. in Animal Nutrition. At present the author is married and has a son.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BNF	Biological Nitrogen Fixation
CEC	Cation Exchange Capacity
CP	Crude Protein
CPY	Crude Protein Yield
CR	Competitive Ratio
CSA	Central Statistical Agency
DAP	Di-ammonium phosphate
DM	Dry Matter
DMD	Dry Matter Digestibility
DMY	Dry Matter Yield
DOMY	Digestible Organic Matter Yield
DVD	Desho-Vicia Dasycarpa intercropping
DVS	Desho-Vicia Sativa intercopping
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization of the United Nations
GLM	General Linear Model
HSARC	Haro Sabu Agricultural Research Center
ICARDA	International Center for Agricultural Research in the Dry Areas
IVDMD	*In vitro* Dry Matter Digestibility
IVOMD	*In vitro* Organic Matter Digestibility
LER	Land Equivalent Ratio
LSD	Least Significant Difference
ME	Metabolizable Energy
MJ	Mega Juole
MoALR	Ministry of Agriculture and Livestock Resource
N	Nitrogen

ABBRIVATIONS (*Continued*)

N_2	Nitrogen gas
NDF	Neutral Detergent Fiber
OC	Organic Carbon
OM	Organic Matter
pH	Power of Hydrogen
ppm	parts per million
RCBD	Randomized Complete Block Design
RY	Relative Yield
RYT	Relative Yield Total
SAS	Statistical Analysis System
SNNPRS	Southern Nations, Nationalities, and Peoples Regional State
SSA	Sub-Saharan Africa
SD	Sole Desho grass
SVD	Sole Vicia Dasycarpa
SVS	Sole Vicia Sativa
WOCAT	World Overview of Conservation Approaches and Technologies

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ABSTRACT

This study was conducted with the objectives of determining the effects of intercropping two vetch species (Vicia sativa and Vicia dasycarpa) at different row spacing on yield and nutritive values of desho grass, compatibility and changes in the soil chemical properties. The study was designed in a factorial arrangement with Randomized Complete Block Design with three inter-row spaces (0.50 m, 0.75 m and 1 m) and intercropping desho grass with two vetch species (Vicia sativa ICARDA 61509 and Vicia dasycarpa lana) with three replications. Soil samples were collected and analyzed before planting and after harvesting the forage. Agronomic parameters, forage yield, seed yield of vetch, chemical analysis and in vitro digestibility of forage samples were determined based on standard methods. Evaluation of intercropping indices such as land equivalent ratio (LER), relative yield total (RYT), competitive ratio (CR) and aggressivity were calculated. Results showed that intercropping increased the total nitrogen content of the soil and decreased the available phosphorous of the soil after harvesting as compared to pre planting. Significant differences (P<0.05) were observed for all measured agronomic parameters of desho grass, with the exception of number of tiller per plant due to interaction of intercropping with spacing. Higher total DMY was obtained through intercropping as compared to sole whereas the forage yield significantly decreased as the row spacing increased from 0.50 to 1 m. However, interaction had no significant (P>0.05) effect on forage yield of desho grass and vetches, except CPY of vetch. The chemical composition of desho grass was not affected by row spacing and interaction ofintercropping with spacing (P>0.05). Intercropping increased the CP and decreased the fiber contents of desho grass. Chemical composition of vetch was unaffected by interaction of intercropping with spacing. Crude protein (CP) and acid detergent lignin of vetches were influenced by intercropping whereas CP, neutral detergrnt fiber and acid detergent fiber were affected by spacing (P<0.05).The in vitro dry matter digestibility (IVDMD), in vitro organic matter digestibility (IVOMD) and metabolizable energy (ME) of desho grass were increased by intercropping (P<0.05), but not affected by spacing and their interaction. For vetches, intercropped Vicia dasycarpa gave higher IVDMD, IVOMD and ME than Vicia sativa ICARDA 61509 and IVDMD increased as row spacing increased from 0.5 to1m. The LER and RYT of desho grass intercropped with vetches at different row spacing were greater than one indicating the yield obtained in intercropping stand were more productive than the species grown as sole with their respective spacing. Thus, the RYT was higher by 67 % and 65% in desho grass grown with Vicia sativa ICARDA 61509 at 0.75 m and 0.5 m spacing respectively and greater compatibility in terms of DMY was observed. In conclusion, intercropping desho with the two vetch species at various spacing had positive effect on total forage yield and nutritive value of desho grass. Desho grass intercropped with Vicia sativa was a better choice for high yield and forage quality in the study area. However, further study at different locations and over years would be vital including feeding trail using animals to see the association effect of these forages on animal performance.

Keywords: Compatibility; Desho grass; Intercropping; *In vitro* digestibility; Nutritive value; Row spacing; Vetch

1. INTRODUCTION

Ethiopia owns the largest livestock population among African countries and they were estimated to be about 60.39 million cattle, 31.30 million sheep, 32.74 million goats, 2.01 million horses, 8.85 million donkeys, 0.46 million mules, 1.42 million camels and 56.06 million poultry (CSA, 2018). This livestock sector has been contributing considerable portion to the economy of the country, and still promising to rally round the economic development of the country. At the household level, livestock plays a significant role as sources of food and family income for smallholder farmers and pastoralists. About 80% of the Ethiopian farmers use animal traction to plough cropping fields (Melaku, 2011). Hence, livestock remains as a pillar for food security, human nutrition and economic growth of the country (Shapiro *et al.*, 2015).

In developing countries including Ethiopia, the productivity of animals are poor (Behnke and Metaferia, 2011) due to low quality and insufficient feed supply (FAO, 2010; Getahun *et al.*, 2010), but demand of animal origin for human foods is increasing from time to time due to human population growth, rise in income and urbanization (Thornton, 2010). In Ethiopia, the major available feed resources are natural pasture, crop residues, aftermath grazing, and agro-industrial by-products (Alemayehu, 2006; Adugna, 2007; Firew and Getnet, 2010). The current report of CSA (2018) revealed that 55.96 %, 30.12 % , 1.61 % and 0.32 % of the total livestock feed supply of the country is derived from grazing on natural pasture, crop residues, agro industrial byproducts and improved feed respectively, and livestock are mainly dependent on naturally available feed resources. However, the contribution of the natural pasture, is retreating (moving back) from time to time due to poor management and continued expansion of crop farming (Solomon *et al.*, 2003), indicating that livestock feed shortage in the country is further aggravated by the continuous conversion of grazing land to crop land. This illustrates the increasing role of poor quality crop residues in livestock feeding (Zewdie and Yosef, 2014) and could not support reasonable animal performance which in turn is illustrative for exploring alternative feed resources.

Farmers of low income countries like Ethiopia could not afford to use industry-based concentrates and chemicals as supplements to improve utilization of roughages. Leguminous forage crops can improve the utilization of low quality roughages and they are being used more extensively throughout the world. In various production systems legumes are capable of enhancing both crop production through sustained soil fertility and livestock production through increased availability of high quality feed.

One of the potential approaches to reduce the existing livestock nutritional constraint is intercropping of forage grass-legumes. Intercropping of forage grass-legume could become an important management practices to fill the production gaps of the forages both in quantity and quality for animal feeds, and increase the profitability and sustainability of the system in tropical regions (Resende *et al.,* 2003). In addition, various legumes may be used to complement indigenous grass forages and help improve or maintain available nutrition and yield. Matt *et al*. (2013) reported that growing mixtures of grasses and legumes improves biomass production as compared to grass monocultures.

Most tropical countries face shortage of fertilizer, especially nitrogen (N). The shortage of nitrogen available in the soil is primarily limiting plant growth and productivity. According to Quadros *et al.* (2003), the amount of biomass produced by vegetation in forage plant communities is often limited by nitrogen availability. Intercropping forage legumes with grasses presents a potential to increase productivity, herbage nutritive value and resource efficiency. Forage legumes can be inter seeded in to the established grass to increase soil nitrogen, thereby reducing fertilizer costs and weed pressure while enhancing forage yield and quality. Replacing N fertilizer with legumes in hay or grazing system can be more efficient and cost-effective. Lithourgidis *et al.* (2011) and Akman *et al.* (2013) stated that intercropping system allows lower inputs through reduced fertilizer and pesticide requirements, and it contributes to a greater uptake of water and nutrients, increased soil conservation, and high productivity and profitability compared to mono crop systems. In addition to increase yield and quality of forage, legumes either annuals or perennials intercropped with grasses improve soil quality through beneficial effects on soil biological, chemical and physical conditions. Therefore, legumes enhance the N-supplying power of soils, increase the soil reserves of organic matter, stimulate soil biological activity, improve soil structure, reduce soil erosion, increase soil aeration, improve soil water-holding capacity and make the soil easier to till (Bowren *et al.*, 1969).

The yield and nutritional qualities of forage are influenced by numerous factors such as seasonal variations, stage of maturity, ecological conditions and management practices. In addition to intercropping, row spacing is another important key factor for increased forage yield of crop as crop geometry is related with the fertility status and competition for resources so ultimately affect the growth and forage yield.

Desho grass has high biomass yield, is currently familiar with the smallholder farmers, grow with low inputs, and are adaptable to different agro-ecological conditions (Anele *et al*., 2009). *Desho* grass is an indigenous adaptable multipurpose grass of Ethiopia belonging to the family of Poaceae (Welle *et al.,* 2006; Smith, 2010). It has vigorous vegetative growth and a high biomass production capacity 30-109 of green herbage/ha/year, 30-40 t/ha without fertilizer application. *Desho* grasses convenient for smallholder farmers as a backyard enterprise for cut and carry feeding systems, and source of income through sale of cut forage and planting material (Bimrew, 2016). Recently, cultivars of *desho* grass were tested in the areas of western Ethiopia at Haro Sabu Agricultural Research Center. It had good performance and well adapted to the climate of the area and soil conditions.

Vetch is annual forage legume well adapted and more promising as short term fodder crops and widely adapted to the highlands of Ethiopia. One attraction of vetch is its versatility, which permits diverse utilization as either ruminant feed or green manure. Forage legumes including vetch are rich sources of N for livestock with cheaper prices compared to concentrates especially in developing countries (Seyoum, 1994). Getnet and Ledin (2001) also found that vetch has a higher crude protein content compared to many other tropical herbaceous legumes. Contribution of vetch in crop-livestock production systems in different parts of the world is well recognized. Due to its high value, vetch is used as protein supplement for ruminants on low quality diets. Species of vetch have different characteristics in terms of growth habit, days to maturity, morphological fractions, and climatic adaptation. In general, growth habit of vetch species can be broadly grouped as erect, creeping or climbing.

1.1. Statement of the Problem

Feed problem both in quantity and quality is the major factor that hinders the development of livestock production in crop-livestock production system in Ethiopia in general and in study area in particular. Due to high population pressure, overgrazing and land degradation through time, animal feed resources were inadequate in the study area and results in reduction of livestock production. So far, natural pasture and crop residues are the major feed resources used for livestock, but these feed resources are poor in nutritive value and low in quantity (Shelema *et al.,* 2018). In order to alleviate the feed shortage in study area, establishment of forage crops with legumes is feasible (reasonable). Legumes are good sources of protein and can be used to compensate cereal or grass protein shortage (Eskandari *et al.,* 2009). Thus, growing of plant mixtures with legumes, which is referred to as intercropping, can boost the forage protein content of ruminant diets.

There are certain information generated on the adaptability and yield performance of pure stand *desho* grass for feed value. Also, the use of this grass in soil and water conservation has been reported (Welle *et al.,* 2006; Smith, 2010). However, there is no work reported on intercropping of *desho* grass with legumes yet. Furthermore, there is no adequate information available in Ethiopia on effect of intercropping vetch species on the yield and nutritional value of *desho* grass. Therefore, it is necessary to know productivity, compatibility performance and management practices that influence the quantity and quality of *desho* grass intercropping with vetch species which is not known in our country so far. Keeping in view the importance of *desho* grass and vetch species for fodder purpose in the country, it is necessary to evaluate the effect of two vetch species (*Vicia sativa and Vicia dasycarpa*) on the yield and quality of *desho* grass.

1.2. Objectives of the Study

General Objective

- To determine the effects of intercropping different vetch species on the productivity and nutritional values of *desho* grass (*Pennisetum glaucifolium*) at various row spacing.

Specific objectives

- To evaluate the effect of intercropping of *Vicia sativa and Vicia dasycarpa* at different row spacing on the growth performance and biomass yield of *desho* grass (*Pennisetum glaucifolium*).

- To determine the effect of intercropping *Vicia sativa and Vicia dasycarpa* at different row spacing on the chemical composition and *in vitro* digestibility of *desho* grass (*Pennisetum glaucifolium*).
- To assess the compatibility of *desho* grass and vetches intercropping under different row spacing.
- To evaluate the growth performance, biomass yield and nutritive value of vetches under intercropping with different row spacing of *desho* grass.
- To determine changes in soil physio-chemical properties due to intercropping of *Vicia sativa* and *Vicia dasycarpa* and row spacing with *desho* grass.

2. LITERATURE REVIEW

2.1. Description and Geographical Distribution of *Desho* Grass

Desho grass is a many-branched leafy grass growing up to 1 m high or more (FAO, 2010; Leta *et al*., 2013). The culms are erect and branching, and the leaves are 15-25 cm long and 4-10 mm wide, flat and glabrous. The spikelets are 4 mm long, usually solitary (Ecocrop, 2010; FAO, 2010). *Desho* grass is used as fodder and considered to be a very palatable species to cattle (FAO, 2010). The grass provides high green herbage yield ranging between 30 and 109 t/ha (Ecocrop, 2010) and compares favorably with Sorghum bicolor. *Desho* grass responds well to fertilizer application and could be combined with fodder legumes either in mixtures or in rotational cropping. In short rotation with maize or groundnuts, the grass yields better than traditional forage grasses, especially when fertilized, while the roots and stubbles also increase soil fertility (Leta *et al.*, 2013). From animal feed resource point of view, *desho* grass is used in temporary pastures or in cut-and carry systems since it provides ample quantities of good quality green forage and stands several cuts a year. The grass is also useful for hay and silage preparation (Ecocrop, 2010).

Desho grass is native to tropical Africa and grows widespread within 20°N and 20°S. The grass is mainly found on disturbed land, road edges and on recent fallow lands, where annual rainfall range between 600 mm and 1500 mm with a rainy season of 4-6 months and average daily - temperatures of about 30- 35°C. *Desho* grass thrives on a wide range of soils (including degraded sandy or ferruginous soils) provided they are well drained. However, the grass is susceptible to water logging and frost but has some drought tolerance (Ecocrop, 2010; FAO, 2010).

2.1.1. Importance and Growing Conditions of *Desho* grass in Ethiopia

Desho grass is a perennial and produces high dry matter yields of forage per unit area and ensures a sustained forage supply due to its multi-cut nature. The importance of *desho* grass can be seen from the role it plays as the potential source of livestock feed, income and soil conservation in the mixed crop-livestock production systems of Ethiopia (Bimrew, 2016).

Desho grass is one of the indigenous potential forage species which needed comprehensive research in Ethiopia. *Desho* grass is native to tropical countries including Ethiopia (Ecocrop, 2010; Leta *et al*., 2013; EPPO, 2014). In Ethiopia *desho* grass is known as a perennial plant originated in Southern Nations, Nationalities Peoples Regional State in a place called Chencha in 1991 (Welle *et al.*, 2006). Currently it is utilized as a means of soil conservation practices and animal feed in the highlands of Ethiopia (Ecocrop, 2010; Yakob *et al*., 2015). It is used to improve grazing land management (Danano, 2007), rehabilitate degraded land (Smith, 2010), control water loss effectively, and recover rapidly after watering even under severe drought (Leta *et al*., 2013). The grass is popular, drought resistant plant, used as feed for ruminants (FAO. 2010; EPPO, 2014). It has the potential of meeting the challenges of feed scarcity since it provides more forage per unit area and ensures regular forage supply due to its multi-cut nature (Ecocrop, 2010). *Desho* grass is suitable for intensive management and performs well at an altitude ranging from 1500 to 2800 m above sea level (Leta *et al*., 2013). *Desho* grass performs best at an altitude greater than 1700 m above sea level (Welle *et al*., 2006).

The provision of all the technical specifications for cultivation of *desho* grass is essential to improve grazing land management practices. Cuts of the grass are ideally planted in rows, spaced at 10 cm by 10 cm, using a hand hoe (Smith, 2010) in Ethiopia by WOCAT project in SNNPRS. This spacing gives each plant sufficient soil nutrients and access to sunlight to achieve optimal growth, while ensuring that the soil is completely covered by the grass once established. It is recommended to plant other leguminous species alongside *desho* grass to promote biodiversity. Multipurpose shrubs/trees (Leucaena *sp* and *Sesbania sp.*) can be planted approximately 5 m apart with no particular layout. Other legumes (alfalfa and clover) can be mixed with *desho* grass by broadcast throughout the plot (Danano, 2007).

Formerly planted, *desho* grass maintenance activities such as applying fertilizer, weeding and gap filling, are required to ensure proper establishment and persistency of *desho* grass (Solomon *et al.*, 2010). Fertilizer should be applied throughout the plot one month after planting. It is recommended to use organic compost in the form of animal manure, leaf litter, wood ash, food scraps, and/or any other materials rich in biodegradable matters (Danano, 2007). Weeding and gap filling are continuous activities in *desho* grass production (Leta *et al*., 2013). After 2 to 3 years, maintenance inputs decrease substantially or cease altogether as the grass cover closes up and the plot becomes a sustainable fodder source. Past interventions have shown that *desho* based grazing land management practices are best implemented when communal grazing land is re-distributed into small plots (less than 0.5 ha) that are convenient for individual use, development and management (Danano, 2007).

2.1.2. Dry Matter Yield and Nutritive Value of *Desho* Grass

The yield and nutritional qualities of forage are influenced by numerous factors representing ecological conditions and management activities (Enoh *et al.*, 2005). Moreover, the nutritive value of fodder crops is also a function of seasonal variations and the stage of maturity (Papachristou and Papanastasis, 1994). Asmare *et al.* (2017) reported that mean value of dry matter yield of *desho* grass was 16.84 t/ha at midland and 14.62 t/ha at high land of Northern Ethiopia. This difference might be due to soil type, stage of harvesting and management system. Yield increment might have been due to additional tillers developed which increased leaf formation, leaf elongation and stem development (Crowder and Chheda, 1982). The highest yield of forage for the longest cutting intervals could also be attributed to the favorable rainfall, temperature and available nutrient in the soil over the extended growing period of the grass.

Tilahun *et al.* (2017) reported dry matter yield of *desho* grass obtained at 75, 105 and 135 days of harvesting were 7.1, 15.7 and 25.5 t/ha respectively. The higher dry matter yields at later stages were to be expected as plants were taller, had more tillers per plant and more leaves per plant. All these characteristics would contribute to increased photo-synthetic activity and hence higher DM production and this showed that dry matter yield increases with the advances of stage of harvesting. Gadisa *et al.* (2019) reported that average dry matter yield of *desho* grass at first and second harvesting cycle were 24.69 and 28.33 t/ha, respectively. This showed that harvesting cycle influences the dry matter yield of *desho* grass. Dry matter yield of different *desho* grass lines of Areka-DZF-590, Kindu Kosha1-DZF-591 and Kulumsa-DZF-592 were produced 30.3, 28.43 and 30.9 t/ha, respectively at Wondogenet Agricultural Research Center (Tekalegn *et al.*, 2017). This difference might be due to line difference, agro ecology, and stage of harvesting.

Desho grass has a crude protein content of 9.6% on DM basis at early stage and 1.6% at straw stage, respectively. The digestibility and voluntary intake decrease with increase in stage of maturity which indicates that the grass should be fed at early stage of maturity. Asmare *et al.* (2017) reported crude protein content was influenced by harvesting period and altitude. The CP content of *desho* grass decreased with increasing age of plants. Highest CP content (9.38%) was obtained at 90 days harvest and the lowest (6.93%) at 150 days harvest. Higher CP content (9.38%) recorded at mid altitude and the lower amount (7.33%) at high altitude which may have been associated with differences in temperature, precipitation and soil characteristics.

Desho grass harvested at young age had excellent nutritional value, particularly high CP concentration, a limiting nutrient in tropical forages. Even forage of desho grass cut at 135 days of age had 9.3 % of CP concentrations that was well above 7.0%, which is the level below which voluntary intake of ruminants might be depressed. All of the forage produced would provide sufficient energy and protein to support some level of production above a maintenance level. However, harvesting forage at the early stage resulted in low DM yields. Allowing the *desho* grass to grow until 135 days of age resulted in much higher yields without a great reduction in quality despite some reduction in CP concentration and increase in NDF (Tilahun *et al.*, 2017). The CP content of *desho* grass was similar to most Ethiopian dry forage and roughage which have a CP content of less than 9% (Seyoum and Zinash, 1989) which is the level required for adequate microbial synthesis in the rumen (Agricultural Research Council, 1980).

Neutral detergent fiber and ADF were affected by altitude and harvesting period. The NDF content was higher for *desho* grass planted at mid altitude (76.0%) than at high altitude (73.5%). The NDF content of grass was highest (77.68%) from late harvesting (150 days after planting) while it was comparatively lower for earlier harvesting periods (72.78% at 90 days and 73.96% at 120 days) (Bimrew, 2016). Tilahun *et al.* (2017) noted that similar trend showed on NDF concentration increase with increase in harvesting age agrees with Bimrew (2016) for the *desho* grass species, where NDF concentration increased from 72.8% at 90 days to 77.7% at 150 days of age.

2.2. Description, Adaptation and Importance of Vetches Species

Vetch is species of herbaceous plants in the pea family (Fabaceae). Vetches are cultivated as fodder and cover crops and as green manure. Like other legumes, they add nitrogen to the soil by means of nitrogen-fixing bacteria and thus are particularly valuable as a soil-enriching crop. Among many annual forage legumes, adaptation of vetch is better and promising than the others in the central highlands of Ethiopia. Vetch is an annual forage legume widely adapted to the highlands of Ethiopia. It grows well on the reddish brown clay soils and the black soils of the highland areas. It has been grown successfully in areas of acid soil with pH of 5.5-6. It is reported that vetches are rich in protein, minerals, and have lower fiber content. With the highest level of crude protein (CP), vetch could be used as supplement to roughages for dairy cows. Forages which are moderate to high in CP reduce the need for supplemental purchased protein (Gezahagn *et al*., 2014).

Vetch is a vigorous climbing/sprawling annual legume with a wide range of adaptation and high level of farmer acceptability. It grows well between 1500 and 3000 m altitude and is suited to a wide range of rainfall – typically anything above 400 mm per annum. It is ideally suited to under-sowing, mixed pasture and backyard forage plots and establishes readily, even on rough seedbeds.

On many places natural regeneration from self-sown seed is minimal, necessitating annual sowing. Vetch is most suited to under-sowing and is self-regenerating where it is allowed to mature and seed before harvest of the companion crop. Seed yields between 400 and 1000 kg/ha are common but shattering occurs. Because of this, vetch grown on trellises or tall companion crops such as maize and sorghum are ideal for seed collection (Gezahagn *et al*., 2014).

Species of vetch have different characteristics in terms of growth habit, days to maturity, morphological fractions, and climatic adaptation. In general, growth habit of vetch 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. This shows that the different vetch species and their accessions need to be assessed for the nutritional quality differences under the different soil types and climatic conditions (Gezahagn *et al.*, 2014).

Vetches are annual, moderate stem strength and grow as small bushes. The vetch species growth habit can be broadly grouped as erect, creeping or climbing. *Vicia sativa* is known as common vetch and it is fast growing annual erect growth habit legume had about 87.1 -102.6 cm of plant height. *Vicia dasycarpa* (Smooth vetch) also annual legume and have creeping or climbing growth habit about the range of 151.6 - 167 cm tall at the forage harvest and they varies based on locations (Gezahagn *et al.*, 2013). It can grow where the annual rainfall of 300-750 mm adapted to a range of soil types from sandy loams to clays of moderate fertility. Prefers neutral to alkaline soils and temperature range of 10-35^{o}C. Can be grown in mixtures with annual ryegrass, volunteer cereals or sown cereals for grass/legume pasture or hay produ ction, and with a range of summer growing grasses in the subtropics.

Vetches are potentially adapted to most areas of highland. Farmers perceive vetches as a reliable, versatile legume for pasture, green manure, hay/silage and grain. Vetch fixes atmospheric nitrogen in the soil; this is beneficial for subsequent cereal crops in both yield and quality. Vetches in crop rotations can be used to manage cereal diseases, grass weeds, improve soil fertility and contribute to increased yield and protein content in following crops. They adapted to a range of soils but not acidic or poorly-drained soils, Restores soil fertility and good for fallows and Combines well for intercropping with cereals, especially oats. According to Gezahagn *et al*. (2013), vetch species which has an erect growth habit is more compatible with small cereals in intercropping/under-sowing systems while creeping or climbing growth habit has better compatibility with large cereals in intercropping/under-sowing systems.

