EFFECT OF ROW ARRANGEMENT AND DIFFERENT LEVEL OF NITROGEN INTERCROP OAT (*Avena sativa* L) FIELD PEA (*pisum sativum* L) ON AGRONOMIC AND YIELD PERFORMANCE OF BOTH CROP AND CHEMICAL COMPOSITION OF OAT FORAGE IN JIMMA, SOUTH WESTERN ETHIOPIA

BY

BASHA BELACHEW

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JIMMA, ETHIOPIA

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MSc Thesis

Submitted to Department of Animal Science, Jimma University College of Agriculture and Veterinary Medicine in partial fulfillment of the requirements for the award of Master of Science in Animal Nutrition

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As Thesis Research advisors, we hereby certify that we have read and evaluated this thesis prepared under our guidance by **Basha Belachew** entitled **"Effect of Row Arrangement and Different Level of Nitrogen Intercrop Oat- Field Pea on Agronomic and Yield Performance of Both Crop and Chemical Composition of Oat Forage in Jimma, South Western Ethiopia"** and we recommend that it be submitted as fulfilling of the MSc Thesis requirement.

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DEDICATION

I dedicate this thesis manuscript to my beloved father **Belachew Mekonin**, my wife Messelech kassa, my daughters Helen Basha, and to all my family for their love, encouragement, patience and support in the success of my life.

STATEMENT OF AUTHOR

I declare and affirm that this thesis is my own work and all sources of materials used have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree in Animal Nutrition to Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) and is deposited in 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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BIOGRAPHY

The author Basha Belachew was born in May 1984 in Kirara district, Konta special Woreda of SNNP Regional State. He attended his primary and secondary education at Kirara Elementary and Dedo Secondary School respectively. The author joined Asella Agricultural Technical Vocational and Education Training College and graduated with Diploma in Animal Science in September/2004 with great distinction. Soon after graduation, he was employed by Jimma Zone, Dedo Rural Development Office as Supervisor of Agricultural Extension in Animal Production. Basha joined Jimma University, College of Agriculture and Veterinary Medicine and graduated with BSc Degree in Animal Science in June/2011 and rejoined his previous work in Dedo. Finally Basha joined Jimma University, College of Agriculture and Veterinary Medicine, in September 2019 to pursue his MSc study in Animal Nutrition.

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LIST OF ABBREVIATION

A.O.A.C O	Association of Official Analytical Chemists
ADB	African Development Bank
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ADP	Adenosine Diphosphate
AFF	Agriculture, Forestry & Fisheries
ANOVA	Analysis of Variance
CP	Crude Protein
DM	Dry Matter
DMRT	Duncan′S Multiple Range Tests
EE	Ether Extract
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GLM	General Linear Models
GRDC	Grain Research Development Corporation
ILRI,	International Livestock Research Institute
LMP	Ethiopian Livestock Master Plan
LSD	Least Significant Difference
ME	Metabolic Energy
NDF	Neutral Detergent Fiber
NDSU	North Dakota State University
NPS	Nitrogen Phosphorus
OM	Organic Matter
RA	Row Arrangement
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SRDI	Soil Resources Development Institute

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ABSTRACT

In Ethiopia, Oats (Avena sativa L.) is widely grown for both grain and forage production and field pea (pisum sativum L.) is grown for grain production. This study was aimed at evaluating the effect of three different oat: field pea row arrangements (RA) (1:1, 1:2 and 2:1) and three different level of nitrogen fertilizer application (0, 23 and 46 kg/ha) on yield and chemical composition of oat and field pea intercropping with factorial arrangement in a Randomized Complete Block Design with three replicates. Replicated plots of pure oat and pure field pea at the three different levels of nitrogen applications (0, 23 and 46 kg/ha) were included in the factorial treatment combination as negative control treatments. Plot size of 3x2m $(6m^2)$ *and Inter-row spacing of 30 cm was used throughout the study. The spacing between the plots and replications (blocks) were 1 and 1.5m respectively. Soil samples were collected before sowing and after harvesting for soil physico-chemical analysis. Data collected on Agronomic and yield performance, and chemical composition of the forages were analyzed with general linear model (GLM) procedure using SAS software (SAS, 2009 version 9.3).* The results obtained indicated that maximum mean plant height, number of tillers per plant and significantly higher number of leaves per plant were recorded from the experimental plots with RA of either 1:1 or 1:2 receiving 46 Kg of N_2 ha^{-1}. *Significantly (P<0.05) higher mean fresh biomass yield of 42.22 t/ha was obtained at RA of 1:2 receiving 46 Kg* N_2 ha^1 *and significantly (P<0.05) lower biomass yield of 29.83 t/ha was harvested from sole oat plots without* N_2*. Maximum mean total DMY of 7.42t/*ha^1 *was recorded at RA of 1:2.Whereas the total DMY of sole oat was significantly reduced to 5.22 t/ha. On the other side, significantly higher (P<0.05) mean total DMY of 7.67 t·*ha^{-1} *was harvested from experimental plots receiving 46 kg* N_2 ha^{-1} *, whereas the minimum mean total DMY of 5.32 t* $ha\text{-}^{1}$ *was recorded from the treatment plots without* N_2*. Seed yield was significantly (P<0.05) higher for plots with RA of 1:1 (3.98 t/ha) and 1:2 (3.96 t/ha) receiving 46 kg* N_2 ha^{-1}*. Maximum CP content of 13.06% was recorded from plots with RA of 1:2 receiving 46 kg* N_2 $ha\text{-}^{1}$ *and the lowest CP content of 8.31% was recorded from plots planted to sole oat without* N_2*. The highest NDF content at 50% flowering of 56.48% was recorded from plots without* N_2 *and the lowest NDF value of 51.94 was recorded from plots receiving at 46 kg* N_2 ha^1*. The economic analysis indicated that the interaction of 46 kg* N_2 ha^{-1} *at 1:2 RA produced net benefit of 405,477.44 ETB* ha^{-1} *with MRR of 32,286.98%, which could be recommended as profitable treatment to Oat-field pea producing farmers in the study area. In summary, the results of the current study indicated that Oat: field pea intercropping at 1:2 RA and application of 46 Kg* N_2 *fertilizer* ha^{-1} *was found to be promising in terms of agronomic characteristics, yield parameters and feed quality. Further research on effect of* N_2 *rate and RA on DMY and chemical composition of oats and seed yield of field pea for its performance over years, across diverse agro-ecologies is also vital to more fine-tuned recommendation.*

Keywords: *Nitrogen, Oats, Field Pea, Row Arrangement, Feed*

1. INTRODUCTION

Livestock production is the backbone of the Ethiopian agriculture contributing for the national GDP, agricultural GDP, export earnings and agricultural employment (Tesfaye, 2017). According to CSA (2017/18), Ethiopia has the largest livestock population in Africa. The Ethiopian livestock population was reported to comprise of about 60.39 million heads of cattle, 31.30 million sheep, 32.74 million goats, 1.42 million camels, 59 million chickens, 2.01 million horses, 8.85 million donkeys and 0.46 mules CSA (2017/18). The Livestock sector is crucial in achieving sustainable development and food security. Livestock provide proteins of high biological value and indispensable micronutrients (Magnusson, 2016). In Ethiopia, the livestock sector serves as a major source of food, family income, power for agricultural inputs and product delivery and crop cultivations (FAO, 2017) indicating that livestock has an enormous contribution in the livelihood of the population and national economy.

Despite its huge population size, the productivity of the Ethiopian livestock is disproportionately low (Tolera, 2008). The low productivity of the Ethiopian livestock sector is attributed to feed shortage (among others) both in quantity & in quality (Zegeye, 2002; Tegegne *et al.,* 2006; Duguma *et al.,* 2011). Feed is the major production input and the major cost item in livestock production, accounting for about 60-70% of the total cost of production (Tolera, 2012). Feed shortage is often cited as the prime constraint to improved productivity of smallholder farms (ILRI, 2014) and feed shortage has remained to be the most limiting factor of livestock production in Ethiopia. Feed resources are either not available in sufficient quantities due to seasonal variation or when available they are poor in nutritional quality (Ahmed *et al.,* 2003; Manaye *et al.,* 2009). Most of the pasturelands are converted to crop production farmlands to satisfy the food requirement of the growing human population. The continuous expansion of arable land led to shrinkage of grazing and browsing lands (Mengistu, 1997). Consequently, livestock are forced to be kept on very limited and deteriorated pastureland, indicating that shortage of grazing land is the major nutritional constraints (Shibru and Sodo, 2017).

The results of the study carried out in Jimma Zone revealed that natural pasture (mainly communal), after math grazing, crop residues, green fodder and non-conventional feeds are the major feed resources available in the area (Kechero, Y., *et al.,* 2013). Husen, M., *et al.*, 2016) reported that the feed supply can no longer support the existing livestock in Jimma Zone unless possible intervention is made by decision making bodies. They indicated that the annual utilizable feed dry matter is estimated to satisfy only 39.5% of the available livestock feed requirement. Thus feed shortage is one of the major challenges of livestock production in Jimma Zone. This situation warrants the increased cultivation of improved feed forages. One of the potential approaches to improve livestock feed availability in terms of quality and quantity is the use of grass-legume mixtures (Alemu *et al.*, 2007).

The role of grass–legume integrated forage production aimed at ensuring quality fodder availability is well recognized (Sanderson *et al*., 2013). Grass–legume integrated improved forage production provides a better source of protein greatly enhancing livestock productivity (Mengistu, 2002). Unfortunately however, improved forage production is not well adopted in most parts of Ethiopia (Tolera, 2007). Intercropping of oats and field pea seems to be appealing under the current Ethiopian condition.

In Ethiopia, Oats (Avena sativa L.) is widely grown for both grain and forage production and field pea (pisum sativum L.) is grown for grain production (Stevens *et al*., 2004; kaigorodova & Pronina, 2016). Oat (Avena sativa) is an annual grass, used as cut and carry system. It is a fast growing, palatable, succulent and nutritious fodder (Nawaz *et al*., 2004). It could be conserved as dry season feed in the form of straw, hay and silage. It performs better under stressful conditions such as poor soil fertility, frost and disease outbreaks (Kebede *et al.*, 2016).

Field pea (*pisum sativum* L.) is the most important legume crop in Ethiopia in terms of cultivated area. It accounts for about 17% of the total legume grain production and plays a significant role in soil fertility restoration (Habtamu and Million, 2013). Field pea is good source of high-quality vegetable protein (21-25%), vitamins, minerals and green manure, when used as rotational crop (Kandel *et al.*, 2014). The inclusion of field pea as legume forage crop in cropping systems could leads to reduction in nitrogen fertilizer requirements, adverse environmental impacts and cost of production (MacWilliam *et al.*, 2014). This being the cases, the major objective of this study was to evaluate the effect of different row arrangements and different level of nitrogen fertilizer application intercrop oat-field pea on agronomic and yield performance of both crop and chemical composition of oat forage, with the following specific objectives

- To evaluate the effect of different level of nitrogen application and row arrangement on agronomic performance, dry matter yield and chemical composition of oat, intercrop with field pea in Jimma.
- To evaluate the effect of different level of nitrogen application and row arrangement on seed yield and yield component of field pea for oat intercrop with field pea in Jimma.
- To evaluate the effect of different level of nitrogen application and row arrangement on economic feasibility of oat and field pea for oat intercrop with field pea in Jimma.

2. LITERTURE REVIEW

2.1 Feed Resources in Ethiopia

Feed is the most important input in livestock production, and adequate feed supply throughout the year is an essential prerequisite for substantial and sustained expansion in livestock production (Legesse *et al.*, 2010). Feeds availability and quality affects the entire livestock sector, including animal productivity, health and welfare, product quality, food safety and land use system (FAO, 2014). Provision of adequate high quality feed throughout the year, makes livestock play, its role of reducing poverty, attaining food and nutrition security & contributing to economic growth. The Ethiopian Livestock Master Plan (LMP, 2014) emphasized the transformation of livestock sector through the development of feeds, indicating that among the various constraints limiting livestock productivity in Ethiopia; inadequate and poor quality animal feed is the major one. In Ethiopia, critical feed scarcity and feed deficiency has been reported from a study conducted on the status of feed resources in the central highlands of the country (Alemu *et al.,* 2013). In the recent years, the rapid increase in human population and the demand for human food of plant origin negatively affected grazing lands & animals are kept on marginal lands such as hilltops, swampy areas & roadsides.