Vetch is one of the important legumes used for fodder production. Vetches (*Vicia sativa* and *Vicia dasycarpa*) are an annual pasture/forage/grain legume, extremely palatable at all growth stages, from early green shoots, as dry matter/hay or silage through to seedpods and seeds over summer. It has very high feed values for animals as green plants and dry matter as well as grain. Vetch species are palatable for grazing and for hay or cut and carry and high nutritive value. The nutritive and feeding values of vetch as a green plant and hay are very satisfactory for ruminants. Dry matter (DM), dry matter digestibility (DMD), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and water-soluble carbohydrate, are inferior to the green plant stage. As the plant matures, dry matter yield, leafiness and crude protein decreases and NDF and ADF increase. Just before flowering the nutritive value of vetches is at its best. For hay/silage the best time to cut vetches is at the flowering-early podding stage. At this stage the balance between feed value and yield is the best. In crop mixtures with cereals or rye grass varieties of these crops have to be chosen to mature at the same time as the vetch crop.

2.3. Benefits of Grass-Legume intercropping System

A major benefit of intercropping is increase in production per unit area compared to sole cropping through the effective use of resources, including water, nutrients and solar energy (Nasri *et al.*, 2014). Also, Sachan and Uttam (1992) realized that legumes planted/ intercropped with the other crops are preferred to sole cropping as a result of superior yield due to better absorption of resources, and that improves soil fertility due to increased nitrogen fixation (Manna *et al.,* 2003). Intercropping systems have some of the potential benefits such as high productivity and profitability (Lithourgidis *et al.,* 2011), improvement of soil fertility through the addition of nitrogen by fixation and excretion from the component legume (Ghosh, 2004), efficient use of resources, reducing damage caused by pests, diseases and weeds (Ross *et al.,* 2005), control of legume root parasite infections (Dhima *et al.,* 2007), provides better lodging resistance (Getnet and Ledin, 2001), yield stability, and improvement of forage quality through the complementary effects of two or more crops grown simultaneously on the same area of land (Lithourgidis and Dordas, 2010).

Forage grasses or cereals are commonly grown with legumes in a mixture because of their ability to increase the herbage yield and to produce forage with more balanced nutrition for livestock feeding (Koc *et al.,* 2013). Legumes are a good source of protein and can be used to compensate cereal or grass protein shortage (Eskandari *et al.,* 2009) and incorporating them into an intercropping system could be of paramount importance for the nutritive value of forage (Nadeem *et al.,* 2010). Thus, growing of plant mixtures with legumes, which is referred to as intercropping, can boost the forage protein content of ruminant diets. Another advantage of grass-legume intercropping is that nitrogen (N) can be transferred from the legume into the soil; hence, grasses can use it during their growth (Mariotti *et al.,* 2009).

When a pure grass pasture is grown without a legume complement, it eventually suffers yield losses through N depletion. Conversely pure stand legume pasture fixes excess N of its requirement exposes the plant for insects attracts and non-legume weeds or grasses invasion (Lemma *et al.,* 1991). A sustainable fodder grass and legume mixture can address these constraints, because compared to a pure grass stand, grass and legume mixtures have the potential to produce higher total dry matter yield with better herbage quality through suppressing weed growth and improving soil fertility (Mureithi and Thrope, 1996). Samuel *et al.* (2015) study result indicated, intercropping Napier grass with herbaceous legumes has significant advantage than growing Napier grass solely in increasing the DM yield harvested. Ibrahim (2005) stated forage intercropping between grasses and legumes increase yield, improve growth, produce palatability, supply the soil with nitrogen by legumes, make a better soil coverage and Keep it from erosion, compete weeds, attained a balanced and highly nutritive feeding to animals and decrease animals bloats.

2.3.1. Effect of Intercropping Legumes on Dry Matter Yield of Grasses

Grass-legume combination plays a key role in higher dry matter productivity. Herbaceous legumes can give high yield when intercropped with grass; and those that are compatible to be intercropped with grass and give high yield. The biomass yield of Napier grass can be affected by intercropping with legumes. According to Taye *et al*. (2007) reports there is an increment of biomass in Napier grass/lablab association. Higher DM yield was obtained from mixtures of 75%:25% oat variety (SRCP 80 Ab 2291) - vetch variety (*Vicia dasycarpa* lana) mixed stand than pure oat and vetch varieties (Fantahun, 2017). Ross *et al*. (2004) reported that forage yield of oat-berseem clover intercrops was 50–100% higher than yields of pure berseem clover under two-cut harvesting in Montana. Caballero *et al*. (1995) showed yields of oats-vetch mixtures to be higher by 34% higher than pure vetch.

Gulwa *et al.* (2017) reported that legume intercropping had an effect on forage DMY and the grass-legume mixture produced more dry matter yield in comparison with the grass only. Forage legumes monoculture has many issues with herbage productivity for the reasons that they yield less. Sima *et al.* (2010) reported that higher yield of forage were recorded from polyculture (grass-legume mixture) over grass and legume monocultures respectively. The basic reason for higher forage herbage productivity might be due to the utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay and Walker, 1989) and allelopathic (Putnam and Duke, 1978) and some other effects. These factors created a micro-environment that favored higher yields than those obtained from sole legume or grass stands (Sengul, 2003). Besides, legumes can cover the N demand of grasses from atmospheric N_2 and therefore legumes intercropped with grasses compete for less for soil mineral nitrogen.

2.3.2. Effect of Intercropping Legumes on Nutritive Value of Grasses

Leguminous forage crops can improve the utilization of low quality roughages and they are being used more extensively throughout the world. In various production systems legumes are capable of enhancing both crop production through sustained soil fertility and livestock production through increased availability of high quality feed (Getnet and Lendin, 2001). Legumes provide proteins that grasses lack and increase dry matter yield by fixing atmospheric nitrogen and converting it into a soluble inorganic form that can be absorbed into plant tissues.

High quality forage has high digestibility, low fiber content and high concentration of protein (McDonald *et al.*, 2002). Legumes have higher nutritive value than grass species so growing mixtures of grasses and legumes can improve forage quality compared to grass monocultures (Zemenchik *et al.*, 2002). Eskandari *et al*. (2009) reported that grasses grown in intercropping with legumes contained a higher CP content than grasses harvested from the monoculture planted. This suggests that legumes grown alongside non-legume plants increase the N uptake of the companion plants by partitioning the atmospheric fixed N by legumes to the non – nitrogen fixing plants grown in association with them. Ojo *et al*. (2013) also reported higher CP levels on *Panicum maximum* intercropped with *Lablab purpureus*. Significant effects of Napier Grass/ Lablab associations and their interactions was observed on crude protein yield (CPY), *in vitro* organic matter digestibility (IVOMD), content of CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ash and hemicelluloses (Taye *et al.*, 2007). Maize and cowpea intercrops gave higher total forage dry matter digestibility than maize or cowpea sole crops and led to increased forage quality (crude protein and dry matter digestibility concentration) than maize monoculture and higher water soluble carbohydrate concentrations than sole cowpea (Dahmardeh *et al.,* 2009).

Crude protein content is one of the very important criteria in forage quality evaluation (Lithourgidis *et al*., 2006). Legume intercropping with grasses affects CP content of the grass as compared to the sole grass. The sole lablab and their association with Napier grass had significantly higher CP content than Napier grass sole (Taye *et al*., 2007). According to Rahetlah *et al.* (2010), the mean crude protein (CP) content increased 6.3% in 50:50 Oat-Vetch mixture and 4.6% in 50:75 Oat-Vetch mixture compared with pure stand of oat. Wagner (1954) reported that legumes exert a beneficial effect by increasing the protein content of the non-legume component of the mixture.

The digestibility of forage in the rumen is related to the proportion and extent of lignifications (Van Soest, 1994). Herbaceous legume contributes high digestible organic matter yield for grasses. Grass/legume association resulted in a significantly higher DOMY than that of the sole grass. According to Taye *et al.* (2007), Napier grass/lablab association resulted in a significantly higher DOMY than Napier grass sole at cutting days of 90 and 120. This indicates that there may be possibility of increasing the DOMY content of Napier grass by intercropping with *Lablab purpureus*.

Roughage diets with NDF content of 45-65 and below 45% were generally considered as medium and high quality feeds, respectively (Singh and Oosting, 1992). According to Taye *et al.* (2007), the NDF contents of lablab sole and Napier grass/lablab, associations could be considered within the medium quality range. Napier grass sole contained higher NDF than in association with lablab. The lower NDF content in Napier grass/legume associations as compared to Napier grass sole indicated improvement in nutritive value, since decrease in NDF content has been associated with increase in digestibility and hence feed intake (Van Soest, 1994; McDonald *et al.*, 2002). According to Fantahun (2017), reported that higher NDF and ADF content was observed in oat and increasing seed proportion of oat in the mixture of vetch compared to sole vetch. This is due to the fact that grasses contain higher concentrations of NDF and ADF than legumes.

Association of Napier grass with lablab could be of an advantage in reducing ADF content of forage only when it is accompanied with early utilization of the biomass. According to Taye *et al.* (2007), ADL content was higher in the lablab compared to Napier grass and this caused an increase in ADL content in the association of Napier grass with the legumes at 90 and 120 days of cutting. This result was as expected due to higher content of ADL in tropical legumes than in tropical grass species (Van Soest, 1994).

Grass with legume intercropping resulted in increased IVOMD and decreased cell wall fiber contents, thus improving the nutritive value of the forages arising thereof compared to the sole grass. The increase in digestibility may also result in increased feed intake as digestibility and feed intake are positively correlated (Van Soest, 1994). The IVOMD at 90 days of cutting for Napier grass/lablab association could be considered as high nutritive value since their IVOMD were above the minimum value of 65% to qualify forages to be of high nutritive value (Moore and Mott, 1973). The forages below this level of IVOMD content may result in reduced feed intake due to lower digestibility. It is indicated that the association of Napier grass with lablab to be a better option to develop the grass/legume mixture (Taye *et al.*, 2007).

2.4. Role of Legumes on Biological Nitrogen Fixation

Biological nitrogen fixation (BNF) is a natural process in which atmospheric or the biological reduction of dinitrogen gas (N_2) is converted in to ammonia or it is the process in which nitrogen gas (N_2) from the atmosphere is incorporated into the tissue of legume plants, with the help of soil microorganisms. It is important for smallholder farmers as it is relatively cheaper source of N compared to inorganic fertilizers, less prone to losses through leaching and denitrification (Mhango *et al.*, 2017). The ability of legumes to fix N_2 and its ability to produce nodules; has brought about its importance and uniqueness (Wilcox and Shibles, 2001).

Legumes are unique for their ability to fix nitrogen from atmosphere by symbiotic relationship with *Rhizobium* bacteria (Giller, 2001). Rhizobia require a plant host; therefore, they cannot independently fix nitrogen. These bacteria are located around root hair and fix atmospheric nitrogen using particular enzyme called nitrogenase (Coskan and Dogan, 2011). When this mutualistic symbiosis is established, rhizobia can use plant resources for their own reproduction whereas fixed atmospheric nitrogen is used to meet nitrogen requirement of both itself and the host plants. Supply of nitrogen through biological nitrogen fixation has ecological and economical benefits (Ndakidemi *et al.,* 2006). BNF offers an economically attractive and ecologically sound means of improving crop yield, reducing external N inputs and enhancing the quality of soil resources which consequently reduce the dependence on mineral fertilizers that could be costly and unavailable to smallholder farmers (Massawe *et al.,* 2016).

The use of legumes is a promising option of increasing yields, profits and nutrition for smallholder farmers in sub-Saharan Africa (SSA), especially in areas where soil nutrient availability is low. They increase soil fertility due their ability to establish symbiotic associations with soil microorganisms, known as rhizobia, capable of fixing nitrogen from the atmosphere (Ahmad *et al.,* 2013; Mhango *et al.,* 2017).

Inclusion of forage legumes in the form of intercropping in low-input grassland mixtures improves forage quantity, quality and soil fertility through addition of nitrogen (N) from N_2-fixation. Intercropping is a multiple cropping practice, which involves growing two or more crops in proximity. Legumes also improve the nutritive value of the low quality native pastures grown with them and are important component of farming system since they have high nutritive value and able to rehabilitate nutrient depleted soil. There are various factors affecting legume growth and development and these factors need to be taken into account when planning to grow legumes. The improvement of forage quantity and quality through forage legume inclusion is crucial for improved animal performance, which is a goal of all livestock farmers. Forage legumes have the potential to improve the diets of ruminants because they increase the crude protein (CP) concentration of the herbage mixture relative to that of grass monocultures.

Nitrogen (N) is limiting crop production of many agricultural soils, and N addition is needed to increase yields and sustain food production. Returning to cultivation of leguminous plants, able to fix atmospheric dinitrogen by means of symbiosis with Rhizobium (biological nitrogen fixation – BNF), may be an alternative solution to enrich soil with nitrogen (Crews and Peoples, 2004).

Among legumes, Vetches have the major advantages in the dry land cropping system in providing an influx of combined nitrogen through their symbiotic nitrogen fixation. There are factors associated with the genotype of the host (legumes) and the symbiont (nodule bacteria), and their interaction, that determine the magnitude of nitrogen fixation. Vetches species biologically fixed nitrogen was ranged from 29 to 91 kg/ha. Of vetch species *Vicia sativa* biologically fixed nitrogen 51 – 80 kg/ha whereas *Vicia dasycarpa* biologically fixed nitrogen 54 – 90 kg/ha (Moneim and Saxena, 2015). N-fixation by nodulated forage legumes is fundamental for the economic and environmental sustainability of mixed farming systems in Ethiopia. The quantity of N fixed by forage legumes differ widely between species and environments (Unkovich and Pate, 2000). The quantity of N-fixed by *Vicia dasycarpa* species was 163 kg/ha under Ethiopian conditions (Haque and Lupwayi, 2000). Sattell *et al*. (1998) noted common vetch (*Vicia sativa*) can fix up to 50 to 120 lb/acre N (56 to 134.5 kg/ha N).

2.5. Effect of Spacing on Biomass Yield and Nutritive Value of forages

Plant density affects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. Use of proper agronomic practices is one of the important factors which contribute for the increase of yield per unit area. Among that practice arrangement of plant in row or plant density in the given farm is one of the essential agronomic practices as it is a major management variable used in matching crop requirements to the environmental offer of resources.

Spacing has significant effect on number of tiller per plant and dry matter production of the *desho* grass i.e. as planting space increases the number of tillers per plant increase. Hence, as increase in number of tillers per plants there will be increase in biomass yield (Worku *et al.*, 2017). According to Sumran *et al*. (2009), row/plant spacing did have effect on crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter digestibility and total dry matter yields. Bagci (2010) reported that the herbage quality increased gradually depending on the rising row spacing, a significant decreasing was determined from the forage yield at narrower row spacing. Tilahun *et al.* (2017) reported that the number of plant tiller was higher in wider plant and row spacing. Heliso *et al.* (2019) reported that wider spacing produces higher dry matter yield per clump 26.61 t/ha at plant: row spacing of 75:100 cm and the lower was 14.09 t/ha at plant: row spacing of 25:50 cm because at wider spacing, light can easily penetrate to the base of the plant, competition for nutrients is less and this may have stimulated and support more tiller development.

With regard to row spacing and forage production, both narrow and wide row spacing have implications for different aspects of forage production (Rao, 1986) as the number of plants per unit area is the primary source of competition. Generally, narrow row/plant spacing suppresses the emergence of various weeds, but additional planting material is required. When density is maintained above optimum, there will be greater total demand for resources that results in stress in the plants (Trenbath, 1986). Wider row/plant spacing requires less planting material and enables greater tillering capacity in forage grasses but the probability of weed invasion increases and may lead to extra cost of weeding.

A higher level of NDF and ADL was resulted from increases of row/plant spaces. While increase in stem percentage and increased lignification with maturity would account for the age effects, the increases with wider plant spacing would possibly reflect larger tiller development in the wider-spaced plants (Tilahun *et al.*, 2017). Tessema *et al.* (2002) and Taye *et al.* (2007) reported that the predominant features of increasing plant density or narrow spacing were a marked reduction in leaf: stem ratio, which in turn resulted in an increase in cell wall and lignin concentrations in Napier grass.

2.6. Compatibility and Yield Advantages of intercropped cultivars

Many concepts have been developed to assess yield advantages as a result of the divergent production goals of different intercropping systems which include land equivalent ratio (LER) and relative yield total (Willey, 1990). A yield advantage of intercropping can be indicated by using different methods, among which LER is the most commonly used to indicate the biological efficiency and yield per unit area of land as compared to mono-cropping system; an LER greater than 1.0 implies that for that particular crop combination, intercropping yielded more than growing the same number of stands of each crop as sole crops and when LER = 1 there is no advantage or disadvantage of the intercropping in respect to sole crop. An LER of less than 1.0 implies that intercropping was less beneficial than sole cropping (Onwueme and Sinha, 1991).

Land equivalent ratio determines the competitiveness of grass and legumes intercropping / mixed cropping, i.e., indicative of competitive relationship between the species. It is the relative land area under sole crops that is required to produce the yields achieved in intercropping. When LER is compared at uniform overall plant density of the sole and intercrops then it is known as Relative Yield Total (RYT). The calculated figure is called the Land Equivalent Ratio (LER), where intercrop yields are divided by the pure stand yields for each crop in the intercropping system and the two figures added together (Willey and Rao, 1980).

$$LER = \frac{\text{Intercropped } \textit{Desho} \text{ Grass}}{\text{Sole } \textit{Desho} \text{ grass}} + \frac{\text{Intercropped Vetch}}{\text{Sole Vetch}}$$

Yield advantages from intercropping, as compared to sole cropping, are often attributed to mutual complementary effects of component crops, such as better total use of available resources. Generally, monoculture legumes have higher yields compared to yields in an intercropping system. LER gives an indication of magnitude of sole cropping required to produce the same yield on a unit of intercropped land and research results indicate that response of N to intercropping generally results in reduced LER values. In a maize-vetches intercropping system, Dawit and Nebi (2017) reported LER of the dry matter yield varied from 1.33 to 1.51 that intercropping under different agro-ecologies and there were greater than 1.0 which indicated as advantage of intercropping over sole crops because of the ability of legumes to fix atmospheric N. Hence intercropping is most important to increase and diverse productivity per unit area as compared to sole cropping.

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 Van der Bergh (1965) as a relative yield total (RYT). RYT describes the resource complementarities between species in a binary mixture (De Wit and Van der Bergh, 1965). The value assumed by this indicates whether the species are performing better in a mixture than in monoculture. RYT equal to one represents the situation where there is no yield advantage in mixed cropping. RYT greater than one the two species are, at least, partly complementary in resource use and there is a biological advantage in mixed cropping. RYT less than one in such instances allopathic effects exist to the extent that one species poison the other. In this case the yield of the dominated species is highly reduced.

In addition to the RYT concept, there are also a number of "competition functions" to describe competitive relationships and which give some indication of yield advantages. These have been developed to study plant competition and also have been tried in the analysis of intercropping experiments. They include the Competitive ratio (Willey and Rao, 1980) and the Aggressivity (Mc Gilchrist, 1965). The numerical value of the aggressivity of both species is the same but the sign of the dominant species is positive and that of the dominated negative; the greater the numerical value the bigger the difference in competitive abilities.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted during the main cropping season in 2019 at Haro Sabu Agricultural Research Center (HSARC), Mata Research Sub-Site, which is located in Western Oromia, Ethiopia, at 648 km far away from Finfine or Addis Ababa, capital city of Ethiopia. The area is located at 8°53'33"N latitude and 34°80'11"E longitude with an altitude of 1900 meters above sea level. It has a sub-humid climate with average minimum and maximum annual temperatures of 16.21 and 27.77°C, respectively. The area receives an average annual rainfall of 1219.15 mm. The relative humidity is 67.5 %. Soil types are classified as about 90% loam, 6% sand and 4% clay soil (Sayo Agriculture and Natural Resource office, Dembi Dollo, Unpublished).

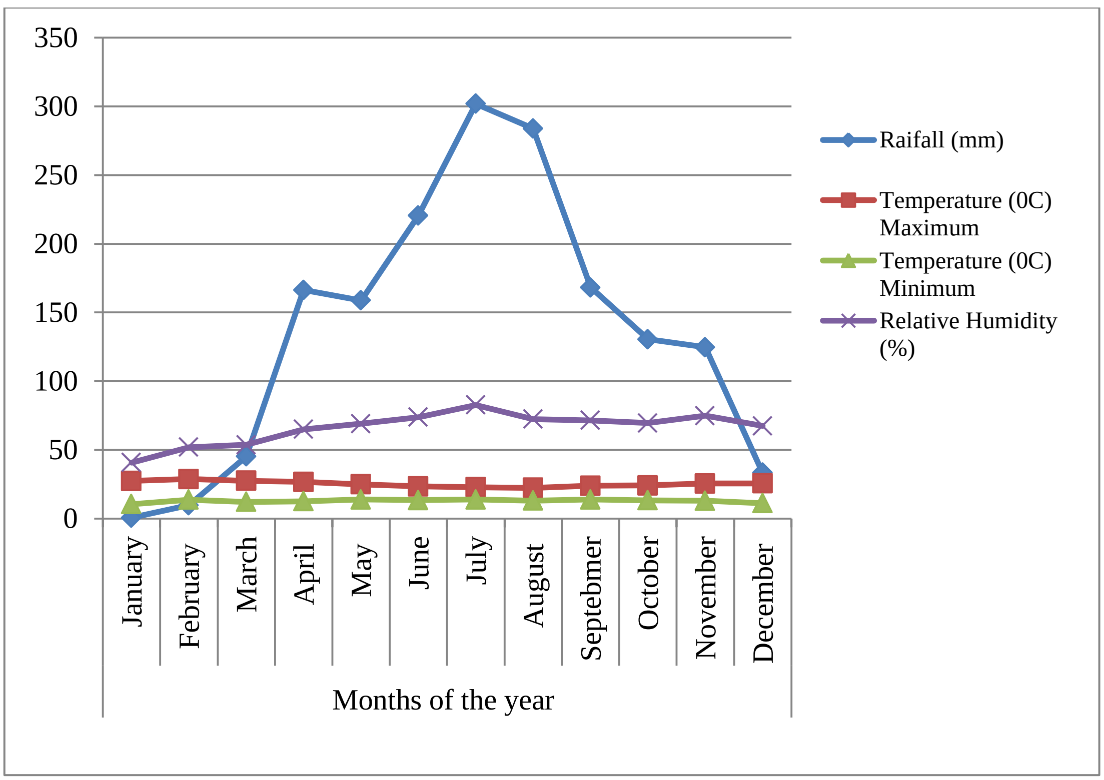


Figure 1. Agro-morphological data of the study area during the experiment year (2019)

Source: Gambella Meteorological Agency (2019)

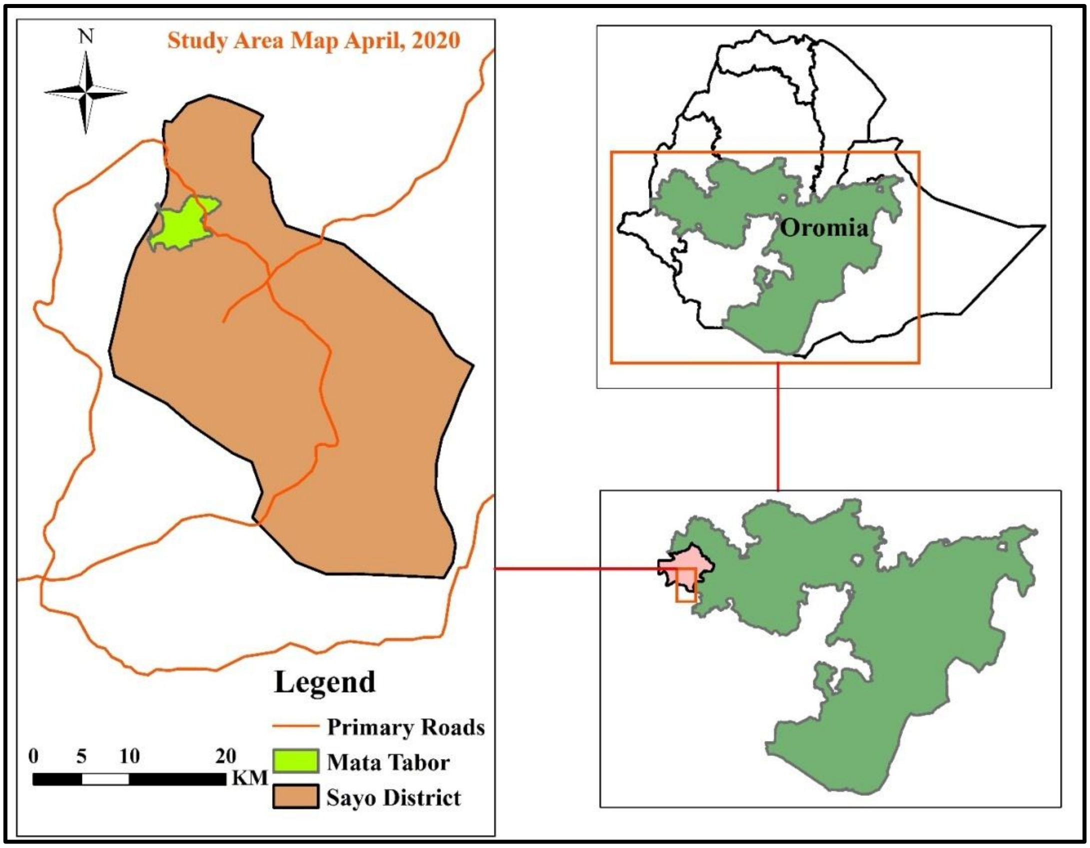


Figure 2. Map of Mata Tabor of Sayo District in Oromia region, Ethiopia, where the field experiment was conducted

3.2. Land Preparation and Planting

Land was ploughed and harrowed with oxen and then hoed to make the soil fine. A fine seedbed plots were prepared before the experimental plots were laid out. Fertilizer was applied at the rate of 100 kg/ha of Di-ammonium phosphate (DAP) during establishment (planting) for all experimental units (Leta *et al*., 2013). *Desho* grass and vetches were planted and sown in rows using root splits and seeds respectively on well prepared soil. Weeding was done by hand and eliminated the regrowth of undesirable plants and promoted the fodder grass growth by increasing soil aerations. The plots were kept weed free throughout the growth period (Orodho, 2006).