In the low lands of Ethiopia, natural pasture accounts for about 90 % of the feed supply. In the mixed crop-livestock system of the highland agro-ecology, the contribution of natural pasture declined from 80-90 % in the early 1960s to 30-40% during the last decade of 2000s (FAO, 2010). The role of natural pasture as a major livestock feed resource is diminishing from time to time due to the shrinkage of grazing land size (Yayneshet, 2010). The use of communal grazing lands, private pastures and forest areas as feed resources has declined while the use of crop residues and purchased feed has generally increased. In the highlands of Ethiopia, the annual dry matter production could satisfy only two-third of the total requirements of the available livestock. During the dry season animals, lose their body condition suggesting that livestock production and productivity are constrained by seasonal feed availability under the current Ethiopian condition (Funte *et al.*, 2009). The major livestock feed resources available in Ethiopia is reported to includes natural pasture and browse, crop residue, improved pasture and forage and agro industrial by-products (Tolera, 2012; CSA, 2017).

2.1.1 Natural Pasture

Grazing is the predominant form of ruminant animal feeding system in most parts of Ethiopia and natural pasture is the primary feed resource throughout the wet season (Gelayenew *et al*., 2016). Natural pasture comprises of mainly grassland available for grazing by herbivores animals. Grasses, legumes, native herbaceous plants species and indigenous browse trees are the dominant component of natural pasture. The quality and availability of natural pasture and browse are subjected to seasonal variation. Natural pasture and browse are low in feed value to fulfill the nutritional requirements of animals by their own particularly during the dry season (Tolera, 2008). According to Altaye *et al. (*2014) overgrazed natural pasture remains to be the major component of basal livestock feed resource in Ethiopia (Bogale, 2004). It has been estimated that natural pastures accounts for 57% of the annual feed supply and reaches peak during a certain season of the year (CSA, 2017).

In the Ethiopian highlands, grazing natural pastures are steadily being converted to farmlands. According to the results of the study conducted to analyze land use change in the Amhara Regional State, it was found that 30.52% of the regional grazing land was converted to crop land during the last 27 years (Amsalu and Addisu, 2014). The remaining grazing lands comprised of marginal lands not suitable for crop cultivation such as waterlogged, flooded soils and steep lands, all of which are low in productivity. In the lowlands of Ethiopia, livestock production is entirely dependent on natural grazing land, subjected to seasonal fluctuation in the availability and quality Bogale, (2004). Natural pastures are generally very poorly managed, have been significantly dwindled, fragmented and limited to areas where conditions are adverse for cropping due to topographic and climatic limitations (Mendo, 2013).

The available natural pastures are highly overgrazed, resulting in severe land degradation, loss of palatable and valuable species and development of unpalatable species (Amsalu and Addisu, 2014) indicating that overgrazing affects the productivity and botanical composition of the natural pasture. The changes brought in botanical composition usually affect the nutritive value of natural pastures, which in turn influence the productivity of animals. Deforestation and overgrazing substantially reduced soil fertility and forage productivity. Increased human population pressure is the major contributor to the land degradation and conversion of grazing lands to croplands (Delgado *et al*., 2001). Natural pastures could support maintenance requirement and some weight gain during wet seasons, but do not support the maintenance requirements during the dry seasons (Funte *et al.*, 2009).

The production performance of natural pasture depends on time and ecological change, rainfall and temperature, altitude, soil type and cropping intensity Birhan and Adugna, (2014). The productivity of the Ethiopian natural grazing land is declining because of temperature stress and scarcity of rainfall. Annual dry matter yield of natural pasture is estimated to range 1-2, 2-4 and 4-6 tones/ ha on well drained, water logged and fertile soils of the lowlands respectively (Kebede *et al.*, 2016). Nevens and Rehuel (2003) indicated that dry matter yield of grazing grassland might not exceeds 1.5 and 2.5 tones/ha at an altitude of 2600m. a.s.l and below this altitude respectively. The energy (ME), crude protein (CP) and dry matter (DM) contents of natural pastures in most cases have been reported to be below the maintenance requirement of domestic animals (Bogale, 2004).

2.1.2 Crop Residue

Crop residues comprises of fibrous by-products obtained after threshing cereals and processing of pulses, oil plants, roots and tubers. In Ethiopia, crop residues are the major livestock feed resource in the mixed crop-livestock production system. Mean annual crop residues are estimated at about 30 million tones dry matter (Tolera *et al*, 2012) of which 70% is utilized as livestock feed. Crop residues are quantitatively important feed resource during dry season throughout the Ethiopian highlands practicing mixed agriculture Asmare and Mekuriaw, (2017) and contributes up to 30-80% of the total annual dry matter supply (Rising, 2014). A wide variety of food crops are grown on subsistence farm holdings generating crop residues after harvesting and separation of grains.

During the dry period, livestock in mixed crop-livestock farming systems depends on cereal straws, stubble and other leftovers such as maize Stover. These crop residues are either grazed or collected and stored for stall-feeding and represent quantitatively important animal feed resource (Alemu *et al.,* 2013). The availability of crop residues as livestock feed resource depends on the farming system, size of arable land holding, agro-ecology, altitude and season of the year Altaye *et al.,* (2014). Due to the decreasing role of grazing land in feed supply as a consequence of arable land expansion, the potential uses of crop residues as animal feed sources have been increasing significantly from time to time Birhan and Adugna, (2014). According to Birhan and Adugna (2014) crop residues are reported to rank on the tops of feed resources in Ethiopia, based on availability and contribution to the total annual dry matter supplies in the mixed crop-livestock farming system.

Crop residues are poor in nutritive value, to provide the nutrient requirements of the animal (Birhan and Adugna, 2014). The major challenge in the use of crop residues as animal feed is attributed to their low nutrient concentration and poor digestibility. Crop residues are fibrous and limited in voluntary feed intake (energy, mineral and vitamin consumption), digestibility and nitrogen retention (Preston, 2007; Chalchissa *et al*., 2014). Food crops are harvested after the plant reaches physiological maturity, indicating that the resulting crop residues are high in cell wall contents and degree of lignification. Crop residues are low in nitrogen and deficient in sulfur, phosphorus and other critical minerals. The most dominantly used crop residues as animal feed are characterized by the predominance of lignified cell wall materials (cellulose, hemicelluloses and lignin), and low content of crude proteins, vitamin, minerals and soluble carbohydrates (Ranjhan, 2001).

The crude protein content of crop residues varied between 3.6 and 6%, the value of which is below the critical level required (7%) for optimum rumen microbial function of ruminant animals (Van Soest, 1982). The major cereal crop residues (teff, wheat and barley straws), commonly used as livestock feed in Ethiopia are reported to contain 3.6-4.2% crude proteins, indicating the importance of supplementary protein feeding especially during dry period, when livestock are entirely dependent on crop residues. According to Kassahun *et al.* (2016), the ash content of haulms of field pea (17.1%) and noug chaff (12.3%). The highest NDF (70%) content was reported from maize straw and the mean ADF content of the other crop residues reported to range between 19.2 and 48.3%.

Improved utilization of crop residues as animal feed could be achieved through either appropriate supplementation or chemical treatment, both of which facilitate the microbial breakdown of the cell wall component of crop residues (Assefa, 1999; Shanahan, *et al.*, 2004). In the past, supplementary feeding of high quality protein concentrates was the recommended strategy to improve the poor nutritional quality of crop residues. But high quality protein concentrates are costly, locally unavailable and not accessible for small holder livestock producers. Thus the development of grass-legume integrated forage crops has been accepted and considered as relatively viable strategy.

2.1.3 Improved Forage

Improved forage is a sown pasture that includes introduced grass species in combination with legumes considered to be better in productivity than local pasture, in terms of digestibility, protein and energy values. According to Assefa *et al.,* (2015), the contribution of improved forage to livestock feed source in Ethiopia is about 0.22%. Improved forages are considered to have many advantages besides their use as animal feeds. Improved forage cultivation is practiced for the purpose of animal feeding, soil conservation, crop rotation, wind break, fence and cooking wood. Improved leguminous forages provide appreciable amount of crude proteins and maintain soil fertility through atmospheric nitrogen fixation (Amede, 2004). The establishment of improved forages improves the organic matter content of the soil, green manure availability and enhances the provision of ground cover in controlling soil erosion. Most of the Ethiopian soils are deficient in nitrogen and one way to combating this problem is the use of forage legumes, capable of fixing atmospheric nitrogen and improving soil fertility.

Improved forage yield is higher than the naturally occurring swards and has higher nutritional value (Nigus, 2017). Most importantly, production of improved forages provides a source of protein, which greatly enhances the productivity of animals placed on crop residues as source of energy for ruminant animal feeding (Menigistu, 2002). Supplementation of leguminous forage improves voluntary feed intake and digestibility of crop residues and poor quality pasture based diets (Adugna, 2007). Improved forages could also improve the feed value of the native pastures since they are better in protein content and quality than naturally occurring grass swards. Over sawing of deteriorated natural pastureland with improved forage, enhance productivity, vegetation composition, and feed value. The nutritional profiles and digestibility of improved browse and legume forages are comparable with that of oilseed seed cakes (Geleti *et al*, 2013) and promising results have been reported in terms of production and reproduction performance of animals (Tolera, 2007).

Several attempts have been made in the establishment of improved forage in Ethiopia by public and nongovernmental organizations in the past. Unfortunately however, the adoption rate and volume of production of improved forages at the farmers' level in most parts of Ethiopia is usually low and unsatisfactory. The major challenges and constraints to enhance improved forage production in Ethiopia are reported to be shortage of land and agricultural inputs, poor extension service, lack of awareness and poor establishment of exotic grass and legume species. Shortage of land is one of the major constraints to the establishment of improved forage production because of the fragmented and extremely low land holding at the level of the Ethiopian farmers and shortage of land is likely to become escalating as the population continues to grow (Teshome, 2014). The problem of shortage of agricultural inputs includes lack of capital to purchase improved forage seed. Extension service is an important pillar in the transformation of subsistence agriculture to market oriented agriculture (Gebremedhin *et al.,* 2006). Technical problems such as poor management of seedlings and insect damage were reported to be constraints to the establishment of improved forage at farmers' level.

2.1.4 Agro-industrial By-products

Agro-industrial by-products are residues resulting from the processing of oil seeds, cereal grains, sugar cane and vegetable and fruit crops. Slaughterhouses and meat packing industries also yield Agro-industrial by-products used as livestock feed (Preston, 2007). The major agro-industrial by products commonly used as animal feed in Ethiopia are obtained from flour milling industries (wheat bran, wheat short and wheat middling), edible oil extracting plants (Noug cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake etc) and from breweries and sugar production factories (Tolera, 2008; Birhan and Adugna, 2014). The fast growing trend of agro-industries in different parts of the country is expected to create a better opportunity for the growth of agro-industrial by products to be used in livestock feeding (Yayneshet, 2010).

Most of the agro-industrial by-products are expensive in cost, are not readily available and not accessible to smallholder farmers (Tolera, 2007) and the relative contributions of agro-industrial by-products to the feed resource of smallholder farmers are minimal (Gebremedhin *et al.*, 2009). The problems in the use of agro-industrial by-product as animal feed at farmers' level could be attributed to the high market prices of the products, limited availability of the feed resources and lack of awareness on the feeding values of the feed resources. The availability and efficient utilization of agro-industrial by-products as livestock feed is restricted to the commercial sub-sector and urban and per-urban areas. The beneficiaries of the Agro-industrial by-products as animal feed includes the commercial livestock fattening and dairy production operations and urban and per-urban dairies located in and in the vicinity of the processing installations (Gebremedhin *et al.*, 2009). Currently, oil seed cake and grain processing byproducts are the major agro industrial byproducts widely used as concentrate supplementary feed in Ethiopia (Firew and Getnet, 2010).

Agro industrial by-products are comparatively rich source of energy and protein and high in digestibility (Preston, 2007). Most of the oil extraction is entirely done by mechanical processing (CSA, 2015). Oil seed cakes are characterized by high protein content of plant origin. Among the oil bearing plants, Noug (*Guizotia abyssinica*) widely grown in Ethiopia. Noug seed cake is very good protein concentrate with 30.8% CP, 32.4% NDF and 29.7% ADF on DM basis (Abebe, 2008).

Wheat bran, middling and short are by product obtained from flour milling plant and is the cheapest and mostly available energy concentrate feed with CP content ranging from 20 – 30% (McDonald *et al*., 2010)

2.2. Oats (*Avena sativa* L) Production

2.2.1. Species Description and Agronomic Characteristics

Oats (*Avena sativa* L.) is annual grass grown as a cool season crop in Mediterranean and tropical areas (Heuze *et al.*, 2016). Oat is well-adapted fodder crop grown in the highlands of Ethiopia (Assefa, 1999). The plant is cultivated for both human consumption and animal feeding (Stevens *et al.*, 2004). The results of efforts made to study the adaptation and productivity of different forage species in Ethiopia, indicated that Oat was found to be a promising pasture and fodder crop under mid and highland altitudes of Ethiopia (Tolera, 2007).