3.3. Experimental Design and Treatments

The experimental design was a factorial arrangement in randomized complete block design (RCBD) consisting of three inter and intra spacing of *desho* grass, 0.50 m x 0.25 m, 0.75 m x

0.25 m and 1 m x 0.25 m with and without two vetches species intercropped between the rows of *desho* grass and sole vetch species with 0.3 m row spacing. The experiment consists of three blocks; each block contains eleven experimental units (plots) which make thirty three plots in total with 3 m x 4 m in each plot. The distance (space) between plots and blocks (replications) were 1 m and 1.5 m respectively. Plots in each block were randomly assigned to the eleven treatments by using the SAS software randomization. For eleven treatments, a total area of land with 645 m^2 was prepared for sowing.

The planting material was recently released *desho* grass (Kulumsa-DZ-592) and vetch species (*Vicia sativa* ICARDA 61509 *and Vicia dasycarpa* lana), which were adapted in Haro Sabu Agricultural Research Center. *Desho* grass was planted by vegetative root splits with the space between plants having 0.25 m according to the recommendations (Worku *et al*., 2017). The seeds of vetch species were sown by drilling method in between the rows of *desho* grass and sole at a seeding rate of 30 kg/ha for *Vicia sativa* ICARDA 61509 and 25 kg/ha for *Vicia dasycarpa* lana (Gezahagn *et al.*, 2013). The vetch species were sown after two weeks of planting the grass based on the recommendation (Alemu, 2016). The treatments arrangements are indicated in Table 1.

Table 1. Treatment arrangements for row spacing and forage plants

Treatments	Row spacing (m)	Plants intercropped
T1	0.50	Sole *Desho* grass (Kulumsa-DZF-592)
T2	0.50	*Desho* grass (Kulumsa-DZF- 592) + *Vicia*sativa ICARDA 61509
T3	0.75	*Desho* grass (Kulumsa-DZF-592) + *Vicia sativa* ICARDA 61509
T4	1	*Desho* grass (Kulumsa-DZF-592) +*Vicia sativa* ICARDA 61509
T5	0.75	Sole *Desho* grass (Kulumsa-DZF-592)
T6	0.50	*Desho* grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana
T7	0.75	*Desho* grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana
T8	1	*Desho* grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana
T9	1	Sole *Desho* grass (Kulumsa-DZF-592)
T10	0.30	Sole *Vicia sativa* ICARDA 61509
T11	0.30	Sole *Vicia Dasycarpa* lana

DZF= Debrezeit forage; ICARDA= International Center for Agricultural Research in the Dry Areas

3.4. Data Collection Procedures

3.4.1. Soil Sample Collection Procedure

Composite soil samples for each treatment from surface soils were collected in replications before forage planting as well as at the end of the experiment following 'Zigzag' method where a conscious effort was made to force the path in to corners and along edges as well as the central parts of the site by using auger (Ryan, 2017). From each plots, five representative surfaces (in each corner and center of plot) of the experimental field soil samples were collected diagonally at a depth of 15 - 20 cm by using auger after forage harvesting.

3.4.2. Soil Analysis Procedure

The collected soil sample from the field was dried in open air. After drying, the subsample serve for laboratory sample was weighed, grounded and passed through a 2 mm sieve after a careful removal of plant parts and other unwanted materials and then milled to pass through 0.2 mm sieve for Nitrogen, soil pH, organic carbon, available phosphorus, organic matter, cation exchange capacity (CEC) and soil particle size distribution (soil texture) determination (Van Reeuwijk, 2002). Soil samples were analyzed at National Soil Testing Research Center Laboratory. The soil pH was measured with digital pH meter potential metrically in supernatant suspension of 1:2.5 soils to distilled water. Organic carbon content of the soil was determined following wet combustion procedure/digestion method as described by (Walkley and Black, 1934) and Organic matter percentage was obtained by multiplying % OC by 1.724. Cation exchange capacity (CEC) was analyzed by ammonium acetate. The available phosphorus was measured by shaking the soil samples with extracting solutions of 0.03 mole ammonium fluorides in 0.1 mole hydrochloric acid by using Oslen II methods (Oslen, 1954).

3.4.3. Agronomic Parameters

For *desho* grass, the per plot agronomic parameters like number of tillers per plant, number of leaves per plant, number of leaves per tiller were counted and plant height and leaf length were measured by using measuring tape and meter stick from five plants that were randomly selected from the middle rows of each plot at 80 days after planting and optimum forage harvesting stage (120 days) (Leta *et al*., 2013; Asmare *et al.*, 2017; MoALR, 2017). In the same way, the per plot agronomic parameters of legumes (vetches) were counted and measured selected from the middle rows of each plot at forage harvesting stage (10% of flowering stage) based on continuous visual observation (Aklilu and Alemayehu, 2007). The plants were randomly selected in the middle rows of each plot to avoid edges or border effect. The leaf to stem ratio of *desho* grass was determined at the optimum harvesting stage by cutting plants from randomly selected inner rows, separated in to leaves and stems, dried and weighed.

3.4.4. Biomass Yield Determination

Total forage herbage per plot of *desho* grass and that of the leguminous forages were harvested at 120 days (optimum harvesting stage) (Leta *et al*., 2013; Asmare *et al.*, 2017; MoALR, 2017) and 10% of flowering stage based on continuous visual observation (Aklilu and Alemayehu, 2007), respectively. Accordingly, harvesting was done by hand using a sickle, leaving a stubble height of 8 cm above the ground and the harvested green forages were separated in to grass and legume components. The fresh weight was immediately recorded in the field by using a top holding field balance scale. Fresh subsamples were taken from each plot and each forage species separately, weighted and then chopped into short length of 2-5 cm for dry matter determination. Then the weights of fresh samples were oven dried at 65 ^{o}C for 72 hours and the dry weight was recorded to estimate the dry matter production. The dry matter production is calculated as

$\mathrm{DMY}\ (\mathrm{t} / \mathrm{ha}) = 10 * \mathrm{TFW} * (\mathrm{DWSs}/(\mathrm{HA} * \mathrm{FWSs}))$ (Tarawali, 1995), where;

TFW: Total Fresh Weight from plot in kg

DWSs: Dry Weight of the Subsample in grams

HA: Harvested Area (meter square)

FWSs: Fresh Weight of the Subsample in grams

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

Crude protein yield was determined by multiplication of dry matter yield with crude protein content of the feed samples. Besides, a chopped and oven dried at 65 ^{o}C for 72 hours of adequate quantity of forage sub-samples of each plot was prepared and saved/stored in airtight bags to be used for chemical analyses.

3.4.5. Seed yield of vetches species

The inner rows of each plot intercropped with grass at different row spacing and sole sown of the two vetch species were maintained for seed yield determination. The plants were harvested at ground level at the optimum seed harvesting time and total seed yield was determined from inner rows after threshing and winnowing. Seed samples were taken and oven dried at 100 °C for 48 hours to adjust moisture content of 10%, a recommended percentage level for legumes (Biru, 1979). Seed yield (t/ha) was then calculated at 10% moisture content.

$$\text{Seed yield (t/ha)} = \frac{\text{quantity of seeds harvested (t)}}{\text{Plot area } (m^2)} \times 10$$

3.4.6. Chemical Composition Analysis

From each plot samples of *desho* grass, composite sample of each vetch species intercropping at various row spacing and sole vetch species were taken and dried in a forced draft oven at 65 ^{o}C for 72 hours and ground using Wiley mill to pass through a 1mm sieve screens for chemical analysis. The AOAC (1990) procedure was used for the determination of DM, Ash and nitrogen. The DM content was determined by oven drying at 65 ^{o}C for 72 hours. Ash was determined by complete burning of the feed samples in a muffle furnace at 600 ^{0}C overnight according to the procedure of AOAC (1990). The residue after burning in a muffle furnace was recorded as the ash component. The Organic matter was determined by subtracting the ash component from 100. Total nitrogen (N) was determined by the Kjeldhal procedure (AOAC, 1990). Crude protein (CP) was calculated as nitrogen (N) x 6.25. The structural plant constituents such as neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed using the detergent extraction method (Van Seost *et al.*, 1991). Hemi cellulose was calculated as the subtraction of ADF from NDF content, though cellulose was calculated by subtracting the ADL from ADF content. The chemical analysis was undertaken at Jimma University College of Agriculture and Veterinary Medicine of Animal nutrition and Post harvest analytical laboratory.

3.4.7. *In vitro* digestibility determination

All samples used in chemical analysis were taken for *in vitro* dry matter digestibility (IVDMD). The two-stage rumen inoculates pepsin method of Tilley and Terry (1963) was used to determine IVDMD. Rumen liquor was collected from three rumen fistulated steers and then transported to the laboratory using thermos flask that have been pre-warmed to 39 ^{o}C. Rumen liquor was taken at the morning before animals were offered the feed. A duplicate sample of about 0.5 g each was incubated with 30 ml of rumen liquor in 100 ml test tube in water bath at 39 ^{o}C for a period of 48 hour for microbial digestion. This was followed by another 48 hour for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid only was also incubated in duplicates for adjustment. Drying of sample residues were done at 60 ^{o}C for 72 hours. The samples were then ashed to estimate *In vitro* OM digestibility (IVOMD). The *In vitro* dry matter digestibility *(*IVDMD) and *In vitro* OM digestibility (IVOMD) analysis were undertaken at Holeta Agricultural Research Center animal feed analytical laboratory.

IVDMD was calculated (Jeans and Yolande, 2007) as:

$$\frac{\text{Dry sample weight - (Residue - blank)} \times 100}{\text{Dry sample weight}}$$

In vitro OM digestibility was calculated as:

$$\frac{\text{OM in the feed – (OM in residue – blank)} \times 100}{\text{OM in the feed}}$$

Where OM = DM- Ash (measure after ignition of feed or residue)

The Metabolizable Energy (ME) content was estimated from IVOMD using the equation:

$$\text{ME (MJ kg}^{-1}\text{ DM)} = 0.15 * \text{IVOMD}$$ (Pinkerton, 2005)

3.4.8. Biological Compatibility

Land equivalent ratio (LER)

The LER was defined as the amount of land required under monoculture to obtain the same dry matter yield as produced in the intercrop. It was calculated according to the equation proposed by Ghosh *et al.* (2006) as follows:

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

Where, Yaa = sole crop yield of species 'a'; Ybb = sole crop yield of species 'b'; Yab = inter crop yield of species 'a' in combination with species 'b' and Yba = inter crop yield of species 'b' in combination with species 'a'.

Relative yield (RY) and Relative yield total (RYT)

The relative yields (RY) of the components in the mixtures were calculated using the equations of Ghosh *et al.* (2006)

RYd = DMYdL/DMYdd

RYL = DMYLd/DMYLL

RTYGL = (DMYdL/DMYdd) + (DMYLd/DMYLL)

Where;

DMYdd and DMYLL are the dry matter yields of *desho* grass and vetches as a monoculture, respectively; DMYdL and DMYLd are the dry matter yields of *desho* grass and vetches in intercropped, respectively. It shows that If RTYdL > 1, there is yield advantage of mixtures compared to the pure stand.

Competitive Ratio

Competitive ratio is used to assess competition between different species. The CR gives a better measure of competitive ability of the crops. The CR represents simply the ratio of individual LERs of the two component crops. It is indicator of competitiveness and was calculated according to the following formula of Willey and Rao (1980):

CRdL = (DMYdL/DMYdd) / (DMYLd/DMYLL)

CRLd = (DMYLd/DMYLL) / (DMYdL/DMYdd)

DMYdd and DMYLL are the dry matter yields of *desho* grass and vetches as a monoculture, respectively; DMYdL and DMYLd are the dry matter yields of *desho* grass and vetches in intercropped, respectively.

Aggressivity

Aggressivity shows the degree of dominance of one crop over the other when sown together. Aggressivity value was calculated by the formula proposed by Mc Gilchrist (1965) and Trenbath (1986):

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

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

DMYdd and DMYLL are the dry matter yields of *desho* grass and vetches as a monoculture, respectively; DMYdL and DMYLd are the dry matter yields of *desho* grass and vetches in intercropped, respectively.

3.5. Statistical Analysis

Data were subjected to ANOVA procedure by using the General Linear Model (GLM) of SAS software (SAS, 2009 version 9.3). Significantly different treatment means were separated and compared using Least Significant Difference (LSD) test at 5 % significant level or 95 % of confidence interval. The statistical model for analysis of data was:

$$Y_{ijk} = \mu + V_i + R_j + (V * R)_{ij} + \varepsilon_{ijk}, \text{ where;}$$

Y_{ijk} = Response (dependent) variable of ijk^{th}

μ = Overall mean

V_i = i^{th} effect of intercropped variety

R_i = j^{th} effect of row spacing

$V*R_{ij}$ = ij^{th} effect of variety intercropped and row spacing interaction

ε_{ijk} = Random error

Pearson correlation analysis was performed to determine the association between the plant morphological parameters (number of tiller per plant, number of leaves per plant, leaf length, and plant height and leaf stem ratio) with yield and selected chemical composition parameters of the grass.

4. RESULTS AND DISCUSSION

4.1. Characterization of the soil of the study area

4.1.1. Physio-chemical properties of the soil prior to planting and after forage harvesting

The pH and soil chemical analysis results before planting and after forage harvesting are shown in Table 2. The pH value of the soil of the composite sample before planting was 5.5 indicating that the soil was moderately acidic based on the rating suggested by Karltun *et al.* (2013). The available phosphorous in the study area of soil was 7.7 ppm which are rated as low based on classification that categorize a relative range of extractable phosphorous of 0-5 ppm (very low), 6-10 ppm (low), 11-15 ppm (medium), 16-20 ppm (high) and 21-25 ppm (very high) (Waugh, 1973). The soil's organic carbon, organic matter, total nitrogen content of the study area before planting were 3.13%, 5.39% and 0.20% respectively indicating that the soil had medium organic carbon and organic matter, and had high nitrogen content as rated by Tekalign *et al.* (1991). The CEC content of soil of the study area was 40.76 mg/100g, which is rated as high noted by Tekalign *et al.* (1991). The soil of the study area is clay loam with sand, silt and clay in proportion of 31%, 30% and 39%, respectively.

The present results for soil parameters after harvesting of the forage indicates that the pH of the soil after harvest was a bit higher as compared to the values before planting (Table 2). This is because of effect of the planting material. The pH of the soil analyzed after harvesting showed no significance difference for spacing, intercropping and their interaction. As per soil pH rating scale of Tekalign *et al.* (1991) the soil of the study area after forage harvesting can be considered as moderate acid soil.

The available phosphorous (AP) content of the soil after harvest was not significantly affected by intercropping, spacing and their interaction ($P>0.05$). The AP for soil samples after harvest was somewhat lower than the initial soil phosphorous level before planting. Such values of AP are categorized as low as per Tekalign *et al.* (1991). This might be due to the fact that there was more utilization of phosphorous by the grass and/or legume planted. The AP value of the soil after forage harvest was higher for mono crop or sole planted forage at different row spacing. The higher AP value was obtained from sole *desho* grass at 1 m row spacing (T9) whereas the lower was obtained from *desho-Vicia sativa* intercropped at 0.50 m row spacing (T2). This might be attributed to forage annual legumes scavenger have extracted the P in the soil as compared to the grass.

Table 2. Soil fertility (Mean±SE) as influenced by intercropping, spacing and interactions of *desho* grass with vetches before and after forage harvesting

Factors	**pH 1:2.5H_2O**	**AP ppm**	**OC %**	**OM %**	**TN %**	**CEC (mg/100g)**
Before planting	5.5	7.7	3.13	5.39	0.20	40.76
After planting						
Varieties intercropped						
DVS	5.6±0.04	5.90±0.14	3.19±0.04	5.49±0.11	0.256±0.01[a]	41.02±0.58
DVD	5.6±0.04	5.81±0.09	3.17±0.07	5.46±0.13	0.260±0.01[a]	41.32±0.51
SD	5.6±0.05	6.16±0.09	3.11±0.07	5.36±0.07	0.210±0.01[b]	40.33±0.59
SVS	5.7	5.79	3.33	5.74	0.269	43.10
SVD	5.7	5.77	3.35	5.78	0.273	43.39
P-value	0.860	0.156	0.740	0.697	0.0001	0.226
Row spacing (m)						
0.50	5.6±0.03	5.79±0.12	3.19±0.04	5.50±0.11	0.24±0.01	41.42±0.58
0.75	5.6±0.06	5.98±0.11	3.11±0.08	5.37±0.12	0.25±0.01	40.38±0.66
1	5.6±0.04	6.10±0.11	3.16±0.06	5.45±0.10	0.23±0.01	40.87±0.41
P-value	0.860	0.245	0.755	0.697	0.068	0.207
Interaction effect						
DVS * 0.50 m	5.6±0.05	5.65±0.27	3.23±0.02	5.57±0.14	0.28±0.02	43.07±0.79[a]
DVS * 0.75 m	5.7±0.11	5.97±0.24	3.15±0.07	5.43±0.16	0.26±0.02	40.02±0.07[cd]
DVS * 1 m	5.6±0.05	6.07±0.24	3.18±0.11	5.48±0.32	0.23±0.01	39.97±0.60[cd]
DVD * 0.50 m	5.6±0.05	5.69±0.25	3.16±0.11	5.45±0.34	0.24±0.02	40.32±0.64[cd]
DVD * 0.75 m	5.6±0.11	5.80±0.11	3.21±0.20	5.53±0.30	0.28±0.01	42.60±0.94[ab]
DVD * 1 m	5.7±0.05	5.95±0.16	3.14±0.09	5.41±0.10	0.26±0.01	41.04±0.69[abc]
SD * 0.50 m	5.7±0.05	6.03±0.01	3.18±0.02	5.48±0.01	0.21±0.01	40.88±0.95[bc]
SD* 0.75 m	5.6±0.11	6.18±0.19	2.98±0.17	5.14±0.14	0.22±0.01	38.52±0.42[d]
SD * 1 m	5.5±0.05	6.27±0.21	3.17±0.16	5.47±0.09	0.20±0.01	41.60±0.71[abc]
P-value	0.407	0.987	0.841	0.780	0.061	0.0023
CV (%)	2.63	6.29	6.92	6.13	8.11	2.90

[a-d] Means with different letters in a column significantly different (P<0.05). DVS = desho grass intercropped with Vicia sativa ICARDA 61509; DVD = desho grass intercropped with Vicia dasycarpa lana; SD = sole desho grass; SVS=sole Vicia sativa ICARDA 61509; SVD= sole Vicia dasycarpa lana; pH = power of hydrogen; AP = available phosphorous; OC = organic carbon; OM = organic matter; TN = total nitrogen; CEC = cation exchange capacity; m = meter; ppm = parts per million; mg = milligram; g = gram; CV = coefficient of variation.

Effect of intercropping, spacing and their interaction on soil organic carbon content was not significant (P>0.05). However, except sole *desho* grass planted at 0.75 m row spacing, the organic carbon content of the soil was higher for the soil samples taken after harvest as compared to pre planting soil samples. Accordingly, the organic carbon content of all soil samples after harvest in the study area were categorized in the range of medium as per rating criteria set by Tekalign *et al.* (1991). Soil organic matter can help to raise the pH and thereby have soil acidity partly corrected. The OM contents of the soil samples taken after harvest can be categorized in the range of medium. Except sole *desho* grass planted at 0.75 m row spacing (T5), the OC and OM contents of the soil samples taken after harvest was a bit increased as compared to the pre planting soil samples (Table 2).

Total nitrogen is more often deficient than any other essential element in soils in general and acid soils in particular (Abebe, 2007). The TN content of the soil after harvest was not significantly affected by spacing and their interaction (P>0.05), but significantly affected (P<0.05) by intercropping with legumes. Thus, Intercropping of vetches with *desho* grass and pure vetches increased the total nitrogen of the soil as compared to sole planted grass and this might be due to legume fixes atmospheric nitrogen. The values total nitrogen content of the soil increased slightly after harvest compared to pre planting values. In terms of total nitrogen, the soil samples after harvest in the study area can be classified as very high in pure vetches and grass-vetch intercropped system and high in sole grass planted as rated by (Tekalign *et al.*, 1991).

The CEC is the reversible process by which positive ions exchangeable cations are exchanged between the negatively charged soils and the liquid phase of soils (Abebe, 2007). CEC of the soil after harvest was significantly affected by interaction of intercropping and spacing, but not affected by either intercropping or row spacing (Table 2). The highest CEC (43.07 mg/100g) was obtained from *desho* grass intercropped with *Vicia sativa* ICARDA 61509 at 0.50 m row spacing (T2) while the lowest (38.52 mg/100g) was obtained from sole *desho* grass at 0.75 m row spacing (T5). Reduction of CEC values after forage harvest in *desho* grass intercropped with *Vicia sativa* ICARDA 61509 at 0.75 and 1 m row spacing, *desho* grass intercropped with *Vicia dasycarpa* lana at 0.50 m row spacing and sole *desho* grass planted at 0.75 m row spacing was due to utilization of the available nutrient in the soil by the forage.

4.2. Agronomic Performance of *Desho* Grass

The results of effects of intercropping vetch varieties, varying inter-row spacing and their interactions on the agronomic performance of *desho* grass at 80 and 120 days growth stage (forage harvest stage) were presented in Figure 3 - 6 and Table 3. Except for number of tiller per plant, other morphological parameters of *desho* grass were significantly affected (P<0.05) by interaction of intercropping with spacing at forage harvesting stage.

4.2.1. Plant Height

Plant height of *desho* grass was significantly affected (P<0.05) by intercropping, spacing and interaction of intercropping with spacing at forage harvest stage (120 days) (Table 3). *Desho* grass intercropped with both vetch varieties had higher plant height as compared to sole *desho* grass at 80 days growth stage and forage harvest stage (120 days). This might be due to the fact that legumes provide nitrogen through fixation which promotes grass growth. This result is in line with the finding reported by Yegrem *et al.* (2019) who noted that the height of *desho* grass intercropped with *Desmodium intortum* was higher than sole *desho* grass. However, the present result disagrees with the report of Ojo *et al.* (2013) who noted that the plant height of *Panicum maximum* intercropped in *Lablab purpureus* was not significantly different from the sole at 14 weeks after planting. The difference between our results could be attributed to such factors as the type of soil, legume and grass considered, date of harvesting and other management conditions.

With regard to the row spacing, the maximum plant height (57.09 and 105 cm) was recorded from narrow row spacing (0.50 m) whereas minimum height (46.57 and 83.46 cm) was recorded from wider row spacing (1 m) at 80 and 120 dates of growth. This indicated that increasing row spacing affects plant height negatively and a resultant of stem elongation of the internodes. Stickler and Laude, (1960) observed that plant height increased as area per plant decreased and decreased as area per plant and row width increased and this response was attributed to the competition for available light. The present result was supported by the finding of Yasin *et al.* (2003) who reported that narrow row spacing in Napier grass increased interplant competition, causing individual plants to grow taller with longer internodes, plus slender, thin and weak stalks due to poor light exposure and hence poor photosynthetic output.

The interaction of intercropping and spacing showed a significant difference ($P<0.05$) for plant height at 80 and 120 days of growth stage. Relatively, within the interaction of spacing and intercropping at 80 days of growth stage the highest *desho* grass height of 65.27 cm was obtained from the grass intercropped with *Vicia dasycarpa* lana at 0.50 m space (T6) followed by similar variety intercropped at 0.75 m space (63.07 cm) (T7) as compared to sole *desho* grass planted at the three different row spaces. This result could probably due to the effect of etiolate (shading) of climbing habit of *Vicia dasycarpa* lana had less effect at this age stage (Figure 3).

Higher *desho* grass heights of 114.4 cm and 104.67 cm were obtained when intercropped with *Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana at narrow row spacing (0.50 m) (T2 and T6), respectively as compared to other treatment interactions. However, lowest height (81.73 cm) was recorded from sole *desho* grass planted at wider row spacing (1 m) (T9). The intercropping of grass and legumes improved the plant height of the grass which could be attributed to the nitrogen fixation by the legumes that became available to the grass as well (Ullah, 2010). Furthermore, plant height during intercropping was higher than sole stand grass at different row spacing due to relatively the production of a high number of tillers in sole stand grass than intercropped grass, which could share the available soil nutrients that could be used for growth. Height of *desho* grass intercropped with vetches at narrow row spacing in the present study was higher than the findings reported by Bimrew (2016) who noted that at 120 dates of harvesting stage the height of *desho* grass was 101.3 cm at mid and 86.83 cm at highland altitudes in northern Ethiopia, and Gadisa *et al.* (2019) noted that *desho* grass (Kulumsa DZF-592) recorded 93.67 cm height at eastern Ethiopia.