The plant is an erect annual grass, growing up to 1.5 m tall and best adapted to an altitude ranging between 1700 and 3000 m asl, with mean annual rainfall of 500-800mm (Mengistu, 2008). Stevens *et al.* (2004) reported that oats are well adapted to a wide range of soil types but perform better on acid soils. It was also reported that oats perform better in loam soils and tolerate acidic and low fertile soils with pH ranging between 4.5 and 8.6 (Heuz *et al.* 2016). According to Mengistu (2002) oat shows good tolerance on relatively low fertility and poor drainage system. On the contrary, soil types that are alkaline, saline, or poorly drained are reported to be not suitable for oat production. Oat performs better on marginal soils than other small- cereal grains (Loes *et al.*, 2007).

Oats is a forage crop useful for integration into the mixed crop- livestock farming systems. It is short-term, and high yielding crop used in crop rotation aimed at overcoming seasonal feed shortages (Assefa, 1999). Oats are useful as a nurse crop with legumes and could be used in combination with hairy vetch and peas for production of forage, erosion control, and weed suppression. Oats is suitable supplementary animal feed under cut and carry system. Oat could be easily be conserved as dry period feed in the form of hay and silage. According to Assefa (2006) Oat forage yields are very variable, depending on year and location and average DM yields range from 4 to 15 tones/ha.

The fertilizer requirement of oats usually depends upon the desired yield level, fertility of the soil, and the type of previous crop cultivated on the field. Application of nitrogen fertilizer is necessary because it is the nutrient most absorbed by plants, particularly by cereal grains. However, the increment in nitrogen application combined with favorable climatic conditions stimulates vegetative growth, favoring plant lodging. As the available nitrogen increases, the growth and yield of the oat crop increases and the amount of available nitrogen affects grain yield and quality.

The rates of seeding of oat vary depending on the location and purpose for which the crop is cultivated. Seed rates of about 125 to 175 kg/hectare are normal for sowing, either in broadcasting or drilling. Excessive seeding rates lead to lodging, which is accompanied by reduction of grain yield. Higher rate of seeding are used to check the problem of weeds. Lower seed rates (80 kg/ha) are used when oat is grown as an intercrop with legumes. As animal feed it can be sown in mixture at the rate of 70 kg ha^{-1} (Feyissa *et al.*, 2008). Oats provide fodder as early as one month after sowing even in cool conditions.

2.2.2. Nutritional Benefits of Oats (*Avena sativa* L)

Oat is amongst the major winter cereal forages, cultivated throughout the country. It is a fast growing, palatable, succulent and nutritious fodder (Mengistu, 1997). Oat is an important fodder crops widely grown at a times when other green forages and fodder crops are in short supply. Oats are one of the most nutritious cereal grain and forage crop. It is high in protein and fiber and considered as a good source of fat, unsaturated fatty acids and digestible carbohydrates. The protein content of Oat is higher than that of other cereal grains and contains approximately 104.9 and 126.7 g kg^{-1} (Biel *et al.*, 2014). The chemical analysis of the oat indicated that the oat proteins have an excellent amino acid balance, nutritionally superior to the other cereal grains (Arendt and Zannini, 2013). Oats contain many essential amino acids (methionine, cysteine, threonine, isoleucine, tryptophan, valine, leucine, histidine, methionine, phenylalanine, and tyrosine) necessary for animals (Biel *et al*, 2009) and high antioxidant activity components such as tocopherols, tocotrienols, and flavanoids (Koenig *et al*., 2014).

2.3. Field Pea (*pisum sativum* L.)

2.3.1. Production and Agronomic Characteristic

In Ethiopia, field pea is the second most important pulse crop in area coverage and annual production. Ethiopia accounts for about 16% of pulse production at global level (Drew *et al.*, 2012). About 0.15 million hectares of land is allocated to field pea production every year putting Ethiopia in the list of the major filed pea-producing countries in the world. It covers an area of about 25,147.69 hectares with an annual production volume of 2.14 million ton (CSA, 2015). The seed yield obtained by local farmers is quite low and variable. The crop has an important role in the highlands and midland of Ethiopia and play significant role in the provision of human food, atmospheric nitrogen fixations and improvement of soil fertility in cereal-based cropping systems (Fikere M *et al.,* 2014). The major yield-limiting constraints in field pea production in Ethiopia are aphids, low yielding local varieties, lodging, diseases (ascochyta blight, powdery mildew), and pod shattering (Tesfaye, 1999).

Field pea (*Pisum sativum* L.) belongs to Pisum Genus and Fabaceae family. Field pea is probably originated in Abyssinia and colonized in the Mediterranean area. Field pea spread to other regions of Europe and Asia gradually with time. It is one of the world's oldest crops, cultivated with cereal grains about 9000 years ago (McPhee, 2003). Field pea is multipurpose leguminous crops used as vegetables, pulses and forage. In Ethiopia, field pea is an important pulse produced in the high and mid-altitudes by smallholder farmers. Field pea is annual and cool-season legume crop grown for different purposes. It is a crop with high protein content (McKay *et al.*, 2003). According to FAO (2016) field pea is the fourth leading legume in terms of consumption, with global total annual production of 10.2 million tones. Field pea improves soil aggregation, conserve soil moisture,, and provide economic diversity (Biederbeck *et al.*, 2005). Field peas are grown in pure stand or in combination with cereal grains for silage and green fodder production (Elzebroek & Wind, 2008).

Field pea (*P.sativum*.) performs well at an altitude of 1800 – 3000 meter above sea level (Ghizaw and Mola, 1994), and under low rainfall environments as compared to the other pulses (Mohammed *et al*., 2016). It requires 800-1100 and 700-900 mm rain fall in high and mid altitude areas, respectively for optimum growth and development. Field pea has moisture requirements similar to those of cereal grains. Field pea is cultivated in a wide range of soil types i.e. light sandy loams heavy clays, fertile &, light-textured and, well-drained soils (Elzebroek & Wind, 2008). Field pea does not tolerate extreme soil salinity, acidity and waterlogged soil conditions. The optimum soil pH for the efficient growth of the plant is 5.5-6.5 (Hartmann *et al.*, 1988). The crop is well modulated and high in water use efficiency, which makes it an excellent rotational crop with small grains, especially in arid areas where soil moisture conservation is critical (AFF, 2016). This crop is usually sown from Mid-June up to the first week of July when there is sufficient moisture (Mohammed *et al*. 2016).