Results indicated that in the current study plant height increased as a growth stage increases. Height was low at early stages of growth and enhanced till the final stage of harvest. The increment of plant height as growth stage increases might be due to the increment of well established plant roots which can quest nutrients from the deeper parts of the soil and also due to the full development of stem and leaf (Figure 3). Plant height is the major attributes involved in the forage yield of grass associated with growth and biomass.

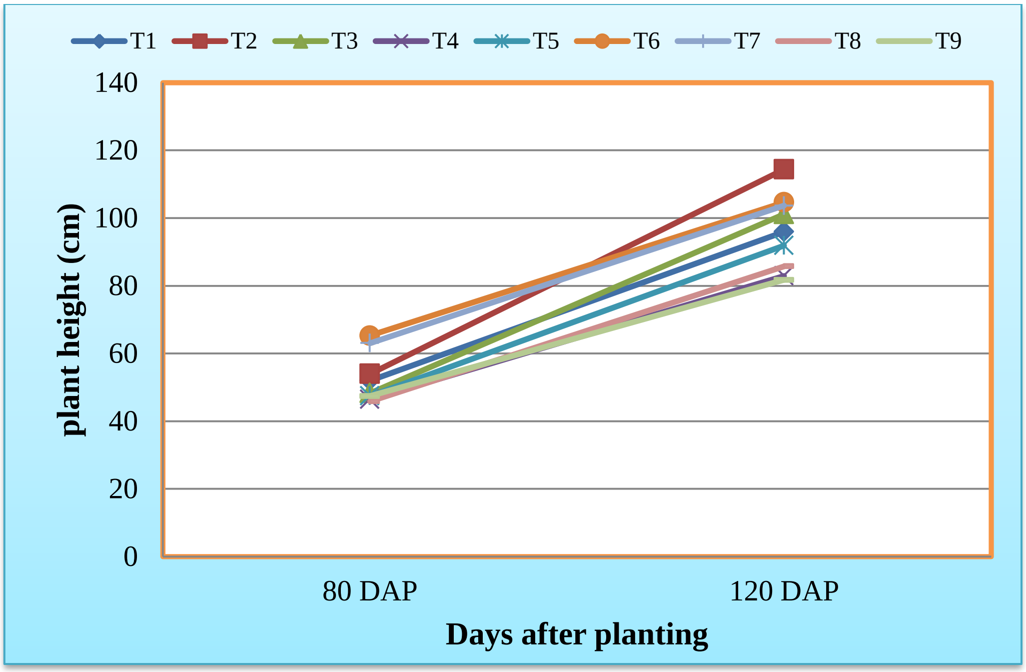


Figure 3. Plant height of *desho* grass intercropped with vetch varieties and sole *desho* grass at different row spacing.

T1 = Sole desho grass at 0.5 m space; T2 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.5 m space; T3 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.75 m space; T4 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 1 m space; T5 = Sole desho grass at 0.75m space; T6 = Desho grass intercropped with Vicia dasycarpa lana at 0.5 m space; T7 = Desho grass intercropped with Vicia dasycarpa lana at 0.75 m space; T8 = Desho grass intercropped with Vicia dasycarpa lana at 1 m space; T9 = Sole desho grass at 1 m space; DAP = days after planting; cm = centimeter.

4.2.2. Leaf Length

Intercropping, spacing and their interaction had a significant effect on leaf length of *desho* grass at 120 days of harvest stage (Table 3). Intercropping vetch varieties did affect ($P<0.05$) leaf length of *desho* grass at 80 and 120 days (forage harvest) growth stage (Figure 4 and Table 3). *Desho* grass intercropped with vetch varieties had higher leaf length as compared to sole *desho* grass at the different growth stage. This is might be due to the efficient utilization of resources in grass-legume intercropping than sole grass cropping. The present result agrees with Alalade *et al.* (2014) who found highest mean values of leaf length for *Panicum maximum* when intercropped with *Stylosanthes hamata* and *canavalia* than for the sole *Panicum maximum*.

Length of leaves was significantly greater at the narrow row spacing (0.50 m) than at the intermediate (0.75 m) and wide spacing (1 m) at both 80 and 120 days growth stage and probably due to the competition of available light. This is in line with the finding of Tilahun *et al.* (2017) who reported that *desho* grass planted at narrow spacing (10 and 30 cm) produced longer leaves than wider spacing (50 cm). The current result was contradicted with the report of (Melakie and Melaku, 2010; Alemu *et al.*, 2007) who noted that Bana grass (*Pennisetum purpureum* × *Pennisetum americanum* hybrid) leaf length at relatively narrow plant spacing was shorter than at medium and wider plant spacing.

Interaction effect on leaf length of *desho* grass as affected by intercropping vetch varieties and row spacing was significantly (P<0.05) different at forage harvest stage (Table 3), whereas there is no interaction effect at 80 days growth stage (Figure 4)**.** The leaf length of *desho* grass ranged from 30.07 to 48.53 cm with a mean of 36.39 cm. The highest leaf length (48.53 cm) was obtained from *desho* grass intercropped with *Vicia dasycarpa* lana at 0.50 m row spacing (T6) followed by intercropped with *Vicia sativa* ICARDA 61509 at 0.50 m row spacing (T2) as compared to the sole *desho* grass planted at the three different row spaces. While sole *desho* grass planted at wider row spacing (T9) (30.07 cm) and intermediate row spacing (T5) (30.4 cm) had the lowest leaf length. The result indicated that the intercropped grass at narrow spacing produced longer leaf than the intercropped grass at wider spacing and the sole grass planted either at narrow or wide spacing. This was attributed due to the provision of fixed N from legumes in closer space was available to the grass and generally, the grass benefited from the legumes by producing significantly higher leaf length than the sole grass. This result agreed with the finding of Ojo *et al.* (2013) who reported that the leaf length of *Panicum maximum* var Ntchisi intercropped with *Lablab purpureus* was significantly longer than the sole *Panicum maximum* across the harvesting times. Leaf length *desho* grass intercropped with vetches and pure stand of the present result was higher than pure stand *desho* grass planted at high altitude (20.72 cm) whereas solely planted grass had relatively comparable leaf length with *desho* grass planted at mid-altitude (32.12 cm) at 120 date of harvesting stage (Bimrew, 2016). The difference might be due to agro ecology, soil and environmental conditions.

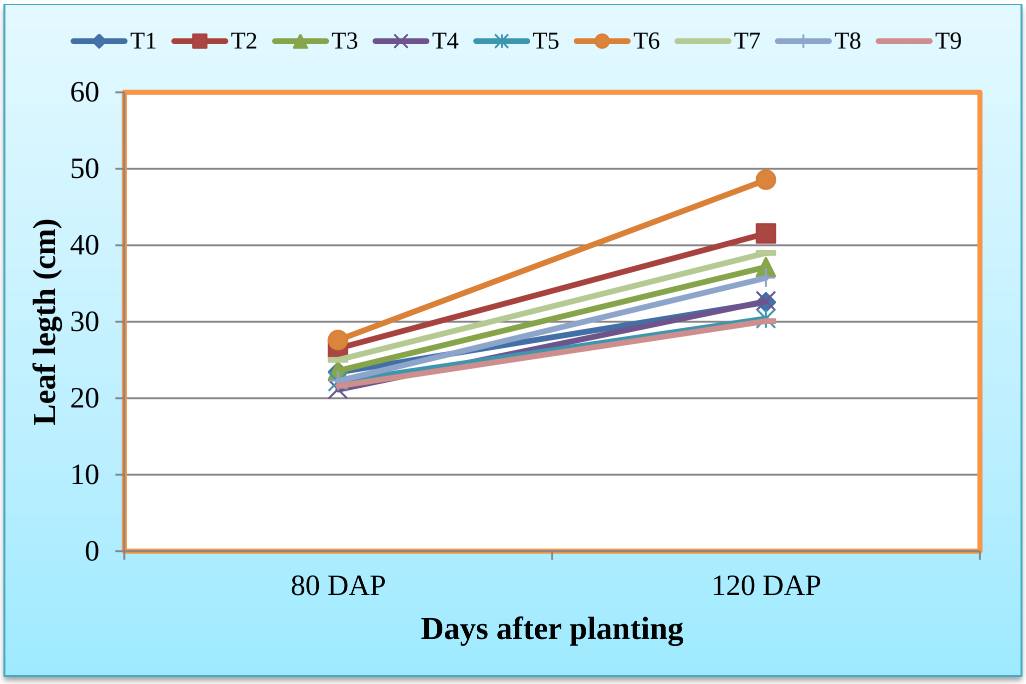


Figure 4. Leaf length of *desho* grass intercropped with vetch varieties and sole *desho* grass planted at different row spacing

T1 = Sole desho grass at 0.5 m space; T2 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.5 m space; T3 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.75 m space; T4 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 1 m space; T5 = Sole desho grass at 0.75m space; T6 = Desho grass intercropped with Vicia dasycarpa lana at 0.5 m space; T7 = Desho grass intercropped with Vicia dasycarpa lana at 0.75 m space; T8 = Desho grass intercropped with Vicia dasycarpa lana at 1 m space; T9 = Sole desho grass at 1 m space; DAP = days after planting; cm = centimeter.

4.2.3. Number of Tiller per Plant

There was no interaction effect (P>0.05) for the number of tiller per plant of *desho* grass at 120 days harvest stage of the forage (Table 3). On the contrary, at 80 days of growth stage, there was interaction effect (P<0.05). Comparison between sole and intercropping showed that number of tillers per plant of *desho* grass was higher in sole cropped than intercropped for both vetch varieties at 80 days of the growth stage. Similarly, at forage harvest stage (120 days) solitary cropped grass had statistically higher NTPP than the grass intercropped with *Vicia dasycarpa* lana (Table 3). This might be due to lack of competition of light, nutrient uptake with legumes in a sole *desho* grass. Tiller number per plant of *desho* grass intercropped with *Vicia sativa* ICARDA 61509 (35.73 and 54.30) was significantly higher than intercropped with *Vicia dasycarpa* lana (30.19 and 43.03) at 80 and 120 days growth stage, respectively. Since *Vicia dasycarpa* lana have creeping behaviour on the grass it increased light competition causing reduced tillering capacity. This result was supported by Ullah (2010) who noted that the legume *Vicia sativa* has an erect growing behaviour, therefore, did not negatively affect the tillering of *Panicum maximum* grass when intercropped up to 67% ratio.

Desho grass planted at 0.75 m row spacing had the highest number of tiller per plant (39.10) at 80 days and 55.2 tillers at 1 m (wider) row spacing during forage harvest stage. Tiller number increased with increasing row space indicating wider space enhanced development of new shoots and encourages the development of new tillers. The present study agrees with Tilahun *et al.* (2017) who reported that the number of tillers per plant of *desho* grass increased as spacing increased. At wider spacing, light can easily penetrate to the base of the plant and this may have stimulated tiller development. Moreover, under wider spacing competition for nutrients are less, so individual plants can support more tillers. The current result is further supported by Yasin *et al*. (2003) who reported that for Napier grass, when sufficient space is available to the individual plant, there is the capacity to increase the number of tillers per plant with the variation among the different spacing being ascribed to variable nutritional areas and access to light. In addition, the works of different authors confirm similar result for *desho* grass (Worku *et al*., 2017; Heliso *et al.*, 2019) where plant tiller number was higher in wider plant and row spacing.

There was an interaction effect of intercropping and spacing ($P<0.05$) on tillering of grass only at 80 days growth stage. A higher number of tillers of grass was recorded from sole *desho* grass at 0.75 m row spacing (42) (T5) followed by sole *desho* grass at 1 m row spacing (41.26) (T9), intercropped with *Vicia sativa* ICARDA 61509 at 0.75 m spacing (41.26) (T3) respectively at 80 days of growth stage whereas the lowest was obtained from *desho* grass intercropped with *Vicia dasycarpa* lana at 0.50 m row spacing (24.80). The number of tiller per plant of *desho* grass intercropped with *Vicia dayscarpa* lana at 120 days of harvest and at the three-row spacing was lower as compared to the values of grass planted solitary at every three spaces. This variation was might due to competition of resources and climbing habit/behaviour of *Vicia dayscarpa* lana over the grass & shed that obstacles the light and airy entrance. The decline in number of tiller per plant was in line with the report of Ullah, (2010) who stated that tillers of *Panicum maximum* decreased when intercropped with cowpea due to space competition because of cowpea has a little erect growing behaviour. Generally, a number of the tiller of *desho* grass intercropped with legumes at narrow spacing was lower may be due to high plant densities leading to competition for resources, namely light, space and nutrients. Contrarily, the result disagreed with Aderinola, (2011) who reported that the highest number of tillers was produced by *Andropogon tectorum* intercropped with *Lablab purpureus* in narrow inter-row spacing. Mean number of tillers was 35.44 and 50.39 at 80 and 120 days of growth stage respectively which indicate the number of tillers was increased as the growth stage increased.

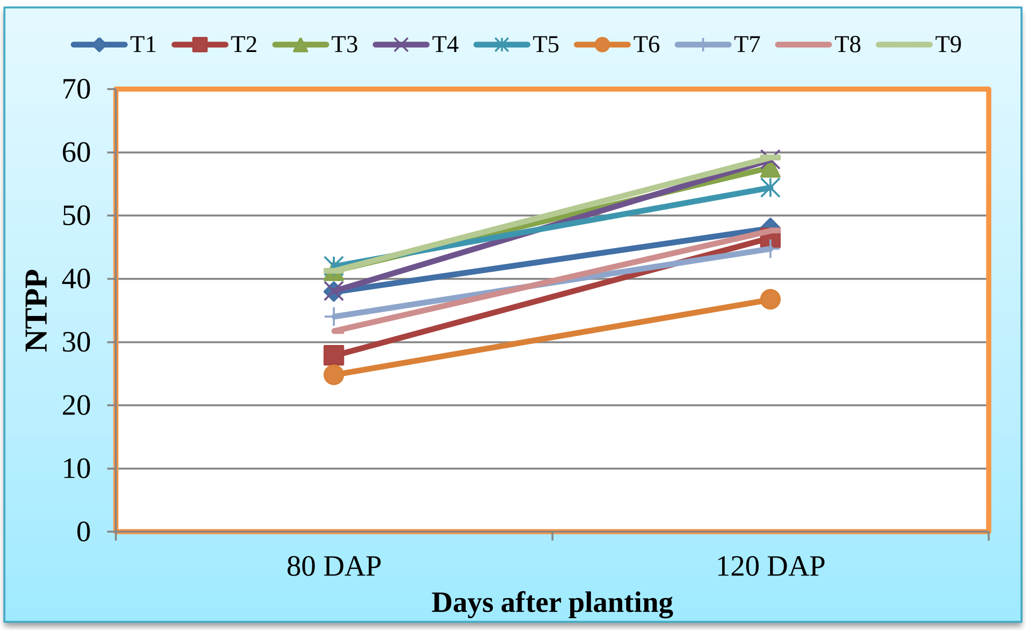


Figure 5. Number of tiller per plant of *desho* grass intercropped with vetch varieties and sole *desho* grass planted at different row spacing.

T1 = Sole desho grass at 0.5 m space; T2 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.5 m space; T3 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.75 m space; T4 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 1 m space; T5 = Sole desho grass at 0.75m space; T6 = Desho grass intercropped with Vicia dasycarpa lana at 0.5 m space; T7 = Desho grass intercropped with Vicia dasycarpa lana at 0.75 m space; T8 = Desho grass intercropped with Vicia dasycarpa lana at 1 m space; T9 = Sole desho grass at 1 m space; DAP = days after planting; NTPP = number of tiller per plant.

4.2.4. Number of Leaves per Plant

Leaf number determines the photosynthetic capacity of the plant. There was an interaction effect ($P<0.05$) for number of leaves per plant of *desho* grass at forage harvest stage (Table 3). Significant effect ($P< 0.05$) was observed for number of leaves per plant (NLPP) at 80 days growth stage by intercropping and spacing (Figure 6 a). Solitary cropped grass had significantly higher NLPP than the grass intercropped with vetch varieties at 80 days and 120 days of harvesting stages due to a greater share a limited environmental resource like nutrients and light in intercropping. Because of intercrop-competition for essential growth factors intercropped sorghum produced less number of leaves per plant than mono cropped sorghum as reported by Azraf-ul-Haq *et al.* (2007). Contrary to the current result, the finding of Yegrem *et al.* (2019) reported that a higher number of leaves per plant were recorded when *desho* grass intercropped with greenleaf *desmodium* than the sole.

Desho grass planted at 0.75 m row spacing (13) had the highest NLPP which was statistically similar with the value at 1 m spacing (12.56) but significantly higher than planting at 0.50 m spacing (11.2) at 80 days growth stage. At 120 days of forage harvesting stage higher leaves number were recorded at wider row spacing than narrow row spacing. This indicated number of leaves per plant increased with increasing row spacing.

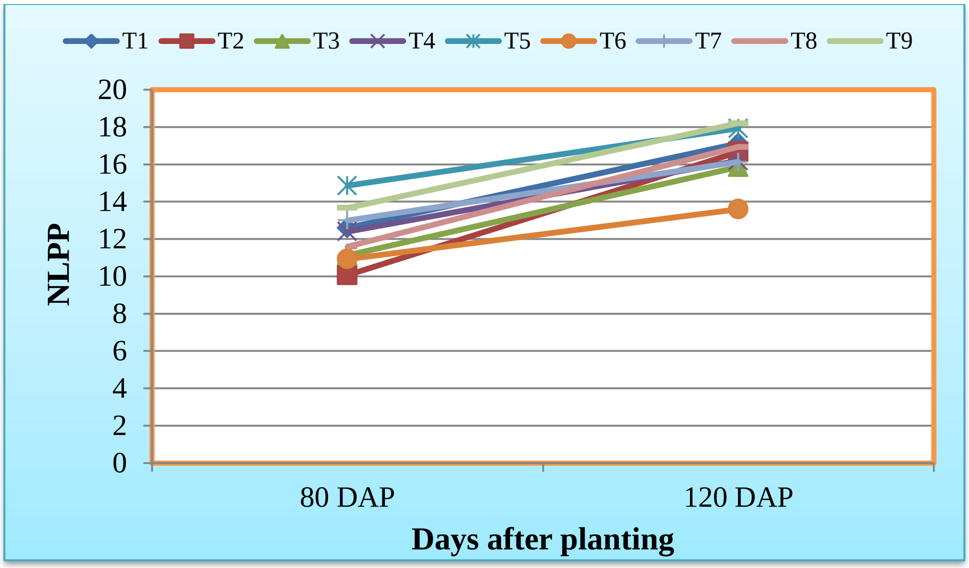
Interaction effect had a significant effect on NLPP only at 120 days of forage harvesting stage; while significant difference was not observed at 80 days growth stage. At 120 days of forage harvesting stage, the highest number of leaves per plant (18.2) was recorded from sole *desho* planted at 1 m row spacing followed by sole stand grass at 0.75 m and 0.50 m spaces (17.93 and 17.13). The lowest leaves number (13.6) was recorded when intercropped with *Vicia sativa* ICARDA 61509 at 0.5 m space. Mean number of leaves per plant increased from 10.07 leaves at 80 days to 18.2 leaves at 120 days. This indicated that the number of leaves per plant was increased with advanced plant age which is in line with what was reported by (Bimrew, 2016 and Tilahun *et al*., 2017); who stated that the number of leaves of *desho* grass was increased with advanced maturity of age.

4.2.5. Number of Leaves per Tiller

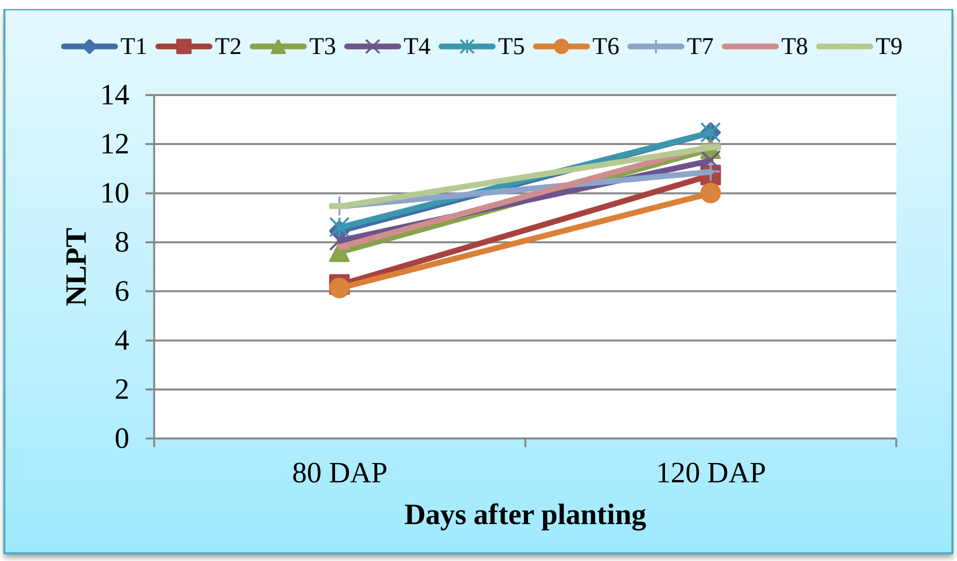
The effect of intercropping, spacing and their interaction on number of leaves per tiller of *desho* grass during the study period of different growth stages was given in (Table 3 and Figure 6 b). Number of leaves per tiller was significantly affected by intercropping ($P<0.05$) at 80 and 120 days of the growth stage of grass. The value of number of leaf per tiller was highest for the sole planted *desho* grass whereas the significant difference was not observed between the grass intercropped with *Vicia dayscarpa* lana and *Vicia sativa* ICARDA 61509 at the two growth stages. This might be due to less competition of resources in sole cropped grass.

Spacing had a significant effect on the number of leaves per tiller ($P<0.05$) at 80 and 120 days growth stage of grass. The value of leaf number per tiller was the lowest for the *desho* grass planted at narrow row spacing (0.50 m) whereas no significant difference ($P>0.05$) were observed between the 0.75 m and 1 m row spacing 80 and 120 days of growth stage, respectively. This indicated that leaf per tiller increased with increasing row width.

The number of leaf per tiller of *desho* grass was affected by intercropping with vetch varieties at different row spacing at 80 and 120 days of the growth stage. Sole *desho* grass planted at 1 m space and grass intercropped with *Vicia dasycarpa* lana at 0.75 m space (9.46) had the highest number of leaf per tiller compared to other interaction treatments followed by sole grass planted at 0.75 m (8.6) and 0.50 m row spacing (8.46) at 80 days of the growth stage. Sole *desho* grass planted at 0.75 m row spacing (12.47) had the highest number of leaf per tiller compared to intercropped forage followed by Sole *desho* grass planted at 0.50 m row spacing (12.46). Whereas *desho* grass intercropped with vetch varieties (legumes) at 0.50 m spacing had the lowest number of leaf per tiller both at 80 and 120 days of the growth stage.



(a)



(b)

Figure 6. Number of leaves per plant and tiller of *desho* grass intercropped with vetch varieties and sole *desho* grass planted at different row spacing

T1 = Sole desho grass at 0.5 m space; T2 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.5 m space; T3 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 0.75 m space; T4 = Desho grass intercropped with Vicia sativa ICARDA 61509 at 1 m space; T5 = Sole desho grass at 0.75m space; T6 = Desho grass intercropped with Vicia dasycarpa lana at 0.5 m space; T7 = Desho grass intercropped with Vicia dasycarpa lana at 0.75 m space; T8 = Desho grass intercropped with Vicia dasycarpa lana at 1 m space; T9 = Sole desho grass at 1 m space; DAP = days after planting; NLPP = number of leaves per plant; NLPT = number of leaves per tiller.

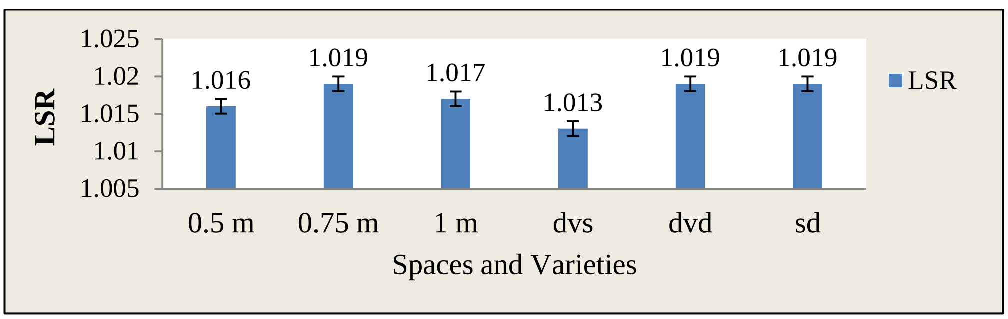
Table 3. Morphological characteristics of *desho* grass (Mean±SE) as affected by intercropping, spacing and their interactions at forage harvesting stage (120 days after planting)

Factors	Parameters				
	NTPP	**NLPP**	**NLPT**	**PH (cm)**	**LL (cm)**
Varieties Intercropped					
DVS	54.30±2.09[a]	16.24±0.27[b]	11.29±0.26[b]	99.49±4.70[a]	37.11±1.67[b]
DVD	43.03±1.95[b]	15.55±0.51[c]	10.93±0.31[b]	98.02±3.33[a]	41.08±2.12[a]
SD	53.86±1.69[a]	17.75±0.22[a]	12.26±0.18[a]	89.85±2.66[b]	30.99±0.64[c]
P-value	<0.0001	<0.0001	0.0004	0.0012	<0.0001
Row spacing (m)					
0.50	43.73±2.14[c]	15.80±0.60[b]	11.06±0.44[b]	105.0±3.04[a]	40.86±2.44[a]
0.75	52.25±1.98[b]	16.64±0.35[a]	11.71±0.26[a]	98.89±1.95[b]	35.50±1.54[b]
1	55.20±1.97[a]	17.11±0.32[a]	11.70±0.12[a]	83.46±1.78[c]	32.82±1.27[c]
P – value	<0.0001	0.0011	0.0396	<0.0001	<0.0001
Interaction effect					
DVS * 0.50 m	46.47±2.24	16.67±0.69[cd]	10.73±0.68[de]	114.40±2.70[a]	41.53±2.35[b]
DVS * 0.75 m	57.60±0.42	15.86±0.35[d]	11.80±0.10[abc]	101.13±1.49[bc]	37.13±2.18[bcd]
DVS * 1 m	58.85±0.96	16.20±0.36[cd]	11.33±0.18[bcd]	82.93±2.54[f]	32.67±1.86[de]
DVD * 0.50 m	36.73±3.18	13.60±0.18[e]	10.00±0.35[e]	104.67±3.75[b]	48.53±0.98[a]
DVD * 0.75 m	44.75±1.28	16.13±0.26[cd]	10.87±0.30[cde]	103.67±1.39[bc]	38.97±1.32[bc]
DVD * 1 m	47.60±1.45	16.93±0.16[bc]	11.93±0.15[ab]	85.73±1.78[ef]	35.73±2.68[cd]
SD * 0.50 m	48.00±1.53	17.13±0.42[bc]	12.46±0.42[a]	95.93±2.08[cd]	32.53±0.93[de]
SD * 0.75 m	54.40±0.57	17.93±0.23[ab]	12.47±0.25[a]	91.89±1.80[de]	30.40±1.29[e]
SD * 1 m	59.17±0.58	18.20±0.20[a]	11.86±0.15[ab]	81.73±4.91[f]	30.07±0.82[e]
Overall mean	50.39	16.52	11.49	95.79	36.39
P-value	0.6315	0.0006	0.0137	0.0462	0.0204
CV (%)	5.35	3.66	4.89	4.99	6.64

[a-f] means with different letters in a column significantly different (P<0.05). DVS= Desho grass intercropped with Vicia sativa ICARDA 61509; DVD= Desho grass intercropped with Vicia dasycarpa lana; SD= Sole Desho grass; NTPP = number of tiller per plant; NLPP = number of leaf per plant; NLPT = number of leaf per tiller; PH = plant height; LL = leaf length; m = meter; cm = centimeter; CV = coefficient of variation.

4.2.6. Leaf to Stem Ratio

The leaf to stem ratio of *desho* grass was not significantly affected (P>0.05) by intercropping, spacing and their interactions (Figure 7 (a) and (b)). The values of a LSR of *desho* grass between intercropping, spaces and their interactions were greater than one and ranged from 1.01 to 1.021. The result recorded from the current study was comparable with the finding of Gadisa *et al.* (2019) who reported that the average LSR produced from *desho* grass (Kulumsa DZF-592) at second harvest cycle (1.07) at Mechara Agricultural Research Center, Eastern Ethiopia. In contrast, the current result was below the finding of Bimrew (2016) who reported that LSR of *desho* grass was 1.18 and 1.15 for mid and high altitude, respectively at 120 harvesting dates and it was higher than Tekalegn *et al.* (2017) who reported that LSR of *desho* grass (Kulumsa DZF-592) 0.47 and 0.57 at first and second harvesting cycle, respectively at southern Ethiopia. This difference might due to differences in agro-ecology like altitude, temperature, rainfall, soil, harvesting stage and other factors.



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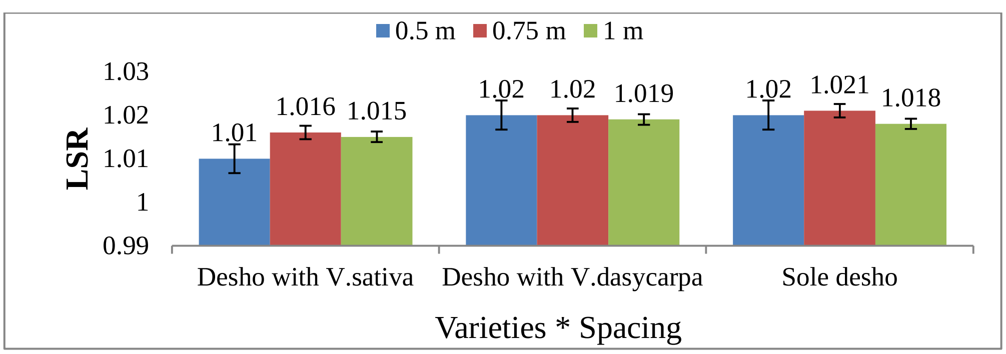


(b)

Figure 7. LSR for *desho* grass as affected by intercropping, spacing and their interactions

dvs = desho grass intercropped with Vicia sativa *ICARDA 61509; dvd = desho grass intercropped with Vicia dasycarpa lana; sd = sole desho grass m = meter; LSR = leaf to stem ratio.*

4.3. Agronomic Performance of Vetches

There was interaction effect ($P<0.05$) on some agronomic parameters like number of leaves per plant and plant height of vetch varieties planted in *desho* grass at different spaces. Intercropping *desho* grass with vetches significantly affected all the measured morphological parameters of vetches while spacing had a significant effect on number of leaf per plant and plant height of the legumes (Table 4).

Plant height of vetches was significantly affected by intercropping ($P<0.05$). *Vicia sativa* ICARDA 61509 showed lower height (81.36 cm) than *Vicia dasycarpa* lana (163.62 cm) and this variation is because of varietal differences particularly *Vicia sativa* have an erect growth habit and short whereas *Vicia dasycarpa* have a creeping or climbing growth habit (Gezahagn *et al.,* 2013). The height of vetches in the mixtures/intercrops were higher as compared to sole vetch varieties planting which could be caused by intercropping of grasses with legumes provides structural support for vetches and improves light interception (Nadeem *et al.,* 2010) and this position might have affected the height of the plant positively.

Plant heights of vetches at forage harvest also showed significant ($P<0.05$) difference by spacing. The highest plant height of vetch (131.08 cm) was recorded at narrow spacing (0.50 m) but statistically not significant difference with at 0.75 m spacing whereas the lowest (112.87 cm) height was recorded at wider spacing (1 m). The present result agrees with the findings of (Akkopru *et al.,* 2007; Bagci, 2010) who reported that plant heights decreased depending on the increasing row spacing. The mean plant height of the intercropped vetch was 122.49 cm, which was higher than the mean of stretched height at forage harvest of five vetch species grown at Holeta (113.8 cm) but lower than the same vetch species grown at Ginchi (131 cm), this height difference could be attributed to genetic variability, soil fertility and environmental conditions (Gezahagn, 2018). The highest plant height (171.90 cm) was obtained from *Vicia dasycarpa* lana intercropped in grass at 0.5 m row spacing (T6) whereas the lowest was obtained from *Vicia sativa* intercropped in the grass at 1 m row spacing (T4).

Number of leaves per plant and leaf length of vetch varieties was significantly affected by intercropping. *Vicia dasycarpa* lana intercropped with grass had significantly higher number of leaf per plant and leaf length than *Vicia sativa* ICARDA 61509 and this could be attributed to species/varieties disparity. However, except number of leaf per plant, spacing did not affect the leaf length of vetches. Number of leaf per plant recorded among the spaces was significantly different (P<0.05) and leaf number increased as row spacing was decreased. The highest number of leaves per plant (400.67) was obtained from *Vicia dasycarpa* lana intercropped with *desho* grass at narrow row spacing (0.50 m) (T6) followed by *Vicia dasycarpa* lana intercropped in *desho* grass at 0.75 m spacing (T7) whereas the lowest (222.67) was obtained from *Vicia sativa* ICARDA 61509 intercropped in *desho* grass at 1 m (T4). However, the overall mean of vetches intercropped with grass for number of leaves per plant and leaf length were higher as compared to sole *Vicia sativa* ICARDA 61509 but lower than the *Vicia dasycarpa* lana.

Table 4. Morphological characteristics of vetch varieties (Mean±SE) intercropped in *desho* grass at different row spacing

Factors	**Parameters**		
	NLPP (count)	**PH (cm)**	**LL (cm)**
Varieties			
DVS	230.93±7.44[b]	81.36±3.07[b]	2.42±0.07[b]
DVD	375.52±10.23[a]	163.62±3.27[a]	2.81±0.08[a]
SVS	199.33±22.57	70.20±10.15	2.37±0.04
SVD	372.67±23.72	153.77±4.96	2.62±0.07
Mean	298.92	119.86	2.58
P-value	< 0.0001	< 0.0001	0.0084
Row Spacing (m)			
0.50	323.00±35.35[a]	131.08±18.36[a]	2.62±0.15
0.75	302.33±35.65[ab]	123.52±18.01[a]	2.59±0.12
1	284.33±29.14[b]	112.87±19.18[b]	2.63±0.10
P-value	0.029	0.0012	0.945
Interaction Effect			
DVS * 0.50 m	245.33±13.13[c]	90.27±3.15[c]	2.35±0.12
DVS * 0.75 m	224.77±16.72[c]	82.40±1.15[c]	2.47±0.14
DVS * 1 m	222.67±7.51[c]	70.40±0.61[d]	2.45±0.12
DVD * 0.50 m	400.67±6.76[a]	171.9±3.25[a]	2.90±0.13
DVD * 0.75 m	379.88±7.88[ab]	163.63±3.5[a]	2.70±0.20
DVD * 1 m	346±19.49[b]	155.33±6.07[ab]	2.81±0.06
Mean	303.22	122.49	2.61
P-value	0.0001	0.0001	0.550
CV (%)	6.89	4.87	9.47

[a-b]*Means with different letters in a column significantly different (P<0.05). DVS= Desho grass intercropped with Vicia sativa ICARDA 61509; DVD= Desho grass intercropped with Vicia dasycarpa lana; SD= Sole desho grass; SVS=sole Vicia sativa ICARDA 61509; SVD= sole Vicia dasycarpa lana; NLPP= number of leaves per plant; PH= plant height; LL= leaf length; m = meter; cm = centimeter; CV = coefficient of variation.*

4.4. Seed Yield of Vetches

The present results showed that intercropping, row spacing and interaction of intercropping with spacing significantly ($P<0.05$) affected the seed yield of vetches. Seed yield in the intercropping of the study area ranged from 0.31 to 0.78 t/ha with a mean of 0.51 t/ha (Table 5). Lower seed yield was recorded due to existence of high rainfall at the blooming/ flowering time of vetches that caused flower shattering and low pod setting, and highly affected the seed yield performance of vetches. The highest seed yield was recorded from *Vicia sativa* ICARDA 61509 at narrow row spacing (0.50 m) followed by *Vicia sativa* ICARDA 61509 at intermediate (0.75 m) row spacing whereas the lowest seed yield was recorded from *Vicia dasycarpa* lana at wider (1 m) row spacing. This result indicated that the seed yield decreased as the row space increased and the yield obtained from *Vicia sativa* ICARDA 61509 was higher than *Vicia dasycarpa* lana when they were intercropped with *desho* grass. The difference could be due to the inherent variation, environmental condition and planting pattern.

On the other hands, the sole cropped vetches gave higher seed yield than the intercropped vetch varieties due to variation of row spaces and higher plant densities occupied in the sole vetches than intercropped vetches. The mean seed yield of vetches tested in the present study was found within a range of seed yield recorded at Holetta between 0.4 to 0.8 t/ha tested from five vetch species but it was lower than 2 to 2.9 t/ha evaluated from similar species at Ginchi by Gezahagn *et al.* (2013). This variation was due to several factors such as agro-ecology, environmental conditions like rainfall, climate, soil fertility, and management practices. The present result was supported also by Sabanci *et al.* (2016) who reported that high seed yield of common vetch (*Vicia sativa*) was observed in narrow row spacing than the wider row spacing.

Table 5. Seed yield (t/ha) of vetches (Mean±SE) as affected by intercropping, spacing and their interactions

Factors	**Row spacing (m)**			**Mean**
Varieties intercropped	0.50	0.75	1	
Desho + Vicia sativa	0.78±0.04[a]	0.61±0.02[b]	0.42±0.02[d]	0.60±0.05[a]
Desho + Vicia dasycarpa	0.53±0.02[c]	0.40±0.02[d]	0.31±0.01[e]	0.41±0.03[b]
Mean	0.65±0.06[a]	0.51±0.05[b]	0.36±0.03[c]	
Sole *Vicia sativa*	0.30 m			1.23
Sole *Vicia dasycarpa*	0.30 m			0.82
P-value	VI	<0.0001		
	RS	<0.0001		
	Interaction	0.0205		
CV (%)	6.98			

[a-e] Means with different letters in a column or a row significantly different (P<0.05). VI = varieties intercropped; RS = row spacing; CV = coefficient of variation; m = meter.

4.5. Forage Yield

Intercropping and spacing did have a significant effect (P<0.05) on dry matter and crude protein yield of *desho* grass and total dry matter and crude protein yield of grass-legume intercropping (Table 6). However, dry matter and crude protein yield of legume were unaffected by intercropping (P>0.05) but affected significantly (P<0.05) by row spacing. Except CP yield of legume, interaction of intercropping with spacing did not show significant differences (P>0.05).

4.5.1. Dry matter yield of *Desho* grass and Vetches

The present results showed that intercropping had a significant effect (P<0.05) on dry matter yield of *desho* grass. The two varieties of vetch didn’t vary (P>0.05) in both dry matter yield (DMY) and crude protein yield (CPY) whereas dry matter yield of *desho* grass when intercropped with *Vicia dasycarpa* lana was lowest by 19.97% as compared to sole *desho* grass as well as *Vicia sativa* ICARDA 61509 intercropped with *desho* grass, both of which are statistically similar. This might be due to the response of growth habits of the vetch variety used in intercropping and also due to resource competition between plants especially for *Vicia dasycarpa* lana having a creeping growth habit that overcrowds on the grass inhibits light, air circulation and creates a high competition of free environment. The dry matter yield of *desho* grass when intercropped with *Vicia dasycarpa* lana was lower than sole *desho* grass planted at different row spaces of the current study was in line with the finding of Lemma *et al.* (1991) who reported that pure *Chloris gayana* produced higher dry matter yields than *Chloris gayana* in legume mixtures in the western part of Ethiopia.

With regard to spacing and forage production, both narrow and wide spacing have implications for different aspects of forage production (Rao, 1986) as the number of plants per unit area is the primary source of competition. The highest dry matter yield (7.36 t/ha) of *desho* grass was obtained at intermediate row spacing (0.75 m) which was not significantly different as compared to narrow spacing but it was significantly higher by 18.75% as compared to wide spacing (5.98 t/ha). The DMY of *desho* grass in narrow row spacing was higher by 16.60% than wider spacing. The higher DMY of *desho* grass at intermediate spacing (0.75 m) was attributed to the higher tiller number, increased number of leaf per plant and tiller as compared to narrow spacing (0.50 m), whereas due to higher plant height, leaf length, leaf number per tiller and plant densities as compared to wide spacing (1 m). Significant differences in dry matter yield of *desho* grass among the row spacing in the present study was in line with the finding of Irfan *et al.* (2016) who reported that maximum dry matter yield was recorded at 12 cm row spacing than 46 cm row spacing at succeeding growth stage of different oat varieties. Also, the current study concurs with Tesssema (2008) who noted difference in DM yield among the different plant density in Napier grass, and dry matter yield increased as plant density increased. Bhatti *et al*. (1985) also noted that green and dried weight yield increases at low inter and intra row spacing.

Nevertheless, the presence of difference with spacing in the current study contradicts with the finding of Semman and Animut (2014) who reported that spacing had no significant difference on dry matter yield of Napier grass intercropped with *Lablab purpureus*. Similarly, Njoka *et al.* (2006) did not observe significant effect on dry matter yield of Napier grass intercropped with *Seca stylo* and *siratro*. The difference between our results could be attributed to the differences of legume and grass, date of harvesting, and other managemet factors. Higher yields at narrow spacing could be explained by improved light interception (Steiner, 1986) and decreased in intra-row competition between plants (De Bruin and Pederson, 2008).

Table 6. Forage dry matter yield, crude protein yield and their total yields of *desho* grass and vetches (Mean±SE) as affected by intercropping, spacing and their interactions

Factors	**DMY (t/ha)**			**CPY (t/ha)**		
	Desho	**Vetch**	**Total**	***Desho***	**Vetch**	**Total**
Varieties Intercropped						
DVS	7.44±0.33[a]	2.42±0.10	9.85±0.38[a]	0.76±0.04[a]	0.423±0.02	1.18±0.05[a]
DVD	5.81±0.26[b]	2.26±0.11	8.10±0.34[b]	0.61±0.03[b]	0.417±0.02	1.03±0.04[b]
SD	7.26±0.28[a]	-	7.26±0.28[c]	0.61±0.03[b]	-	0.61±0.03[c]
SVS	-	4.04	4.04	-	0.74	0.74
SVD	-	3.87	3.87	-	0.79	0.79
P-value	0.0001	0.1827	<0.0001	<0.0001	0.7818	<0.0001
Row Spacing (m)						
0.50	7.17±0.34[a]	2.63±0.08[a]	8.92±0.47[a]	0.69±0.03[a]	0.45±0.02[a]	0.99±0.09[a]
0.75	7.36±0.31[a]	2.26±0.13[b]	8.87±0.47[a]	0.73±0.04[a]	0.42±0.02[ab]	1.01±0.10[a]
1	5.98±0.31[b]	2.12±0.09[b]	7.42±0.39[b]	0.56±0.02[b]	0.39±0.01[b]	0.82±0.07[b]
P-value	0.0008	0.0101	0.001	<0.0001	0.0181	<0.0001
Interaction Effect						
DVS *0.50 m	7.76±0.50	2.60±0.17	10.36±0.52	0.81±0.01	0.43±0.03[ab]	1.24±0.04
DVS * 0.75 m	8.14±0.07	2.52±0.18	10.66±0.25	0.87±0.01	0.47±0.03[a]	1.33±0.03
DVS * 1 m	6.40±0.45	2.13±0.08	8.54±0.35	0.61±0.01	0.38±0.02[b]	0.98±0.01
DVD * 0.50 m	6.08±0.50	2.66±0.08	8.73±0.74	0.64±0.05	0.47±0.03[a]	1.10±0.07
DVD * 0.75 m	6.20±0.30	2.03±0.03	8.23±0.31	0.67±0.04	0.38±0.01[b]	1.05±0.03
DVD * 1 m	5.15±0.38	2.10±0.17	7.35±0.52	0.52±0.02	0.41±0.01[ab]	0.93±0.05
SD * 0.50 m	7.66±0.11	-	7.66±0.11	0.63±0.01	-	0.63±0.01
SD * 0.75 m	7.72±0.14	-	7.72±0.14	0.66±0.03	-	0.66±0.03
SD * 1 m	6.38±0.57	-	6.38±0.57	0.55±0.06	-	0.55±0.06
Overall mean	6.83	2.34	8.40	0.66	0.42	0.94
P-value	0.9168	0.1381	0.7003	0.1122	0.0441	0.0665
CV (%)	9.64	9.99	9.14	7.61	9.84	8.01

[a-c] Means with different letters in a column are statistically different (P<0.05). DMY= dry matter yield; CPY= crude protein yield; TDMY= total dry matter yield; TCPY= total crude protein yield; DVS= desho grass intercropped with vicia sativa ICARDA 61509; DVD= desho grass intercropped with vicia dasycarpa lana; SD= sole desho grass; SVS=sole Vicia sativa ICARDA 61509; SVD= sole Vicia dasycarpa lana; m = meter; CV = coefficient of variation.

The interaction of intercropping with spacing had no significant effect (P>0.05) on the dry matter yield of *desho* grass (Table 6). Intercropping of *desho* grass with *Vicia sativa* ICARDA 61509 at 0.50, 0.75 and 1 m row spacing did not show negative trend due to the recorded increased biomass yield of the grass as compared to the grasses planted alone. The increased yield of fodder grasses in intercrops compared to sole grass during production phase could be due to improved soil fertility through nitrogen fixation by the legume and efficient available of space between the plants. Seresinhe *et al.* (1994) has indicated that the inclusion of legume in a pasture mixture stimulates the growth and increases the N uptake of grass. However, DMY of *desho* grass intercropped with *Vicia dasycarpa* lana at the three different spaces were non significantly lower than sole planted *desho* grass at the three different row spacing. This might be due to resource competition and the response of *Vicia dasycarpa* lana growth habit. This result is in line with Mwangi and Thorpe (2002) who found out that intercropping *desmodium* depressed dry matter yield of Napier grass but overall total dry matter yield (grass + legume) was higher.

Legumes (vetch varieties) didn't show a significant difference (P>0.05) on dry matter yield when intercropped with *desho* grass and interaction of intercropping vetches with row spacing of *desho* grass. However, the sole cropped vetches gave higher DMY than the intercropped vetches in *desho* grass due to discrepancy of row spacing and higher plant densities occupied in the sole vetches. The DMY of the present result of vetch varieties are less than the results reported by Gezahagn *et al.* (2013) who stated mean DMY (5.33 t/ha) of different vetch species tested at Holeta and Ginchi research stations in Ethiopia. These differences were probably because of the agronomic activities and various soil and climate conditions at the experimental sites. In addition, forage DMY of vetches in this study was higher as compared to the vetch DMY ranged between 1-1.7 t/ha in vetches-maize intercropping in different agro-ecologies of West Arsi and East Showa zone of Oromia, Ethiopia probably due to variations in variety, soil moisture and fertility (Dawit and Nebi, 2017). The reason of the lowered vetch dry matter yield of the present study might be due to high rainfall that occurred at the blooming stage of vetches that caused plant parts decay close to ground (lodging).

DMY of vetch was significantly affected (P<0.05) by row spacing. The highest dry matter yield of vetches (2.63 t/ha) was obtained at narrow spacing which was significantly higher by 14.06% and 19.39% as compared to intermediate and wider spacing respectively. This greater yield of vetches in narrow spacing could be attributed to more plant densities; number of leaves per plant and plant height than intermediate and wider spacing and because of intercropping of forage grasses with legumes provides structural support for vetch and improves light interception (Nadeem *et al.,* 2010). Significant difference in DMY of legumes (vetches) among row spacing in the current result was in agreement with the report by Kusvuran (2014), in Hungarian vetch and annual Ryegrass intercropping system in which highest yield was obtained at 30 cm row spacing and the yield decreased with increasing row spacing. The current result concurs also with the finding of Alemu (2016) who noted that highest vetch dry matter yield (3.34 t/ha) was obtained when vetch intercropped with sorghum in 75 cm than in 150 cm row space. Generally, DMY of legume declined as the spacing between rows increased. Narrow spacing and decrease within-row plant spacing are effective means of increasing dry matter production as reported by Brown *et al.* (1964) and Caravetta *et al.* (1990). Dry matter yield on an individual plant basis decreased with an increased plant density since higher densities contained more plants per unit land area. Dry matter yield per unit area increased with plant densities (Esechie, 1992).

Grass-legume intercropping and spacing had a significant effect ($P<0.05$) on total dry matter yield (Table 6). Total dry matter yield of the intercropping of *desho* grass with *Vicia sativa* ICARDA 61509 (9.85 t/ha) was higher by 17.76 and 26.29 % than the intercropping of *desho* grass with *Vicia dasycarpa* lana, and sole *desho* grass respectively. This is due to erect growth habit and additive effect of *Vicia sativa* intercropping on total dry matter yield. In addition, the total dry matter yield of intercropping *desho* grass with *Vicia dasycarpa* lana was significantly higher than the sole *desho* grass and sole vetches. This result was in agreement with the finding of Njoka *et al.* (2006) who indicated that the total dry matter production of the mixture of Napier grass and legume was higher than the sole Napier grass. The present result concurs with the finding of Taye *et al*. (2007) who showed that association of Napier grass with lablab produce significantly higher dry matter yield when compared to sole Napier grass. Gulwa *et al.* (2017) also reported that legume intercropping affected forage DMY and the grass-legume mixture produced more dry matter yield in comparison with the grass only. Sima *et al.* (2010) reported that a higher yield of forage was recorded from polyculture (grass-legume mixture) over grass and legume monocultures respectively. The basic reason for higher forage herbage productivity might be the utilization of available land, utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay and Walker, 1989) and allelopathic (Putnam and Duke, 1978) and some other effects. Contrarily, the present result disagreed with Tessema and Baars (2006) who reported that yields of pure grass were not significantly different from the mixed pastures.