Field pea is a rapid-growing herbaceous legume with a single stem (could branch from nodes below the first flower). It is a climbing annual legume with weak, vine and relatively succulent stems. It grows to a length of 1 m and requires supporting crops in order to ascend

(AFF, 2016). The plant has a taproot that grows as deep as 1 m with numerous lateral roots and have shallow root susceptible to drought on sandy soils (AFF, 2016). The shallow root system of the plant limits its ability to utilize stored soil moisture below 0.6 m. Pods are dehiscent and contain several seeds that may be globular or angled, smooth or wrinkled. A leaf consists of one to three pairs of leaflets with a terminal, branched tendril. Pods are about to contain four to nine seeds (AFF, 2016).

Field Pea matures when seeds in the bottom pods are detached, loose in the pods and the upper pods are turned yellow. Pods could be harvest when 40-45% of the pods have turned yellow. Harvest should occur during humid climatic conditions to minimize shattering. Field pea seeds mature within 20 to 30 days after bloom or 80 to 90 days after planting (AFF, 2016). According to NDSU (2016) flowering usually begins 40 to 50 days after planting. Field pea is sensitive to heat stress at flowering. Flower duration is normally two to four weeks, depending on the growth habit and environment conditions during flowering (NDSU, 2016). The plants can still perform well with the aid of the available moisture at a time of pod filling and ripening during scarcity of rainfall. During flowering, extremely hot weather or drought stress can reduce seed and pod set dramatically. There can be 2,200 to 7,700 pea seeds per kilogram, depending on the pea cultivar and species.

Weed infestation lowers field pea yields by competing for soil moisture, soil nutrients, space and light. Harboring various insects and fungi makes harvest difficult. Fernandez *et al.* (2012) observed that weed control increased pea yields by an average of 63%. Harker *et al.* (2001) reported yield loss of field pea ranging between 40 and 70% due to weed competition. Weed control by hand might be an option as part of an integrated weed control strategy, especially when the applied farming practices are incompatible with herbicide use. Bacterial and fungal disease severely damage field pea crop. The most important diseases of field pea are ascochyta blight, powdery mildew, downy mildew and bacterial blight. Ascochyta blight is one of the most important pea diseases at the global level (Bretag *et al.*, 2006). Crop rotation prevent some weed species becoming dominant in the field and reported to be an effective cultural method to control pea diseases.

2.3.2. Nutritional Benefits of Field Pea

Grain legumes play an essential role in human nutrition in correcting nutrient deficiencies of cereal grain-based diet (Valencia *et al.,* 2008). Legumes are source of protein and family income for the poor farmers and field pea is an important pulse, used as family income and human food (source of protein) for the poor farmers in Ethiopia. Field pea is high in digestible proteins, carbohydrates and, fats along with minerals (Ca, P and Mg) and vitamins. Field pea rich in protein, carbohydrates and high in energy. According to Nikolopoulou *et al. (*2007), field pea proteins are rich in lysine and tryptophan, the limiting amino acids in plant proteins and deficient in cereal grains (Kandel *et al.,* 2014). Unfortunately however, the nutritional value of field pea seeds is limited by the presence of anti-nutritional factors such as tannins, oligosaccharides, phitynians, trypsin inhibitors, lectins and other compounds that negatively affect digestibility, palatability and food or feed intake (Nikolopoulou *et al.,* 2007). Field pea is also characterized by a relatively high antioxidant activity (Han & Baik 2008), known for a cholesterol-lowering effect. Low glycemic index of cooked pea generates slow and moderate postprandial glucose and insulin response and has a beneficial effect on the management of diabetes and hyperlipidemia (Jenkins, 2007).

2.4. Grass-Legume intercropping

2.4.1. Intercropping

Intercropping is the practice of growing of two or more crops simultaneously on the same field during the long period of overlapping growth of the crops including the vegetative stages. Intercropping allow more efficient utilization of on land and soil resource in sustainable way. Compared with single pure cropping in which one species is planted, intercropping consists of planting of two or more crops. Intercropping could comprises of annual plants intercropped with annual crops, annual plant intercropped with perennial plants or perennial plants intercropped with perennial plants (Eskandari *et al.,* 2009). Intercropping is divided into the following four groups (Vandermeer, 1992):

Row arrangement or row intercropping is growing two or more crops simultaneously by planting and growing randomly in alternative rows. Mixed- intercropping: Growing two or more crops simultaneously with no distinct row arrangement and this type of intercropping can be suitable for grass-legume intercropping in pastures. Strip-intercropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically. Relay intercropping: Growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest.

Intercropping is a common practice that dominates tropical subsistence agriculture. Intercropping of legumes plants with grasses improve feed values of the resulting forage both in quality and in quantity Peoples *et al.,* (2009). Legume forage benefit grasses through the contribution of nitrogen to the soil and atmospheric nitrogen fixation. Comparing to intercropping growing crops of the same species has been linked to reductions in soil and water quality in the environment (Malezieux *et al.,* 2009). Adoptions of forage legumes have the advantage of improving livestock feed status and reduce soil erosion and land degradation (Kassie, 2011). The inclusion of grain leguminous plants in cropping systems leads to increment in yield of forage production (MacWilliam *et al*, 2014) and improved forage productions improve animal production and productivity.

Legume grains are used as human food throughout the world and are the second to cereal grains as source of human food and animal feed. Legume crops have the ability to fix atmospheric nitrogen, thereby increasing soil organic nitrogen. Cereal grain crops planted alongside of legumes could exploit the soil nitrogen fixed with the leguminous plant without dependency on inorganic fertilizer and fossil energy resources (Neumann *et al.,* 2007). Cultivation of grass and legume crops intercropping is important in enhancing feed and food crop production, both in quantity and in quality in Ethiopia.