Total DMY in narrow and intermediate row spacing was significantly higher than wide row spacing due to more dry matter of both grass and legumes were produced in narrow and intermediate spacing than wider spacing. Sumran *et al*. (2009) found out that Napier grass biomasses increased when inter and intra row spacing is decreased and obtained the highest total dry matter yield of 70.84 ton/ha from 50 x 40 cm plant spacing than that from other higher plant spacing.

Grass and legume intercropping with three different row spaces did not affect (P>0.05) total DMY. In general, it was observed that grass and legumes intercropped with three different row spaces numerically produced more yield in comparison with the grass only except grass intercropped with *Vicia dasycarpa* lana at wider spacing. In the current study highest total DMY (10.66 t/ha) was obtained in the *desho* grass intercropped with *Vicia sativa* ICARDA 61509 at 0.75 m row space (T3) followed by desho grass intercropped with *Vicia sativa* ICARDA 61509 at 0.50 m row space (10.36 t/ha) (T2) whereas the lowest total DMY (6.38 t/ha) was recorded in the *desho* grass alone at 1 m row space (T9). This finding is in agreement with the study of Sturludóttir *et al*. (2013), who reported that on average, the legume-grass mixture plots had more DMY than the most productive monoculture. The attainment of high DMY in the grass-legume mixture may be attributed to beneficial effects of mixing grasses and legumes.

4.5.2. Crude Protein Yield of *Desho* Grass and Vetches

Table 6 shows the calculated CPY from the DMY of *desho* grass, vetch and their mixtures. Diriba (2014) suggested that CPY is the product of total dry matter yield and crude protein concentration in the plant. Significant variation was observed in crude protein yield of *desho* grass by intercropping and spacing, but no significant difference was observed due to their interactions. The highest CPY of grass was obtained when intercropped with *Vicia sativa* ICARDA 61509 as compared to sole *desho* grass. This could be due to the benefits of legumes for grass through nitrogen fixation. Higher CPY of *desho* grass was recorded from the intermediate row spacing which was statistically not significant with narrow spacing whereas lower CPY was recorded from wider space due to low biomass productivity of the grass at wider spacing. In the narrow spacing plant densities were high and legumes were closer to the grass that able to support nutrient for their growth resulted high DMY and CPY of grass than wider space. Interaction effect showed no significance difference on crude protein yield of grass. However, the grass intercropped with *Vicia sativa* ICARDA 61509 at 0.75 m (T3) and 0.50 m spacing (T2) numerically scored higher CPY than other interaction treatments. The present result was in agreement with the report by Taye *et al.* (2007) noted that intercropping of lablab with Napier grass increased CPY of Napier grass as compared to sole Napier grass.

Interaction of intercropping with spacing and spacing alone affected (P<0.05) CPY of vetch whereas no significant difference was observed by intercropping with *desho* grass. However, higher CPY was obtained from pure vetches than the vetches intercropped in grass because of higher DMY and CP content was recorded from sole vetches. Higher CPY of vetches were recorded from the narrow spacing due to high dry matter yield of vetches at narrow space whereas the lower CPY was recorded from wider spacing. The highest CPY of vetch (0.47 t/ha) was obtained from *Vicia dasycarpa* lana intercropped in *desho* grass at 0.50 m row spacing (T6) and *Vicia sativa* ICARDA 61509 intercropped in *desho* grass at 0.75 m spacing (T3) followed by *Vicia sativa* ICARDA 61509 intercropped in *desho* grass at narrow spacing (0.50 m) (T2) whereas the lowest CPY was recorded from *Vicia dasycarpa* lana at intermediate row spacing (T7) and *Vicia sativa* ICARDA 61509 at wider spacing (T4). This was due to higher dry matter yield of legumes obtained at narrow space because of higher plant densities available.

Intercropping and spacing did affect (P<0.05) total crude protein yield (Grass+Legume) (Table 6). The highest mean total CP yield (1.18 t/ha) was recorded from *desho* grass and *Vicia sativa* ICARDA 61509 intercropped followed by *desho* grass and *Vicia dasycarpa* lana intercropped (1.03 t/ha) and the least (0.61 t/ha) was recorded from sole *desho* grass. In the current study, the total CP yield recorded in intercropping of *desho* grass and *Vicia sativa* ICARDA 61509 higher than the grass intercropped with *Vicia dasycarpa* lana might be due to the differences in varieties intercropped in the grass as well as due to the ability differences of legume provides fixed nitrogen that promotes the growth and nutrient for grass, and this was in line with reported by Molla *et al.* (2018) noted that CPY of oat-vetch mixture varied due to differences in varieties of oat and vetch across different harvesting stages.

Row spacing varied significantly the total CP yield of grass-legumes intercropped in the current study. The highest total crude protein yield was obtained at narrow and intermediate spaces than wider spaces. Total CP yield was not affected by interaction of intercropping and spacing. However, higher total CP yields (1.33 t/ha and 1.24 t/ha) were recorded from *desho* grass intercropped with *Vicia sativa* ICARDA 61509 at 0.75 m (T3) and 0.50 m row spacing (T2), respectively while lower total CP yield was recorded from sole *desho* grass at wider space (T9). Diriba (2014) suggested that higher CPY indicates higher importance of the forages.

4.6. Chemical Composition of *Desho* Grass

The present results showed that row spacing and interaction of intercropping with legumes at different row spacing did not show a significant effect (P>0.05) on the chemical composition of *desho* grass. However, except dry matter, Ash, ADL and Hemicelluloses; intercropping vetch varieties affected (P<0.05) other chemical composition of *desho* grass (Table 7).

4.6.1. Dry matter and Ash contents

Dry matter and ash content did not differ (P>0.05) between the grass intercropped with vetch varieties, row spacing as well as the interaction of intercropping and row spacing (Table 7). Absence of variation in DM can be attributed to the soil-related factors, climate and probably the physiological stage of the plant at harvest. The present result was in agreement with Hailemariam and Animut (2014) who reported that no difference was observed in DM values when sudan grass intercropping with lablab at different plant mixing proportions. Similarly, lack of significant variation for ash content among intercropping, row spacing and interaction of intercropping of vetch varieties with row spaces on *desho* grass was contrary with the finding reported by Aderinola (2011) who noted that intercropping of *Andropogon tectorum* grass with *Lablab purpureus* at various inter-row spacing significantly affected the mineral contents of *Andropogon tectorum* grass and closer planting geometry legume grass ratio results higher content of minerals in the *Andropogon tectorum* grass. This could be due to significant contribution of legumes to the nutritive value of grass species in grass-legume mixture.

Table 7. Chemical composition of *desho* grass (Mean±SE) as affected by intercropping, spacing and their interactions

Factors	Parameters							
	DM (%)	**Ash (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**	**Hemcell (%)**	**Cell (%)**
Varieties Intercropped								
DVS	92.88±0.24	9.15±0.21	10.28±0.32[a]	58.24±0.45[b]	37.89±0.22[b]	7.48±0.25	20.35±0.46	30.41±0.19[b]
DVD	93.02±0.07	9.27±0.29	10.48±0.17[a]	58.33±0.32[b]	37.87±0.37[b]	7.47±0.28	20.45±0.49	30.40±0.40[b]
SD	93.35±0.13	9.75±0.32	8.39±0.17[b]	60.58±0.30[a]	40.88±0.74[a]	8.17±0.18	19.70±0.60	32.71±0.60[a]
P-value	0.157	0.389	<.0001	<.0001	0.0005	0.118	0.625	0.0015
Row Spacing (m)								
0.50	93.08±0.10	9.20±0.37	9.70±30.45	59.27±0.58	39.45±0.79	7.79±0.29	19.82±0.5	31.66±0.59
0.75	93.24±0.11	9.59±0.26	10.01±0.4	58.40±0.54	38.53±0.78	7.58±0.26	19.87±0.6	30.95±0.68
1	92.94±0.26	9.48±0.21	9.41±0.32	59.47±0.37	38.66±0.43	7.77±0.25	20.81±0.43	30.90±0.38
P-value	0.460	0.649	0.215	0.069	0.379	0.822	0.427	0.379
Interaction Effect								
DVS * 0.50 m	93.19±0.20	9.02±0.39	10.56±0.69	57.98±0.40	37.97±0.53	7.43±0.53	20.01±0.93	30.54±0.17
DVS * 0.75 m	93.12±0.03	9.17±0.58	10.74±0.22	57.43±0.51	37.35±0.07	7.29±0.57	20.08±0.57	30.06±0.51
DSV * 1 m	92.32±0.65	9.26±0.14	9.54±0.54	59.31±1.04	38.36±0.11	7.73±0.32	20.95±1.02	30.63±0.27
DVD * 0.50 m	92.81±0.12	9.64±0.84	10.47±0.28	58.56±0.45	38.06±0.77	7.50±0.49	20.50±1.20	30.56±0.61
DVD * 0.75 m	93.12±0.05	9.46±0.41	10.82±0.25	57.41±0.48	37.28±0.65	7.25±0.39	20.13±1.02	30.03±1.04
DVD * 1 m	93.15±0.08	9.02±0.18	10.15±0.33	59.01±0.38	38.28±0.63	7.68±0.72	20.73±0.57	30.60±0.61
SD * 0.50 m	93.23±0.08	8.95±0.78	8.16±0.27	61.28±0.72	42.32±0.67	8.43±0.40	18.96±0.05	33.89±0.27
SD * 0.75 m	93.47±0.31	10.14±0.18	8.48±0.21	60.37±0.18	40.97±1.55	8.20±0.24	19.40±1.65	32.77±1.31
SD * 1 m	93.34±0.29	10.15±0.36	8.53±0.42	60.09±0.37	39.35±1.22	7.89±0.32	20.74±0.88	31.46±1.04
Overall mean	93.08	9.42	9.72	59.05	38.88	7.71	20.16	31.17
P-value	0.319	0.499	0.485	0.199	0.279	0.850	0.962	0.408
CV (%)	0.54	9.54	7.20	1.62	3.77	9.95	8.71	4.05

[a-b] Means with different letters in a column significantly different ($P<0.05$). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped with Vicia dasycarpa lana; SD = sole desho grass; DM = dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; Hemcell = hemicellulose; Cell= cellulose; m = meter; CV =coefficient of variation.

4.6.2. Crude protein content

Intercropping grasses with legumes can improve the forage quality in terms of the crude protein content than grass alone. The interaction of intercropping and row spacing has not shown a significant difference in CP content of *desho* grass. But intercropping of vetch varieties affected ($P<0.05$) the CP content of grass (Table 7). Crude protein of the grass increased within intercropped vetches varieties as compared to sole *desho* grass. This might be due to the fact that intercropped legumes fix nitrogen in the soil which supports the growth of grass. *Desho* grass intercropped with *Vicia dasycarpa* lana had the highest percentage of crude protein content (10.48%) which was not significantly different from the grass intercropped with *Vicia sativa* ICARDA 61509 (10.28%) whereas the lowest CP content was recorded from sole grass. This might be due to the ability of *Vicia dasycarpa* species to fix nitrogen 163 kg/ha (Haque and Lupwayi, 2000) which is relatively higher than *Vicia sativa* (common vetch) that can fix N 56 to 134.5 kg/ha (Sattell *et al.,* 1998). The mean CP content of *desho* grass planted alone was higher than the CP content of *desho* grass harvested at 120 days at high altitude and relatively comparable with *desho* grass at midland altitude at northern Ethiopia reported by Bimrew (2016). This difference attributed to several environmental factors such as variations in climatic conditions, soil fertility, and altitudes.

Introduction of legumes significantly affected the CP content of forages. The finding of this study corresponds to the results of Eskandari *et al.* (2009) who reported that grasses grown in intercropping with legumes contained a higher CP content than grasses harvested from the monoculture planted. This suggests that legumes grown alongside non-legume plants increase the N uptake of the companion plants by partitioning the atmospheric fixed N by legumes to the non-nitrogen fixing plants grown in association with them. Ojo *et al.* (2013), also reported higher CP levels on *Panicum maximum* intercropped with *Lablab purpureus*. Gulwa *et al.* (2017) stated that native grasses harvested from *Trefolium repens* had the highest crude protein content whereas grasses harvested from alone had the lowest CP content of pastures in the eastern cape province, South Africa. The present result is in line with the finding of Taye *et al.* (2007) who reported that Napier grass associated with lablab and *desmodium* resulted in higher CP content than sole Napier grass.

Regarding row spacing, the present result agreed with Tilahun *et al.* (2017) who noted that plant densities did not significantly affect the CP content of *desho* grass. Contrarily, the result disagreed with Aderinola (2011) who showed that the crude protein content of *Andropogon tectorum* was significantly affected when inter-planted at various spacing with *lablab purpureus* and higher crude protein content the *Andropogon tectorum* was observed in narrow legume inter-row spacing. This could be attributed to the influence of the legume and the legume inter-row spacing which allowed for greater percentage of nitrogen fixation. The CP content of the current result was above the minimum level of 7% required for optimum rumen function (Van Seost, 1994). The main advantage of cereal legume mixtures have been increased CP yield relative to cereal crops (Negash *et al.,* 2017) legume supply nitrogen to grass-legume mixtures, so it produced more forage yield than grasses grown alone and grasses grown in intercropping with legumes also contain a higher percentage of protein.

4.6.3. Fiber contents

Under this section, results for NDF, ADF, ADL, Hemicellulose and Celluloses will be discussed. As indicated in Table 7, there was no significant effect of row spacing and its interaction with variety on fiber composition (P>0.05). Nevertheless, fiber composition was highest in sole desho grass as compared to its intercropping with both varieties, whereas the result of intercropping with the two vetch varieties made no difference to each other.

The neutral detergent fiber (NDF) of a feed is important for determining within the parameter of digestibility. The lower content of NDF appeared in *desho* grass intercropped with vetches than the sole grass because of the ability of legumes to fix nitrogen in the soil which helps to improve nutritional values of grass or non-legume forages and which results in reduction of NDF content of forages. Njoka *et al.* (2006) and Taye *et al.* (2007) also noted that intercropping of Napier grass with legumes has a significant effect on NDF contents of the forage. However, the current result disagrees with the finding of Semman and Animut (2014) who noted that the intercropping of Napier grass with lablab has no significant effect on NDF content of Napier grass. This difference may be due to atmospheric nitrogen fixation by the respective legumes.

Tessema (2008), and Semman and Animut (2014) also noted that plant density does not affect the NDF content of Napier grass. Contrarily, Tilahun *et al.* (2017) found out that the value of NDF of *desho* grass was affected by plant densities and harvesting stage at highland of Ethiopia. The mean values of NDF content of *desho* grass intercropped with vetches and alone obtained in the present study was lower than the mean NDF values of *desho* grass harvested at 120 days growth stage reported by Bimrew (2016) at high altitude of northern Ethiopia. The variability in %NDF content might be attributed to agro-ecology, soil fertility, altitudes and intercropping system of legumes with grass.

Roughage diets with NDF content of 45-75% and below 45% were generally considered as medium and high quality feeds respectively (Singh and Oosting, 1992). Accordingly, the current results in NDF content lies in the medium range signifying the good nutritional value of the forage of the current study. According to Van Seost (1982), reducing the contents of NDF has been associated with increasing digestibility and hence improve feed intake. The lower NDF content in *desho* grass /legume associations as compared to sole *desho* grass indicated improvement in nutritive value through improved digestibility and hence feed intake (Van Seost, 1994; McDonald *et al.*, 2002). Legumes benefited *desho* grass by fixing atmospheric nitrogen and therefore improving the CP content and reducing the fibers content of forages (Schwenge and Kerridge, 2000).

Acid detergent fiber is the percentage of highly indigestible forages and slowly digestible material in a feed or forage. Intercropping legumes had a significant effect on ADF of *desho* grass ($P<0.05$), but not affected by row spacing and by the interaction of the two factors (Table 7). Lower ADF indicates more digestible forage and is more desirable. In the present study, pure *desho* grass had significantly higher ADF content than the grass in intercropping with *Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana. Hence, grass-legume intercropping could be of an advantage in reducing the ADF content of forages. The result of the present study is in agreement with that reported by Demlew *et al.* (2019) who noted that grass-legume mixture decreases the ADF content of the grass. Similarly, Taye *et al.* (2007) noted that intercropping Napier grass with lablab has significant effect on ADF content of the forage. Higher ADF content in pure grass of the current study was in line with that reported by Ojo *et al.* (2013) who noted that the ADF value of the sole *Panicum maximum* had a higher value than the *Panicum maximum* in intercropped with *Lablab purpurues*. The lower value of ADF recorded from the intercropped grass is in line with the report of Njoka *et al.* (2006) that intercropping legumes benefit the associating grasses by improving the CP content, thereby reducing the fiber content.

Lack of difference among treatments due to spacing in the present study on ADF content of *desho* grass was in line with the report of Tilahun *et al.* (2017) who reported that ADF content of *desho* grass was not affected by plant densities. In addition, Semman and Animut, (2014) reported that spacing and interaction of spacing and intercropping of Napier grass with lablab has no significant effect on the ADF content of Napier grass.

Roughages with less than 40% ADF are categorized as high quality and those with greater than 40% as poor quality (Kellems and Church, 1998). Except the sole *desho* grass planted at narrow (42.32%) and intermediate (40.97%) row spacing, the ADF value of *desho* grass in the present study when intercropped with vetch varieties are less than 40% and lies within the range of high quality feeding value of the grass.

The ADL content of *desho* grass was not significantly affected (P>0.05) by intercropping, spacing and the interaction of intercropping different vetch varieties with spacing (Table 7). Regarding the spacing effect, it agrees with the finding of Tessema (2008) which noted that the plant density has no significant effect on ADL content of Napier grass. However, the result of the current study disagreed with the finding of Tilahun *et al.* (2017) who stated that ADL content of *desho* grass was affected by planting densities and harvesting age in the northern highland of Ethiopia.

Absence of significant difference (P>0.05) in the present result on ADL content of *desho* grass conformed with the finding of Semman and Animut, (2014) who noted that intercropping, spacing and the interaction of intercropping with spacing has no significant effect on ADL content of Napier grass. The present study agreed with the report of Ojo *et al.* (2013) who stated that the ADL values of the sole *Panicum maximum* was higher than intercropped with *Lablab purpureus* across the harvesting time, and this shows that the sole grass is less digestible compare to the intercropped one by the animals. The ADL content of *desho* grass in the present study was higher than the maximum level of 7% that limits DM intake and livestock production (Reed *et al*., 1986). Lignin is completely indigestible and forms lignin-cellulose /hemicelluloses complexes (Kellems and Church, 1998) due to physical encrustation of the plant fiber and making it unavailable to microbial enzymes (McDonald *et al*., 1995).

Intercropping, spacing and interaction of intercropping *desho* grass with *Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana at different row spacing has no significant effect on hemicelluloses of *desho* grass (Table 7). This result is in line with the reports of Semman and Animut (2014) who reported that intercropping Napier grass with lablab, spacing and their interaction has no significant effect on hemicelluloses content of Napier grass. Similarly, Tessema (2008) also noted that the plant density has no significant effect on Hemicellulose contents of the Napier grass.

Contrarily, Taye *et al.* (2007) reported that intercropping Napier grass with lablab has a significant effect on hemicellulose content of Napier grass. The result disagreed with Negash *et al.* (2017) who reported that there is a significant effect ($P<0.05$) when mixed pure stands of oat and vetch by different plant population on hemicelluloses content of oats forage. Such variation might be associated with environmental factors. Hemicelluloses contents of most tropical grasses are 35.4% as noted by Moore and Hatfield, (1994) and therefore, the hemicelluloses content of *desho* grass in the present study was below most tropical grasses.

The cellulose content of *desho* grass was significantly ($P<0.05$) affected by intercropping with legumes, but not affected by row spacing and by the interaction of the two factors (Table 7). Sole *desho* grass had significantly higher cellulose content than *desho* grass in intercropped with vetches. This might be due to the benefit of intercropping legumes with grass which has reduced the fiber content. Numerically the highest celluloses content (33.89%) was recorded from sole *desho* grass at 0.50 m row space (T1) followed by sole *desho* grass at 0.75 m space (T5) (32.77%) and 1 m row space (T9) (31.46%) whereas the lowest (30.03%) was recorded from plants of *desho* grass intercropped with *Vicia dasycarpa* lana at 0.75 m space (T7). This result is in line with the reports of Semman and Animut (2014) who reported that spacing and interaction of intercropping Napier grass with lablab at different spaces has no significant effect on cellulose content of Napier grass. This result was contrary with Negash *et al.* (2017)

who reported that mixed and pure stands of oats and vetch significantly affected ($P<0.05$) the cellulose contents of oats forage. This difference might be due to different ecological conditions, harvest time and different varietal materials.

4.7. Chemical Composition of Vetches

The chemical composition of vetch varieties intercropped in *desho* grass and the pure stand was given in Table 8. Intercropping, row spacing and interaction of intercropping with spacing did not affect ($P>0.05$) the dry matter content of vetch varieties.

The present result showed that the ash content of vetch species significantly ($P<0.05$) varied among vetch varieties when intercropped with *desho* grass. But no significant difference was observed among spaces and interaction of intercropping and spaces (Table 8). Among vetches intercropped in *desho* grass, the highest ash content (10.3%) was recorded from *Vicia dasycarpa* lana whereas the lowest (9.01%) was recorded from *Vicia sativa* ICARDA 61509. Intermediate to late maturing vetch species (*Vicia dasycarpa*) had relatively higher ash content than early maturing vetch species (*Vicia sativa*), which could be due to differences in proportions and composition of morphological fractions (Gezahagn *et al.*, 2013).

Interaction effect had no a significant effect on CP content of vetch varieties, while the CP content of vetches significantly affected by intercropping and row spacing (Table 8). The CP content of *Vicia dasycarpa* lana intercropped with *desho* grass was greater than *Vicia sativa* ICARDA 61509 and also sole sown vetches had higher crude protein than with respective vetches intercropped in the grass. This difference was attributed to species or varietal differences among the legumes. This result was in agreement with Rahetlah *et al.* (2010) who reported that pure stand of vetch had higher CP concentration than vetch mixed in oat. However, in the current result, sole *Vicia sativa* ICARDA 61509 had higher CP content than the result reported by Kassahun and Wasihun, (2015) and this variation could be due to agro ecology differences, rainfall, temperatures and soil fertility factors. The present result was in line with Gezahagn *et al.* (2013) who reported that *Vicia dasycarpa* species had comparatively higher CP content than *Vicia sativa* species.

Among the row spaces, vetches sown at intermediate and wider spacing had higher CP content than narrow space (0.50 m) which might be due to more soil resource competition by the grass. Getnet and Ledin (2001) reported that vetch has a higher CP content compared to many other tropical herbaceous legumes. Most of the herbaceous legumes have CP content of >15%, a level which is usually required to support lactation and growth, which suggests the adequacy of herbaceous legume to supplement basal diets of predominantly low quality pasture and crop residues (Norton, 1982). Therefore, the result of the present study was greater than the required CP for lactation and growth of animal.

Interaction effect and intercropping had no significant effect on NDF content of legumes (vetch varieties), while the NDF content of vetches was significantly affected by spacing (Table 8). The NDF content of vetches at narrow and intermediate spaces were higher than the wider space. This is because of inter-row plant competition at wider space was less than at narrow and intermediate spaces. The mean NDF values of intercropped vetch varieties were higher than the pure vetches tested in the present study and this is probably due to legumes share resources from the grass as compared to pure stand vetch. Among the pure stand legumes, Sole *Vicia dasycarpa* lana had higher NDF content than sole *Vicia sativa* ICARDA 61509. This result was contrary with the report by Gezahagn *et al.* (2013) who noted that *Vicia sativa* species had higher NDF content than *Vicia dasycarpa* and *Vicia antropurpurea* species and also he reported that early maturing and erect growing type of vetch species had comparatively higher NDF content than intermediate to late maturing and creeping type of vetch species. The NDF contents is above the critical value of 60% result which can decrease voluntary feed intake, feed conversion efficiency and longer rumination time (Meissner *et al*., 1991). However, the NDF content of all the tested vetch species was found below this threshold level which indicates higher digestibility. A high amount of protein is associated with NDF, increasing the ruminal and total tract digestibility (Mustafa *et al*., 2000).

Interaction effect and intercropping had no significant effect on ADF content of legumes (vetch varieties), while the ADF content of vetches was significantly affected by spacing (Table 8). The result revealed that the vetch varieties in narrow space recorded the highest ADF content (34.41%) than intermediate space insignificantly and wider space significantly. The current result showed sole sown vetch varieties had lowest ADF content than for the overall mean of vetch varieties intercropped in the grass at different row spaces. Legumes with less than 31% ADF values are rated as having superior quality whereas those with values greater than 55% are considered as inferior quality (Kazemi *et al.*, 2012). Therefore, the ADF content of vetch varieties in the current study was categorized in the medium range of quality.

The ADL content of *Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana intercropped in *desho* grass was significantly affected by intercropping, but not significantly affected by ($p>0.05$) row spaces and interaction of both factors. *Vicia dasycarpa* lana intercropped in *desho* grass had significantly higher ADL values than *Vicia sativa* ICARDA 61509 and this is due to variation among species of the legumes. The ADL of vetches intercropped in *desho* grass was ranged from 6.71% to 9.1% with an overall mean of (8.47%) which was slightly higher than sole sown vetches.

Table 8. Chemical composition of vetches (Mean±SE) as affected by intercropping, row spacing and their interactions

Factors	Parameters					
	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)
Varieties intercropped						
DVS	92.14±0.15	9.01±0.25[b]	17.36±0.32[b]	47.28±0.38	33.19±0.35	8.04±0.25[b]
DVD	92.47±0.13	10.3±0.23[a]	18.58±0.36[a]	46.64±0.49	33.87±0.41	8.90±0.19[a]
P-value	0.126	0.004	0.014	0.157	0.107	0.013
Row spacing (m)						
0.50	92.07±0.16	9.56±0.43	17.04±0.41[b]	48.16±0.41[a]	34.41±0.24[a]	8.95±0.18
0.75	92.42±0.12	9.37±0.42	18.34±0.23[a]	46.87±0.34[a]	33.43±0.30[ab]	8.42±0.25
1	92.42±0.23	10.06±0.33	18.53±0.55[a]	45.85±0.42[b]	32.74±0.58[b]	8.04±0.42
P-value	0.304	0.299	0.029	0.004	0.016	0.071
Interaction Effect						
DVS * 0.50 m	91.91±0.28	8.94±0.47	16.49±0.27	48.13±0.88	34.13±0.24	8.80±0.35
DVS * 0.75 m	92.32±0.14	8.52±0.11	17.96±0.21	47.21±0.51	33.28±0.61	7.96±0.28
DVS * 1 m	92.18±0.34	9.56±0.46	17.64±0.72	46.51±0.24	32.16±0.31	7.37±0.24
DVD * 0.50 m	92.23±0.15	10.18±0.58	17.60±0.68	48.19±0.25	34.69±0.38	9.10±0.14
DVD * 0.75 m	92.52±0.21	10.23±0.39	18.73±0.26	46.52±0.43	33.59±0.26	8.88±0.13
DVD * 1 m	92.66±0.31	10.57±0.29	19.43±0.44	45.2±0.63	33.32±1.11	8.71±0.62
Overall mean	92.30	9.67	17.97	46.96	33.53	8.47
Sole *Vicia sativa*	92.13	9.09	18.40	40.61	30.56	7.10
Sole *Vicia dasycarpa*	91.93	9.76	19.87	43.45	32.39	8.26
P-value	0.847	0.717	0.605	0.445	0.658	0.358
CV (%)	0.46	7.75	4.87	1.91	2.42	7.08

[a-c] Means with different letters in a column significantly different ($P<0.05$). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped with Vicia dasycarpa lana; DM = dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; m = meter; CV =coefficient of variation.

4.8. *In Vitro* Digestibility and Metabolizable Energy values of *Desho* Grass

4.8.1. *In Vitro* Dry Matter and Organic Matter Digestibility

Intercropping vetches had a significant effect (P<0.05) on the *in vitro* dry matter digestibility of d*esho* grass (Table 9). *Desho* grass intercropped with vetches had higher IVDMD (P<0.05). The highest *in vitro* dry matter digestibility of *desho* grass (67.79%) was recorded when intercropped with *Vicia sativa* ICARDA 61509 followed by grass intercropped with *Vicia dasycarpa* lana (65.88%) whereas the lowest was recorded from sole *desho* grass (62.14%). This is in line with the finding of Njoka *et al.* (2006) which noted that Napier grass intercropped with *Seca stylosanthes* was significantly more digestible than the sole Napier grass. This is partly because while intercropping the grass with lablab there is an increase in crude protein and a decrease in ADF and ADL, which increases the IVDMD of the Napier grass (Tessema, 2000; Njoka *et al.,* 2006). Contrary to intercropping, row spacing and interaction of intercropping with spacing had no significant effect (P>0.05) on *in vitro* dry matter digestibility of *desho* grass (Table 9). The IVDMD value of *desho* grass intercropped with vetch varieties at a different spacing in the present study was lower than the result reported by Semman and Animut (2014), for IVDMD of Napier grass intercropped with lablab at different spacing when harvested at 90 days. Such variation could be associated with various factors like rainfall, light and temperature, soil fertility, varietal difference, harvesting stage and other management practices.

The nutritive value of forages like voluntary feed intake, crude protein, and structural carbohydrates and the digestibility of the grass could be improved by the inclusion of legume with grass (Negash *et al.,* 2017). Grass associated with legume inclusion might increase feed intake as the IVDMD and feed intake are positively correlated (Van Seost, 1994). Owen and Jayasuriya (1989) noted that the critical threshold level of IVDMD for feeds to be 50% to be considered as having acceptable digestibility. Similarly, Mugerwa *et al*. (1973) stated that digestibility higher than 65% indicates good nutritive value and values below this level limit intake. Hence, the *In Vitro* Dry Matter Digestibility (IVDMD) value of *desho* grass intercropped within vetch varieties at different spaces of the current study fits with the digestibility of most tropical grasses and it could be considered to be acceptable.

Intercropping vetches had significant effect (P<0.05) on the *in vitro* organic matter digestibility of *desho* grass. *Desho* grass intercropped with vetches had higher IVOMD (Table 9). The highest *in vitro* organic matter digestibility of *desho* grass (60.5%) was recorded when intercropped with *Vicia sativa* ICARDA 61509 followed by grass intercropped with *Vicia dasycarpa* lana (58.75%) whereas the lowest was recorded from sole *desho* grass (54.39%). This is in line with Taye *et al.* (2007) who noted that intercropping Napier grass results significantly in higher values than sole Napier grass. This may be due to the influence of accumulation of cell components (ADF, ADL and crude protein) due to intercropping. Intercropping *desho* grass with vetches improved the IVOMD of *desho* grass indicating that the feeding value of *desho* grass can be enhanced in terms of nutrient content and digestibility.

Contrary to intercropping, row spacing and interaction of intercropping with spacing had no significant effect (P>0.05) on *in vitro* organic matter digestibility of *desho* grass (Table 9). The IVOMD value of *desho* grass intercropped with vetch varieties at different spacing in the present study was lower than the result reported by Semman and Animut (2014), for IVOMD of Napier grass intercropped with lablab at different spacing when harvested at 90 days. This variation might be due to a number of factors like climate, season, weather, soil type and fertility, varietal difference, soil moisture, physiological and morphological characteristics, harvesting stage and these factors may vary with annuals versus perennials, grasses versus legumes, etc (Kilcher, 1981). Those factors bring rate of change in nutrient composition and digestibility with advancing plant development and maturity stages. The extent of digestion of *desho* grass when intercropped with vetches was greater than for sole *desho* grass and this is in line with that noted by Njoka *et al.* (2006) that legumes in association with grasses positively influence digestibility of the grass probably due to increased N level from legume. The IVOMD values of *desho* grass in the present study was above the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989).

4.8.2. Metabolizable Energy

Since the metabolizable energy (ME) was calculated from IVOMD values in this study, the ME content took a similar trend as that of IVOMD. Intercropping vetches had a significant effect (P<0.05) on the Metabolizable energy of *desho* grass. *Desho* grass intercropped with vetches had higher ME (Table 9). Among the intercropping effect, the highest ME of *desho* grass (9.08 $MJkg^{-1}$) was recorded when intercropped with *Vicia sativa* ICARDA 61509 whereas the lowest was recorded from sole *desho* grass (8.16 $MJkg^{-1}$). Contrary to intercropping, row spacing and interaction of intercropping with spacing had no significant effect (P>0.05) on ME content of *desho* grass (Table 9). Metabolizable energy for all intercropping, spacing and interaction of intercropping with spacing was higher than the critical thresh hold level of 7.5 $MJkg^{-1}$ for roughages and forages as noted by (Owen and Jayasuriya, 1989).

Table 9**.** *In vitro* digestibility and Metabolizable energy of *desho* grass (Mean±SE) as affected by intercropping, spacing and their interactions

Factors	**Parameters**		
	IVDMD (%)	**IVOMD (%)**	**ME (MJ kg^{-1})**
Varieties Intercropped			
DVS	67.79±0.33[a]	60.50±0.43[a]	9.08±0.16[a]
DVD	65.88±0.34[b]	58.75±0.35[b]	8.81±0.14[a]
SD	62.14±0.34[c]	54.39±0.46[c]	8.16±0.23[b]
P-value	<.0001	<.0001	0.012
Row spacing (m)			
0.50	65.16±1.08	57.71±1.23	8.66±0.23
0.75	65.47±0.83	58.57±0.77	8.79±0.24
1	65.18±0.73	57.36±0.89	8.60±0.20
P-value	0.766	0.060	0.793
Interaction effect			
DVS * 0.50 m	68.31±0.78	61.39±0.50	9.21±0.40
DVS * 0.75 m	67.69±0.52	60.85±0.40	9.13±0.22
DVS * 1 m	67.36±0.43	59.25±0.74	8.89±0.25
DVD * 0.50 m	65.87±0.34	58.45±0.86	8.77±0.24
DVD * 0.75 m	66.13±1.02	59.13±0.26	8.87±0.17
DVD * 1 m	65.63±0.41	58.68±0.72	8.80±0.39
SD * 0.50 m	61.30±0.77	53.30±0.61	8.00±0.18
SD * 0.75 m	62.59±0.36	55.72±0.31	8.36±0.70
SD * 1 m	62.54±0.39	54.14±0.74	8.12±0.33
Overall mean	65.27	57.88	8.68
P-value	0.392	0.086	0.952
CV (%)	1.54	1.76	6.69

[a-c] Means with different letters in a column significantly different (P<0.05). DVS= desho grass intercropped with Vicia sativa ICARDA 61509; DVD= desho grass intercropped with Vicia dasycarpa lana; SD= sole desho grass; IVDMD= in vitro dry matter digestibility; IVOMD= in vitro organic matter digestibility; ME= metabolizable energy; m = meter; MJ = mega joule; kg = kilogram; CV = coefficient of variation.

4.9. *In Vitro* Digestibility and Metabolizable Energy Values of Vetch

4.9.1. *In Vitro* Dry Matter and Organic matter Digestibility of Vetches

The *in vitro* dry matter digestibility of vetch varieties was significantly affected by intercropping and spacing, however, no significant difference (P>0.05) by the interaction of intercropping with spacing was declared (Table 10). Among vetch varieties intercropped in the grass, *Vicia dasycarpa* lana was the highest, while the lowest was obtained from *Vicia sativa* ICARDA 61509 (P<0.05). This might be due to competition of nutrient among the legumes with grass and inherent characteristics difference. The result was concurrent with Gezahagn *et al.* (2013) who reported that the early maturing vetch species had lower IVDMD compared to intermediate to late maturing vetch species that could be due to the presence of higher fibers and cell wall constituents, and low crude protein in early maturing vetch than the intermediate to late maturing vetch species. The overall mean value of IVDMD of vetches intercropped in *desho* grass was lower than sole sown vetches (Table 10).

Among the row spaces, the highest IVDMD vetches were recorded at wider row spacing (1 m) which was not statistically different from intermediate row space (0.75 m), whereas the lowest was recorded at narrow row spacing (0.50 m). This could be due to the competition of environmental resources which may result in the presence of higher fiber and cell wall constituents and lower CP contents in narrow space than wider space. IVDMD of any forage crop varied with harvesting stage, fiber and cell wall constituents (Mustafa *et al.*, 2000); proportions of morphological fractions (Fekede, 2004); soil, plant species and climate (Getnet and Ledin, 2001). The IVDMD values greater than 65% indicates good feeding value and values below this threshold level result in reduced intake due to lowered digestibility (Magerwa *et al.*, 1973). The IVDMD values observed in this study were below this threshold level for all vetches which may implicate lower voluntary intake and digestibility except sole *Vicia dasycarpa* lana.

The *in vitro* organic matter digestibility (IVOMD) of vetch varieties was significantly different (P<0.05) at intercropping and interaction of intercropping with spacing, however, no significant difference (P>0.05) due to row spacing was noticed (Table 10). Among vetch varieties intercropped in the grass, *Vicia dasycarpa* lana produced higher IVOMD than *Vicia* *sativa* ICARDA 61509 ($P<0.05$). This might be due to competition of nutrient among the legumes with grass and inherent characteristics difference.

The interaction of intercropping with spacing was significantly ($P<0.05$) affecting the IVOMD of vetches. The IVOMD ranged from 47.26% to 57.97% with a mean of 52.99%. The highest IVOMD of vetch (57.97%) was recorded from *Vicia dasycarpa* lana intercropped in *desho* grass at wider row spacing (1 m) (T8) followed by *Vicia sativa* ICARDA 61509 at 0.75 m space (T3) (54.36%), *Vicia dasycarpa* lana intercropped in *desho* grass at 0.75 m spacing (T7) (54.13%) respectively, whereas the lowest (47.26%) was recorded from *Vicia sativa* ICARDA 61509 intercropped in *desho* grass at wider (1 m) row spacing (T4). On the other hands, the values of IVOMD of sole vetches were higher than the overall mean of interaction treatments of vetches within the grass. Therefore, in the present study the mean IVOMD values of vetches were higher than the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989).

4.9.2. Metabolizable Energy

Intercropping vetches with *desho* grass significantly ($P<0.05$) affected the metabolizable energy (ME) of vetch varieties used in the current experiment. However, row spacing and interaction of intercropping with spacing did not significantly affect ($P>0.05$) the ME content of the vetch varieties (Table 10). Among the intercropping effect, higher ME (8.27 $MJkg^{-1}$) was obtained from *Vicia dasycarpa* lana intercropped in *desho* grass as compared to *Vicia sativa* ICARDA 61509. In general, Metabolizable energy for all intercropping, spacing and interaction of intercropping with spacing was higher than the critical threshold level of 7.5 $MJkg^{-1}$ for roughages and forages as noted by (Owen and Jayasuriya, 1989).

Table 10. *In vitro* digestibility and Metabolizable energy of vetches (Mean±SE) as affected by intercropping, row spacing and their iteractions

Factors	**Parameters**		
	IVDMD (%)	**IVOMD (%)**	**ME (MJ kg^{-1})**
Varieties intercropped			
DVS	61.19±0.73^{b}	50.85±1.23^{b}	7.63±0.25^{b}
DVD	63.62±0.51^{a}	55.14±1.01^{a}	8.27±0.15^{a}
P-value	0.002	0.006	0.044
Row spacing (m)			
0.50	60.79±0.99^{b}	52.14±0.87	7.82±0.20
0.75	63.31±0.52^{a}	54.24±0.92	8.13±0.19
1	63.12±0.86^{a}	52.62±2.59	7.89±0.42
P-value	0.009	0.378	0.639
Interaction Effect			
DVS * 0.50 m	59.03±1.05	50.93±1.15^{bc}	7.64±0.38
DVS * 0.75 m	63.16±0.78	54.36±1.70^{ab}	8.15±0.34
DVS * 1 m	61.39±0.61	47.26±1.21^{c}	7.09±0.45
DVD * 0.50 m	62.55±0.83	53.34±1.02^{b}	8.00±0.14
DVD * 0.75 m	63.46±0.84	54.13±1.17^{ab}	8.12±0.26
DVD * 1 m	64.85±0.60	57.97±1.90^{a}	8.69±0.20
Overall mean	62.41	52.99	7.95
Sole *Vicia sativa*	63.77	54.73	8.21
Sole *Vicia dasycarpa*	65.38	56.38	8.46
P-value	0.078	0.012	0.089
CV (%)	1.98	4.93	7.44

[a-c] Means with different letters in a column significantly different (P<0.05). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped with Vicia dasycarpa lana; IVDMD = in vitro dry matter digestibility; IVOMD= in vitro organic matter digestibility; ME = Metabolizable energy; m = meter; MJ = mega joule; kg = kilogram; CV =coefficient variation.

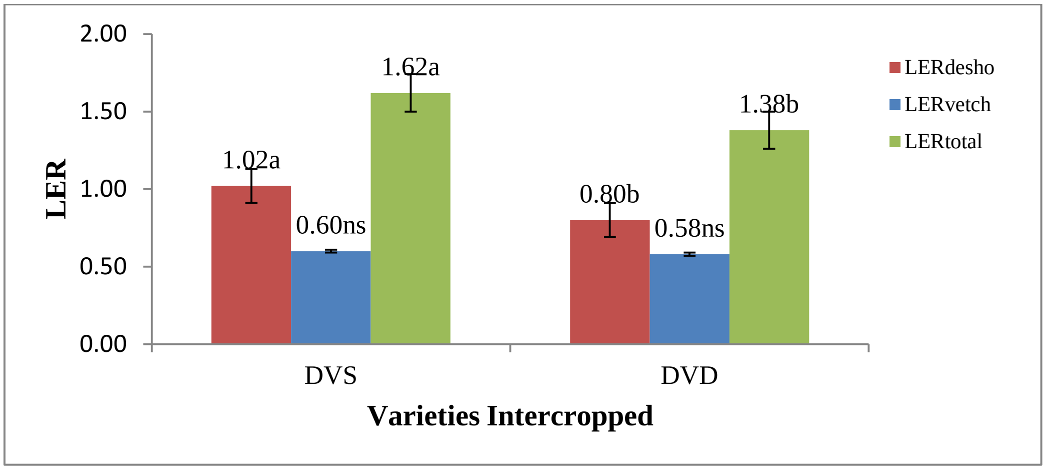
4.10. Biological Compatibility and Yield Advantages of *Desho* and Vetch Intercrops

4.10.1. Land Equivalent Ratio

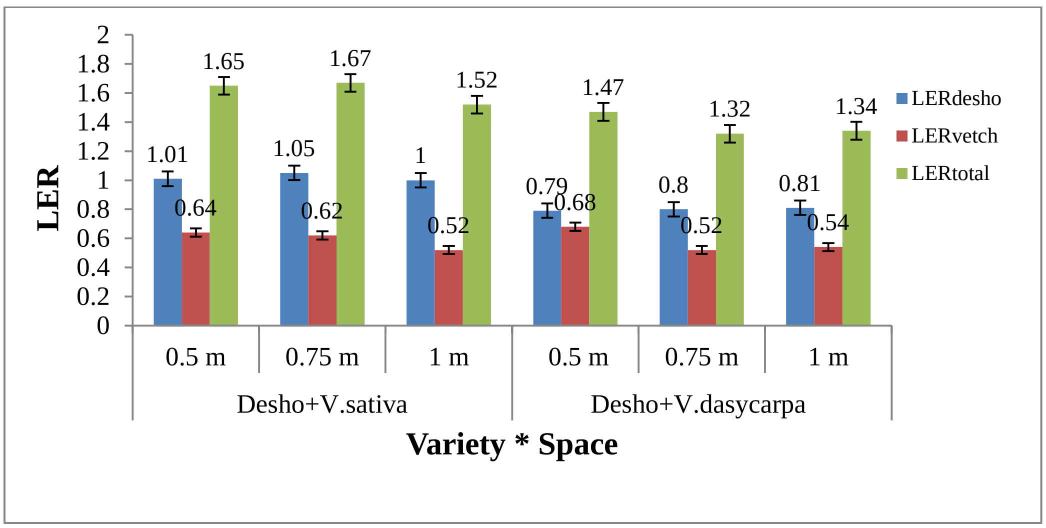
Land Equivalent Ratio is the most important commonly used indicator of the biological efficiency and DM yield per unit area of land as compared to mono cropping system. The land equivalent ratio (LER) for intercropping of vetch varieties and *desho* grass under different row spaces were shown in Figure 8 (a) and (b). Interaction effect and row spacing did not significantly ($P>0.05$) affect the partial and total LER of *desho-vetch* intercropped forage. It showed that the total LER and partial LER of *desho* grass had significant differences under the influence of intercropping different vetch varieties ($P<0.05$), but partial LER of vetch was not significantly affected by intercropping. The partial LER of *desho* grass was higher than that of vetch varieties, thereby showing that the grass component contributed more to the total LER of the intercropping system than the vetches component.

In the current study, intercropping *desho* grass with *Vicia sativa* ICARDA 61509 gave higher LER than *desho* grass intercropped with *Vicia dasycarpa* lana. This indicates that *Vicia sativa* ICARDA 61509 was more favored for intercropping with *desho* grass than *Vicia dasycarpa* lana because due to varietal difference on growth habits. The maximum LER values (1.62) was obtained from *desho* grass with *Vicia sativa* intercropping, thereby suggesting that the maximum advantage of intercropping was obtained by coordinating the growth of both crops in the *desho*-vetch intercropping system. Whereas the lowest (1.38) was obtained from *desho* grass intercropped with *Vicia dasycarpa* lana.

The total LER ranged from 1.32 to 1.67. This indicates that 32 % to 67 % more land area would be required by a mono cropping system for equal yield of intercropping system, which indicated the advantage of the intercrops over mono crops. Higher LER indicates yield advantages because of improved land productivity in intercropping (Mead and Willey, 1980). All the intercrops showed total LER greater than one. With the values of total LER greater than 1 from the results, showing that intercropping is advantageous. Yield advantage in terms of total LER was greatest in the cases of *desho* grass and *Vicia sativa* ICARDA 61509 intercropping at 0.75 and 0.50 m row spacing. This indicates an advantage from intercropping over pure stand in terms of the use of environmental resources for plant growth and better land utilization. This result is in line with the finding of Dawit and Nebi (2017), who reported in maize-vetches intercropping system, LER of the dry matter yield varied from 1.33 to 1.51 that intercropped under different agro-ecologies corresponding to the sole, yield advantages have been recorded.



(a)



(b)

Figure 8. Land Equivalent ratio (LER) for intercrops of vetch varieties with *desho* grass at three row spacing and their interactions

Different letters within the same LER (bars with the same color in the graphs) indicate statistically significant differences at (P<0.05). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped with Vicia dasycarpa lana; LER = land equivalent ratio.

4.10.2. Relative Yield and Relative Yield Total

The relative yield (RY) of *desho* grass and vetches as affected by intercropping, spacing and their interaction were given in Table 11. Vetch varieties intercropped in *desho* grass (intercropping) significantly affect (P<0.05) relative yield of *desho* grass and relative yield total (RYT) but no significant difference was observed among vetches. The RY which compare the yield of the component varieties in the intercrops with the respective to pure stand varieties; as indicated *desho* grass in intercropped with *Vicia sativa* ICARDA 61509 had superior RY value than intercropped in *Vicia dasycarpa* lana. This was probably because of creeping behaviour of *Vicia dasycarpa* lana and less resource competition in intercropped *Vicia sativa* ICARDA 61509 with grass as compared to the intercropping of grass with *Vicia dasycarpa* lana.

The RY value of *desho* grass in intercropped with *Vicia sativa* ICARDA 61509 gave yield (1.019) greater than one, indicated that the dry matter yield of *desho* grass obtained from intercropped with *Vicia sativa* ICARDA 61509 was higher than 1.9% in sole stand of *desho* grass. The RY of *desho* grass component in intercropped with vetch varieties were higher than the RY values of legumes, though *desho* grass intercropped with *Vicia sativa* seemingly appropriate for the grass and legume, yet the grass was found to have higher RY values than legumes, which evidently suggests the higher competitive ability of *desho* grass over vetches.

Row spacing and interaction of intercropping with row spacing had no significant effect on RY values of grass, legumes (Table 11). However, generally among row spacing, the RY value of *desho* grass higher than the legumes, and they showed their RY was less than one. The RY values less than one means the yield obtained in the intercropped/mixed stand is less than those obtained in sole/pure stands. Besides, the RY showed a relationship with the row spacing which shows the RY of legumes was decreased trend with an increased row spaces and vice versa in RY of *desho* grass. In the present study, numerically, the relative yield of *desho* grass (1.05) indicated that the dry matter yield of *desho* grass obtained from the intercropping of *desho* grass and *Vicia sativa* ICARDA 61509 at 0.75 m spacing was higher than 5% in sole stand of grass at respective row spacing.

The result from Table 11 revealed that the RYT was significantly affected by intercropping but not affected by row spacing and the interaction of both factors. The greatest RYT (1.616) was observed in the *Desho-Vicia sativa* intercropping significantly higher than *Desho-Vicia dasycarpa* lana (1.381). This indicates that 61.6% and 38.1% more area would be required for a sole cropping system to equal the yield from an intercropping system. Moreover, the RYT of all intercrops of vetch varieties with *desho* grass was greater than one. In the present study, vetch varieties (*Vica sativa* ICARDA 61509 and *Vicia dasycarpa* lana) intercropped with *desho* grass (Kulumsa DZF-592) indicated that the yield obtained from intercropping was better than the yield obtained in the pure stand. In line to the current result, Diriba and Diriba (2013) reported that *Panicum coloratum* grown with *Stylosanthes guianensis* in a different mixture of seed proportions and planting patterns, the grass component performed better than the legume and gave RYT greater than one. Dawit and Nebi (2017) also reported that intercropping vetch with maize was more advantageous than the sole cropping.