2.4.2. Grasses

Most ruminant livestock in Ethiopia rely on local grasses for their roughage and much of their nutrition. Many of the local grass species have low palatability, poor productivity and inadequate in nutrients content to maintain animal performance especially during the dry season. Grasses yields less protein per hectare and are low in protein and essential amino acids content compared to legume. Grasses are natural feed resource of livestock and considered suitable forage plants for ruminant animal feeding either in the form of grazing or cutting and carrying system of feeding. Grasses have a wide range of adaptability and reproduction of fresh shoots by tiller as means of recovery from grazing or cutting. Many grasses maintain continuous vegetative growth if not interrupted by drought or cold. Many grasses have spread root system, give rapid ground coverage; the root system binds soil particles together and brings nutrients to the surface layer, which would have been leached into the sub soil by heavy rainfall. Selected grass species are productive, palatable, and high in nutritive value and adapt to local soil and climatic conditions. Yields of improved pasture, forage grasses and legumes range from 6–8 and 3–5 DM ton/ha respectively (Mengistu *et al.*, 2017)

Pasture grass is an appropriate source of feed for ruminants, mainly under tropical climate attributed to its availability of large number of species and possibility of survival throughout the year. Ruminants are capable of utilizing grass fibrous feeds and there is no competition for grasses between human and ruminant animals, indicating that grasses are cheap and economical feed source. The digestibility of dry matter of grasses ranges between 14% to 85% depending on the percent composition of Neutral Detergent Soluble (NDS) and Neutral Detergent Fiber (NDF) contained in the dry matter (Van Soest, 1982). Jancik *et al. (*2009) reported that the digestibility of different grass species could distinctly be different, and influenced by temperature, light intensity, rainfall, soil type and fertilizer application, stage of maturity and preservation method. As stage of maturity of grass advance, there is increase in lignin and indigestible plant components including cellulose. Increasing lignin content decreases digestibility of cellulose and lower available energy. According Van Soest (1994), lignin concentration affects the availability of cell wall polysaccharides.

Forages high in CP are considered to be high quality forages because little or no protein supplement is needed and high CP forages are usually more digestible. Grasses grown in association with legumes contain a higher percentage of protein. The protein content of legumes is typically much higher than that of grasses and forage legumes generally higher in nutritive value than grass species. Growing grasses and legumes in mixtures can improve herbage nutritive value compared with grass monocultures (Zemenchik *et al.,* 2002). Tropical grasses are relatively low in energy and protein and high in fiber content compared with temperate grass species. This has largely been a result of the rapid physiological growth and early maturation of tropical grasses as influenced by temperature and light.

2.4.3. Legumes

Forage legumes are herbaceous plants used in under-sowing, intercropping and over sowing of poor grazing areas. Some legumes are enhance improvement of natural pasture in the stock exclusion areas and in the establishment of mixed pasture (Mengistu, 2002). Legumes are important forage plants capable of substantially improving poor quality roughage feed resource through the supplementations of essential nutrients Akinlade *et al.*, (2005). Legume are generally included in cropping systems due to their ability to reduce soil erosion, suppress weeds, fix atmospheric nitrogen, add soil organic matter and reduce pests and diseases (Wilkins, 2007). Legume is also included in the cropping system to spread labor requirement (Peoples, 2009) and maintain productivity of the land during the subsequent years (Kebede *et al.,* 2016).

According to Peoples *et al.* (2009), the primary agronomic benefits of legumes are their contribution to the nitrogen economy on cultivated agricultural lands. Legume production in relation to biological nitrogen fixation also offers a number of benefits, including characterized ecosystem and economic and environmental benefits. Inclusion of forage legumes in the form of intercropping in low-input and poor quality grassland improves biomass production, forage quality and soil fertility through the addition of nitrogen fixation. The amounts of nitrogen fixed in some forage legumes could be equal or even exceed the recommended nitrogen fertilizer levels for highly productive grassland. The contribution of nitrogen in turn increase herbage production, herbage feed value and ultimately ruminant productivity with minimum nitrogen fertilizer inputs.

The protein content of legumes is typically much higher than that of grasses and legumes fiber tends to be digesting faster than that of grass fiber and allows high feed consumption in ruminant animals. The inclusion of forage legumes in to low-input and poor quality grassland mixtures is vital to improve biomass production, forage quality and soil fertility. The improvement of forage quantity and quality is crucial for the improvement of animal performance. Mixture of legumes and grasses serves as an alternative forage supplementary feeding since pure grasses or cereals provide poor quality fodder due to their inherent lower crude protein content. On the top of proteins, legumes have the potential of improving ruminant diets in terms of minerals (Ca, Zn and Fe) and vitamins.

2.4.4 Oat and Field pea Intercropping

2.4.4.1. Intercropping of Oat with legume crops

Intercropping is a traditional and extensive agricultural practice used in low input cropping systems at global level (Anil *et al.,* 1998). Intercropping cereals with legumes, have several major benefits such as higher total yield, better land use efficiency (Dhima *et al,* 2007), yield stability, better utilization of light, water, and nutrients improved soil conservation and better control of pests and weeds (Vasilakoglou *et al.,* 2008). Oat as fodder can be sown in mixture with a legume such as a Vetch, and pea (Undersander, 2003). Oats is a well-adapted fodder crop used as energy source for livestock feeding (Mengistu, 2008).

Oats intercropped with legumes is effective in reducing diseases, controlling weeds and improving the nutritive value of the crop compared to oats alone (Undersander, 2003). Vetch and oat mixtures were found to be advantageous in increasing forage yield. According to Canan and Adnan (2007) herbage dry matter yield of vetch and oat mixtures increased when the proportion of vetch in the mixture is low. If it is desired to obtain higher herbage dry matter yield per unit area, it is suggested that the mixture should be 25% vetch + 75% oat. It is suggested that the mixture of 75% vetch +25% oats is optimum to obtain good quality oat hay yield per unit area. Herbage nutritive value of forage grasses and legumes is negatively related to DM accumulation (Belanger *et al.,* 2001). Thus, increases in herbage DM yield are expected to result in a decrease in nutritive value of the mixture compared to either of the two legume monocultures.

Oats could provide support for climbing field pea, improve light interception through the canopy, facilitate mechanical harvesting, and reduce rotting of field pea. Intercropping increase diversity may reduce pest and disease incidence and leads to less pesticide application. Intercropping increases habitat for beneficial insects and microorganisms and result in an overall reduction in farm input. There is general public interest in intercropping as alternative agronomic practices to reduce the impact of agriculture on the environment including reduction of chemical fertilizers (Mengistu *et al.,* 2016).