4.10.3. Competitive Ratio

The competitive ratio (CR) is the way to know the degree with which one crop competes for the other crops. Results from the analysis of variance for competitive ratio of intercropping *Desho* grass-Vetches as affected by intercropping, row spacing and their interaction were presented in Table 11. The interaction effect did not significantly affect (P>0.05) the CR values of grass and legumes, and also row spacing not significantly affected the CR of grass but significantly affected the CR values of vetches. However, CR values of grass and legume was significantly affected by intercropping factor. The intercropped *desho* grass with *Vicia sativa* ICARDA 61509 gave significantly higher CR than *desho* grass intercropped with *Vicia dasycarpa* lana. The reverse pattern to that of the grass was observed for the legume component in intercropping. For the *desho-Vicia sativa* ICARDA 61509 intercropping, the CR of legume was less by 19.53% than the legume in *Desho-Vicia dasycarpa* lana intercropping, suggesting that *Vicia sativa* ICARDA 61509 to be less competent than *Vicia dasycarpa* lana when intercropped with *desho* grass.

Regarding the effect of row spacing, the legume was favoured in the narrow row spacing (0.50 m) followed by 0.75 m row spacing whereas the least CR was recorded in wider spacing (1 m). In case of an interaction effect, numerically, the lower CR values for the legumes (intercrops) than the based *desho* grass indicated that all the legumes under study were less competitive than *desho* grass when grown in intercropped with each other under all the interaction effects. It is thus evident from the data regarding CR that *desho* grass in each cropping system was dominant while legumes (vetches) were dominated. Among the vetches, *Vicia dasycarpa* lana proved to be the better competitive when in intercropped with *desho* grass. This result was supported by the findings of Azraf-ul-Haq *et al.* (2007) who reported that sorghum intercropped with different legumes at different planting patterns more competent than intercrops legumes and had yield advantages over the legumes.

4.10.4. Aggressivity

Aggressivity indicates that the dominance of certain species in component species. The results of Aggressivity confirmed to those of Relative yield (Table 11). Aggressivity of *desho* grass was higher in intercropped both vetch varieties. In the present study, *desho* grass had positive values of Aggresivity indicating *desho* grass was more dominant than *Vicia sativa and dasycarpa* and it was insignificantly increased as spaces increased. Such a result was expected since the grasses are likely to be more competitive than legumes. The current result was in line with the findings of Arsyadi *et al.* (2014) who noted that *Bracharia decumbens* was more dominant than *Centrosema pubescens* and *Clitoria ternatea* when mixed cropped with the two legumes. Among vetch varieties intercropped in *desho* grass, *Vicia dasycarpa* lana relatively less dominated than *Vicia sativa* ICARDA 61509 by the grass and this might be due to varietal and morphological characteristic difference of the legumes. Also, the dominance of *desho* grass was probably due to forming more tillers that could compete for nutrients and space over legumes.

Generally, in the present study, it was observed that the compatibility of forage grass-legume intercropping is considerably affected by varieties of the forage legumes. This is supported by Getnet *et al.* (2011), who noted that the compatibility of cereal crop and legumes (in case of Barley and vetch) is considerably affected by species of the forage legumes, varieties of the cereal crops, soil effect (location) and fertilizer application. Therefore, *desho* grass was found to be better compatible and gave high considerable forage yield when intercropped with *Vicia sativa* ICARDA 61509 than *Vicia dasycarpa* lana.

Table 11. Relative yield, Relative yield total, Competitive Ratio and Aggressivity as affected by row spacing and *desho* grass based- intercropping systems

Sources	**Relative Yield (RY)**			**Competitive Ratio (CR)**		**Aggressivity (A)**	
Varieties intercropped	*Desho*	Vetch	Total	*Desho*	Vetch	*Desho*	Vetch
DVS	1.019[a]	0.597	1.616[a]	1.740[a]	0.589[b]	0.422[a]	- 0.422[b]
DVD	0.799[b]	0.582	1.381[b]	1.398[b]	0.732[a]	0.217[b]	- 0.217[a]
SE	0.034	0.027	0.048	0.084	0.032	0.038	0.038
P-value	0.0011	0.711	0.0062	0.016	0.010	0.0036	0.0036
Row spacing (m)							
0.50	0.898	0.662	1.560	1.372	0.753[a]	0.237	- 0.237
0.75	0.925	0.573	1.498	1.615	0.623[b]	0.352	- 0.352
1	0.903	0.533	1.437	1.720	0.605[b]	0.370	- 0.370
SE	0.042	0.033	0.059	0.103	0.039	0.047	0.047
P-value	0.893	0.053	0.369	0.094	0.045	0.146	0.146
Interaction effect							
DVS * 0.50 m	1.007	0.640	1.647	1.587	0.640	0.367	- 0.367
DVS * 0.75 m	1.050	0.623	1.673	1.703	0.590	0.427	- 0.427
DVS * 1 m	1.000	0.527	1.527	1.930	0.537	0.473	- 0.473
DVD * 0.50 m	0.790	0.683	1.473	1.157	0.867	0.107	- 0.107
DVD * 0.75 m	0.800	0.523	1.323	1.527	0.657	0.277	- 0.277
DVD * 1 m	0.807	0.540	1.347	1.510	0.673	0.267	- 0.267
Overall mean	0.909	0.589	1.498	1.569	0.661	0.319	- 0.319
SE	0.059	0.046	0.083	0.145	0.056	0.067	0.067
P-value	0.892	0.309	0.508	0.628	0.390	0.720	0.720

[a,b] Means with different letters in a column significantly different (P<0.05). DVS= desho grass intercropped with vicia sativa ICARDA 61509; DVD= desho grass intercropped with vicia dasycarpa lana; m = meter; SE = standard error.

4.11. Correlation Analysis of Morphological, Yield and Nutritional Parameters of *Desho* Grass intercropped with vetch varieties

The simple bivariate correlation analysis among morphological, quality and yield of *desho* grass are presented in Table 12. NTPP was positively correlated with some morphological parameters such as NLPP and NLPT whereas their correlations with the plant height and leaf length were negative. Plant height at forage harvest showed positive correlation with forage DMY and supported by Fekede (2004) who reported plant height of oat at forage harvest positively correlated with herbage yield. Dry matter content and dry matter yield of *desho* grass were positively correlated with NDF, ADF, ADL, NTPP, NLPP, and NLPT and with each other. DM and DMY positively associated with fibers (NDF, ADF and ADL). This indicated that as the cell wall constituents are contributed for increments of plant parts, the DM content also increased which eventually leads to increment to total DMY. This was agreed with (Bimrew, 2016; Tilahu *et al.*, 2017) reported similar result for *deho* grass. DMY was negatively correlated with crude protein content.

Crude protein content and yield of *desho* grass showed a significant ($P<0.05$) positive correlation with each other and negatively correlated with fiber components (NDF, ADF and ADL). The fiber components (NDF, ADF and ADL) were positively correlated with each other. This indicated that there was a high relationship among the different cell wall constituents that resulted from spacing and intercropping effects among plants and these components of cell wall might be increased as the row spacing decreased and competition within and among plant enhanced especially in pure stand grass. Fibers were positively correlated with some morphological parameters like NTPP, NLPP and NLPT.

IVDMD and IVOMD were positively and significantly correlated with CP and CPY; this indicated that intercropping increased the protein contents which resulted for cell contents in plants which help well digestible. This is in agreement with Tessema *et al.* (2002), who reported that CP showed positive correlation with IVDMD in Napier grass. However, IVDMD and IVOMD negatively correlated with fibers (NDF, ADF, and ADL) this indicates with declined spacing and a pure stand of grass (no legume intercropped) that increased fibers and reduced *in vitro* digestibility. The IVOMD decreased due to increase the structural carbohydrate fraction and the higher degree of reinforcement with indigestible materials specially lignin as described by Van Seost (1982). This result was supported by Taye *et al.* (2007) who stated that *in vitro* digestibility negatively correlated with cell wall fibers in Napier grass and its association with lablab and *desmodium* and in agreement with report of Bimrew (2016) for *desho* grass.

Leaf to stem ratio (LSR) was positively correlated with *in vitro* digestibility (IVDMD and IVOMD) and ME which might be due to leaves are more digestible and have more organic matter that contribute the dry and organic matter digestibility and available energy for metabolism. The direct relationship of LSR with CP and *in vitro* digestibility and indirect association of leaf to stem ratio and fiber was in agreement with reported by Bimrew (2016) for *desho* grass.

Table 12. Correlation coefficient among morphological parameters, chemical composition, yield and *in vitro* digestibility of *desho* grass intercropped with vetch varieties

	DM	DMY	CP	CPY	NDF	ADF	ADL	NTPP	NLPP	NLPT	PH	LL	LSR	Ash	IVDMD	IVOMD	ME
DM	1	0.07	0.03	0.06	0.09	0.35	0.18	0.01	0.35	0.36	-0.08	-0.16	0.28	0.001	-0.31	-0.22	0.14
DMY		1	-0.26	0.75**	0.09	0.27	0.25	0.30	0.19	0.19	0.36	-0.12	-0.16	-0.01	-0.03	0.01	-0.07
CP			1	0.44*	-0.73**	-0.66**	-0.45*	-0.32	-0.59**	-0.47*	0.41*	0.60**	0.02	-0.14	0.72**	0.73**	0.52**
CPY				1	-0.43*	-0.23	-0.09	0.10	-0.23	-0.14	0.62**	0.29	-0.15	-0.08	0.47*	0.52**	0.31
NDF					1	0.66**	0.49*	0.18	0.38*	0.44*	-0.49*	-0.43*	-0.21	0.11	-0.67**	-0.78**	-0.52*
ADF						1	0.61**	0.12	0.42*	0.42*	-0.27	-0.42	0.11	0.10	-0.74**	-0.69**	-0.31
ADL							1	0.23	0.26	0.34	-0.21	-0.16	-0.04	0.04	-0.48	-0.44	-0.12
NTPP								1	0.53**	0.57**	-0.55**	-0.70**	-0.10	0.26	-0.11	-0.13	-0.07
NLPP									1	0.61**	-0.42*	-0.79**	0.0003	-0.04	-0.41*	-0.40*	-0.34
NLPT										1	-0.51**	-0.64**	0.27	0.07	-0.53**	-0.44*	-0.24
PH											1	0.62**	-0.17	-0.13	0.38	0.48*	0.22
LL												1	-0.04	-0.15	0.46*	0.45*	0.43*
LSR													1	0.27	0.33	0.31	0.04
Ash														1	-0.32	-0.19	-0.05
IVDMD															1	0.89**	0.52**
IVOMD																1	0.65**
ME																	1

*Level of significance: * = P<0.05; ** = P<0.01; DM = dry matter; DMY = dry matter yield; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; NTPP = number of tiller per plant; NLPP = number of leaf per plant; NLPT = number of leaf per tiller; PH = plant height; LL = leaf length; LSR = leaf stem ration; IVDMD = in vitro dry matter digestibility; IVOMD = in vitro organic matter digestibility; ME = metabolizable energy.*

5. CONCLUSIONS

In current study, intercropping of vetches with *desho* grass at different row spacing for forage yield revealed improved soil chemical properties after forage harvesting, compared to initial soil samples. Among soil parameters, only total nitrogen was significantly affected ($P<0.05$) by intercropping. Intercropping legumes with grass increased total nitrogen, OC, OM, CEC values but decreased available phosphorous content of the soil after harvest as compared to the initial soil samples.

Intercropping vetches improved the plant height and leaf length of *desho* grass at narrow spacing than wider spacing as compared to the sole planting at different spacing. The number of tillers per plant, leaves per plant and tiller were higher in a pure stand of *desho* grass than intercropped with vetch varieties and they increased as row spacing increases. Among vetch varieties, *Vicia dasycarpa* lana showed higher height, tillers, leaf numbers and leaf length than *Vicia sativa* ICARDA 61509 when intercropped with *desho* grass as well as a pure stand. Similarly, *Vicia sativa* ICARDA 61509 produced higher seed yield with *desho* grass at different row spacing as compared to *Vicia dasycarpa* lana.

The dry matter yield (DMY) and crude protein yield (CPY) of *desho* grass was higher when intercropped with *Vicia sativa* ICARDA 61509 as compared to sole *desho* grass whereas these parameters were lower when intercropped with *Vicia dasycarpa* lana. Intercropping and interaction of intercropping with row spacing resulted in higher total forage yield than pure stand grass due to additive effect of vetch intercropped. Wider row spacing gave lower yield as compared to intermediate and narrow spacing. Intercropping of *desho* grass with *Vicia sativa* and *Vicia dasycarpa* increased the CP content and decreased the fiber contents of the *desho* grass whereas spacing and interaction of both factors did not significantly affect the chemical composition of the grass. Among vetches intercropped with desho grass, *Vicia dasycarpa* lana recorded higher ash, CP and ADL contents than *Vicia sativa* ICARDA 61509 due to varietal difference. The CP content of vetches was increased and the fiber contents (NDF and ADF) decreased as row spacing increased.

IVDMD, IVOMD and ME of *desho* grass were increased by intercropping it with vetches as compared to pure stand grass whereas spacing and interaction of both factors did not significantly affect *in vitro* digestibility of *desho* grass. IVDMD, IVOMD and ME of *Vicia dasycarpa* lana was significantly higher than *Vicia sativa* ICARDA 61509 in intercropped *desho* grass.

LER and RYT of all intercropping were greater than 1 and showed higher yield advantages than sole cropping. The higher yield advantage was recorded for *desho* grass and *Vicia sativa* intercropping system than *desho* grass and *Vicia dasycarpa* intercropping regardless of row the spacing. In different intercropping system, *desho* grass appeared to be the dominant forage by its higher values of competitive ratio and positive sign of aggressivity. In general, *desho* grass grown in association with *Vicia sativa* ICARDA 61509 was more efficient system of intercropping whereas intermediate row spacing followed by narrow spacing was a better choice of spacing for intercropping of grass-legumes in the present study.

6. RECOMMENDATIONS

From the present study legumes improved the overall forage yield and nutritive value of fodder grass than sole grass. Accordingly, *desho* grass intercropped with *Vicia sativa* ICARDA 61509 was a better choice based on compatibility, forage quantity and quality. This can practically be applicable under smallholder farmers in the study area in particular and Ethiopian condition in general. However, the present experiment was conducted in one location over a single season under rain fed condition. Therefore, based on the current work, the following recommendations are highlighted.

- Further study of *desho*-vetch intercropping for their performance over years, across diverse agro ecologies (different locations) and on-farm farmer evaluations are also vital to come up with sound recommendation.
- It is necessary to evaluate the effect of vetch intercropping on the next stage of re-harvesting *desho* grass.
- Furthermore, it is advisable to run animal feeding trail on both forage species to see the associative effect of *desho* and vetch mixtures on animal performance.

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8. APPENDICES

8.1. List of appendix Tables

Table 1. Mean square of ANOVA for morphological characteristics of *desho* grass at forage harvesting stage as affected by intercropping, spacing and their interactions

Source	DF	Mean square				
		NTPP	NLPP	NLPT	PH	LL
Rep	2	10.70 ns	0.44 ns	0.47 ns	17.12 ns	33.56 ns
Varieties intercropped	2	366.67**	11.39**	4.27**	242.63**	231.96**
Row spacing	2	318.87**	3.96**	1.25**	1108.74**	150.92**
VI * RS	4	4.77ns	3.26**	1.39**	70.67**	23.11**
Error	16	7.28	0.36	0.31	22.88	5.85
Total	26					
CV (%)		3.35	3.66	4.89	4.99	6.64

**, ns = significant and non significant at 5%; DF = degree of freedom; NTPP = number of tiller per plant; NLPP = number of leaves per plant; NLPT = number of leaves per tiller; PH = plant height; LL = leaf length; Rep = replication; VI = varieties intercropped; RS = row spacing; CV = coefficient of variation.

Table 2.Mean square of ANOVA for morphological characteristics and yields of vetches as affected by intercropping, spacing and their interactions

Source	DF	Mean square							
		NTPP	NLPP	NLPT	PH	LL	DMY	CPY	SY
Rep	2	0.34 ns	831.01 ns	149.67 ns	36.45 ns	0.04 ns	0.04ns	0.001ns	0.004ns
Varieties intercropped	1	3.46**	94081**	100352**	30455**	0.66**	0.11ns	0.0001ns	0.16**
Row spacing	2	0.17 ns	2246.23**	26 ns	502.52**	0.003 ns	0.41**	0.005**	0.13**
VI * RS	2	0.26 ns	508.45**	284.66**	8.73**	0.04 ns	0.13ns	0.007**	0.007**
Error	10	0.13	436.43	503.33	35.57	0.06	0.05	0.002	0.001
Total	17								
CV (%)		3.35	3.66	4.89	4.99	6.64	9.99	9.84	6.98

**, ns = significant and non significant at 5%; DF = degree of freedom; NTPP = number of tiller per plant; NLPP = number of leaves per plant; NLPT = number of leaves per tiller; PH = plant height; LL = leaf length; SY = seed yield; DMY = dry matter yield; CPY = crude protein yield; Rep = replication; VI = varieties intercropped; RS = row spacing; CV = coefficient of variation.

Table 3. Mean square of ANOVA for chemical composition and *in vitro* digestibility of *desho* grass as affected by intercropping, spacing and their interactions

Source	DF	Mean square										
		DM	Ash	CP	NDF	ADF	ADL	Hemcell	Cell	IVDMD	IVOMD	ME
Rep	2	0.04ns	0.10ns	0.15ns	1.04ns	0.94ns	1.13ns	1.01ns	2.4ns	1.6ns	1.59ns	0.68ns
VI	2	0.52ns	0.81ns	11.97**	15.84**	26.94**	1.44ns	1.49ns	15.91**	74.14**	89.15**	2.004**
RS	2	0.20ns	0.36ns	0.83ns	2.9ns	2.21ns	0.12ns	2.77ns	1.64ns	0.27ns	3.47ns	0.08ns
VI*RS	4	0.32ns	0.71ns	0.44ns	1.55ns	3.01ns	0.19ns	0.45ns	1.69ns	1.1ns	2.56ns	0.05ns
Error	16	0.25	0.81	0.49	0.91	2.15	9.42	3.08	1.59	1.01	1.03	0.33
Total	26											
CV (%)		0.54	9.54	7.20	1.62	3.77	9.95	8.71	4.05	1.54	1.76	6.69

**, ns = significant and non significant at 5%; DM = dry matter; CP = crude protein; NDF =neutral detergent fiber; ADF = acid detergent fiber; ADL =acid detergent lignin; Hemcell = hemicelluloses; Cell= cellulose; IVDMD = *in vitro* dry matter digestibility; IVOMD = *in vitro* organic matter digestibility; ME = metabolizable energy; DF = degree of freedom; Rep = replication; VI = varieties intercropped; RS = row spacing; CV = coefficient of variation.

Table 4. Mean square of ANOVA for yields of *desho* grass as affected by intercropping, spacing and their interactions

Source	DF	Mean square			
		DMY	CPY	TDMY	TCPY
Rep	2	0.46ns	0.008ns	0.51ns	0.005ns
VI	2	7.14**	0.072**	15.78**	0.79**
RS	2	5.01**	0.075**	6.5**	0.10**
VI*RS	4	0.1ns	0.006ns	0.32ns	0.02ns
Error	16	0.43	0.003	0.59	0.006
Total	26				
CV (%)		9.64	7.61	9.14	8.01

**, ns = significant and non significant at 5%; DMY = dry matter yield; CPY = crude protein yield; TDMY = total dry matter yield; TCPY = total crude protein yield; DF = degree of freedom; Rep = replication; VI = varieties intercropped; RS = row spacing; CV = coefficient of variation.

Table 5. Mean square of ANOVA for chemical composition and *in vitro* digestibility of vetches as affected by intercropping, spacing and their interactions

Source	DF	Mean square								
		DM	Ash	CP	NDF	ADF	ADL	IVDMD	IVOMD	ME
Rep	2	0.22ns	0.3 ns	0.23ns	1.24ns	2.67ns	0.25ns	3.9ns	1.09ns	0.05ns
VI	1	0.5ns	7.84**	6.73**	1.88ns	2.06ns	3.27**	26.49**	83.07**	1.86**
RS	2	0.24ns	0.76ns	3.94**	8.01**	4.22**	1.25ns	11.81**	7.34ns	0.16ns
VI*RS	2	0.03ns	0.19	0.4 ns	0.71ns	0.28ns	0.41ns	5.09ns	48.88**	1.08ns
Error	10	0.18	0.56	0.76	0.80	0.65	0.36	1.52	6.83	0.35
Total	17									
CV (%)		0.46	7.75	4.87	1.91	2.42	7.08	1.98	4.93	7.44

**, ns = significant and non significant at 5%; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL =acid detergent lignin; IVDMD = *in vitro* dry matter digestibility; IVOMD = *in vitro* organic matter digestibility; ME = metabolizable energy; DF = degree of freedom; Rep = replication; VI = varieties intercropped; RS = row spacing; CV = coefficient of variation.

Table 6. Mean square ANOVA for biological compatibility as affected by row spacing and *desho* grass based- intercropping systems

Source	DF	Mean square							
		LER	RYd	RYv	RYT	CRd	CRv	Ad	Av
Rep	2	0.004ns	0.004ns	0.001ns	0.004ns	0.04ns	0.004ns	0.005ns	0.005ns
VI	1	0.247**	0.22**	0.001ns	0.247**	0.53**	0.09**	0.19**	0.19**
RS	2	0.022ns	0.001ns	0.026ns	0.022ns	0.19ns	0.04ns	0.03ns	0.03ns
VI*RS	2	0.015ns	0.001ns	0.008ns	0.015ns	0.03ns	0.009ns	0.004ns	0.004ns
Error	10	0.02	0.01	0.006	0.02	0.06	0.009	0.01	0.01
Total	17								

**, ns = significant and non significant at 5%; LER = land equivalent ratio; RYd = relative yield of *desho*; RYv = relative yield of vetches; RYT = relative yield total; CRd = competitive ratio of *desho*; CRv = competitive ratio of vetches; Ad = aggressivity of *desho*; Av = aggressivity of vetches; DF = degree of freedom; Rep = replication; VI = varieties intercropped; RS = row spacing.

8.2. List of Appendix Figures

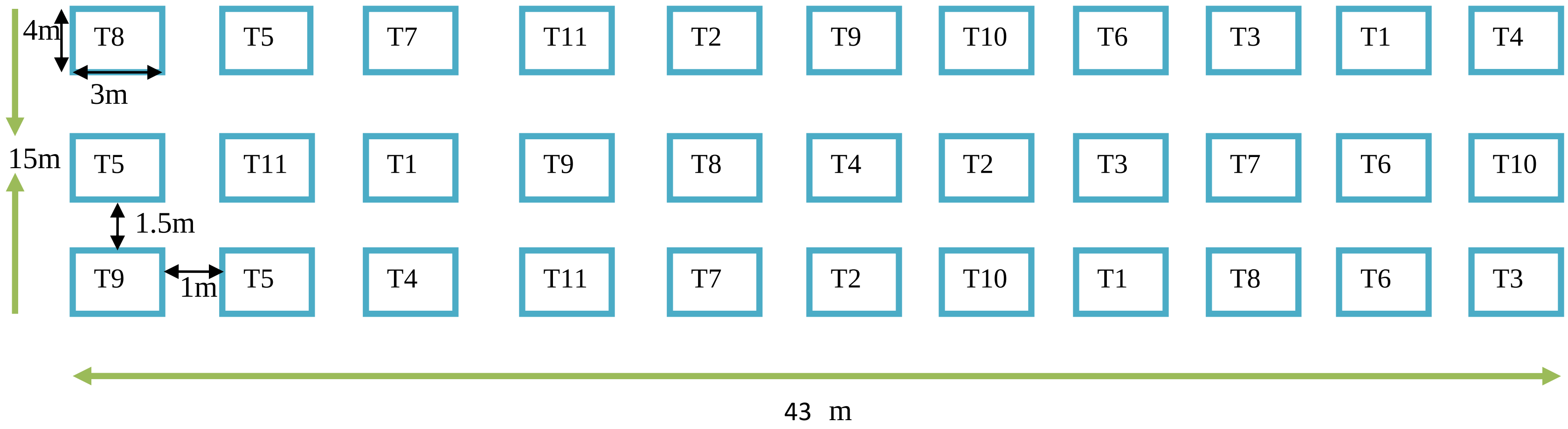

Figure 1. Experimental design setup

Note: T1: Sole *desho* grass (0.25 m x 0.5 m)

T2: *Desho* grass x *Vicia sativa* ICARDA 61509 (0.25 m x 0.5 m)

T3: *Desho* grass x *Vicia sativa* ICARDA 61509 (0.25 m x 0.75 m)

T4: *Desho* grass x *Vicia sativa* ICARDA 61509 (0.25 m x 1 m)

T5: Sole *desho* grass (0.25 m x 0.75 m)

T6: *Desho* grass x *Vicia dayscarpa* lana (0.25 m x 0.5 m)

T7: *Desho* grass x *Vicia dayscarpa* lana (0.25 m x 0.75 m)

T8: *Desho* grass x *Vicia dayscarpa* lana (0.25 m x 1 m)

T9: Sole *desho* grass (0.25 m x 1 m)

T10: Sole *Vicia sativa* ICARDA 61509 (0.3 m)

T11: Sole *Vicia dayscarpa* lana (0.3 m)

Original image processed photo of Experiment on field

Figure 2. Experiment on field site

Original image processed photo during forage data collection, forage sample preparation and soil sample

Figure 3. Photos of forage data collection, sample preparation and soil sample

Original image processed photo during laboratory analysis

Figure 4. Photo of laboratory analysis