Haq *et al.* (2018) reported that the CP content of oats-vetch and oats-pea mixture was higher than oats grown alone and lower than legume mono-crop. Legume-cereal intercrops may produce higher grain and protein yields as compared to cereal mono-crop (Lauk & Lauk, 2005).

2.4.4.2 Intercropping of Field Pea with other crops

Common beans are comparatively poor in fixing atmospheric nitrogen compared to their nitrogen requirements. Other grain legumes, such as peas, peanuts, cowpeas and soybeans are good in fixing their nitrogen requirement other than that absorbed from the soil (Lindemann and Glover, 2003). Fixed atmospheric nitrogen directly absorbed by the plant and leaks into the soil for use by neighboring non-legume plants. Eventually, nitrogen returns to the soil following the death and decomposition of the leguminous vegetation (Rahman *et al*., 2009). Excessive use of inorganic fertilizers contributes to the environmental damage such as nitrate pollution. On the other side legumes grown in intercropping are regarded as an alternative and sustainable way of introducing atmospheric nitrogen into the plant-soil agro ecosystems (Fustec *et al*., 2010).

Intercropping of legume crop with other none leguminous food or feed crops brings about better utilization of available resources and results in increased productivity compared with pure stand of either of the two crops intercropped (Agegnehu *et al*., 2008; Mao *et al*., 2012). Yield of the mixture (intercropped crops) is increase because of the growth resources such as light, water and nutrients are efficiently absorbed and converted to crop biomass over time and space as a result of differences in competitive ability for growth resources between the two intercropped crops. The intercropped pea provides high-quality forage, rich in crude protein and mineral elements (Lauk, Lauk, 2008). Unfortunately however, grain production of the mixture can be very unstable due to stem lodging, which causes significant losses. Therefore, intercropping can be a suitable tool for growing species prone to lodging in combination with species with upper growing stem. Legumes intercropping with cereal grains are one of the patterns used to overcome the problems of pea stability and provide nitrogen input for cereals in organic and/or low input production systems.

Gilliland and Johnston (1992) reported that pure field pea cultivars are prone to lodging, and appropriate field pea cultivars should carefully be selected for intercropping to minimize the risk of lodging. Lodging causes the soil contamination of the harvested herbage and affects the capacity of suppression of the under sown crop. Competition is one of the factors significantly affecting yield of the mixture (intercropped crops) compared with the pure stand of either of the two crops (Caballero *et al.,* 1995). This indicates that legumes grown in mixtures achieve higher productivity per unit area than legumes grown in pure stand under similar climatic conditions.

2.5. Biological Nitrogen Fixation and Mineral Requirement of Plants

2.5.1. Biological Nitrogen Fixation

Nitrogen fixation by leguminous plants is considered to be the most fundamental and important biological process. Biological nitrogen fixation is the process by which atmospheric nitrogen is converted to ammonia (NH_3) through the exploitation of the nitrogenase enzymatic system (Abbasi *et al.,* 2009). Nitrogen is the most yield-limiting nutrient in human agriculture and most of the biologically fixed nitrogen in agri ecosystems arises from the symbiotic co-existence of nitrogen fixing bacteria and legume crops nodule root system. Biological nitrogen fixation is the mutually beneficial relationship between the host crop (legumes) and rhizobia bacteria. The rhizobium bacteria colonize and infect the roots of the host plant after germination, to form root nodules within 4–10 weeks. The bacteria are dependent on the host plant for water, and other nutrients. The bacteria supply the plant with ammonium, $NH4^+$ (GRDC, 2018) and the legume plant roots accommodate the nitrogen fixing bacterial colonies within their root nodule system. Biological nitrogen fixation is influenced by temperature, soil moisture, rhizobia bacterial species and varieties, and the nitrogen content of the soil.

The use of symbiotically fixed nitrogen, instead of application of chemical fertilizers decreases production costs and environmental implication of crop production. Industrially produced nitrogen is high in market price and unavailable in many regions. The prices of nitrogenous fertilizers have been increasing from time to time attributed to increased price of natural gas used in fertilizer industry (Fertecon, 2008). In 2005, synthetic nitrogen provided three times as much as biologically fixed nitrogen through the leguminous plants in the global agricultural system (Galloway *et al.,* 2008). With increasing price of fossil fuels, small-scale (household) agricultural economies are likely to face food shortages resulting from high costs of nitrogen fertilizer. At present the decline in the fertilizer purchasing power of many developing countries including Ethiopia will have a significant implication on food production. At present it seems that the biological nitrogen fixation system with the use of rhizobial bacteria is greatly underutilized resource.

Biological nitrogen fixation is desirable than the use of commercial nitrogen fertilizers due to economic, environmental and agronomic benefits (Silva and Uchida, 2000). Grain legumes are particularly well suited to increase crop production in low-nitrogen environments because they could be used for the production of grains with high nitrogen content for human consumption and generate crop residue of high nitrogen content for animal feeding. In the 1990s, the amount of Nitrogen arising from the cultivation of legumes was estimated to be up to 40 million tons annually at the global level, providing about 20% of the available N_2 in agricultural systems (Crews and Peoples, 2004).

2.5.2. Essential Mineral Requirement of Plants

2.5.2.1. Nitrogen Requirement

Nitrogen has been identified as the most limiting nutrient in plant growth. Nitrogen exist fundamental component of many compounds such as amino acids, proteins, chlorophyll, nucleotides, enzymes, hormones, vitamins, co-enzymes and some non-protein compound, all of which are essential for plant growth (Brady and Weil, 1999). Plants require Nitrogen in relatively larger amounts than the other elements (Marschner, 1995). Application of nitrogen fertilizer increases the nitrogen uptake of plants with positive effect on chlorophyll concentration, plant height, photosynthetic rate, total number of leaves and dry matter accumulation (Zewide *et al.,* 2012). Increased nitrogen uptake brings about production of extra leaves and branches and extension and expansion of leaf area (Muthoni and Kabira, 2011). Being the essential constituent of protein, nitrogen is involved in all the major process of plant development. Good supply of nitrogen to the plant stimulates root growth; plant development, and crop yield and encourages the uptake of the other nutrients (Mozumder *et al*., 2003).

Plants absorb nitrogen either in its cationic form (NH_4^+), anionic form (NO_3^-), in the form of urea or ammonia (NH_3). The major sources of readily available nitrogen for the plants include biological nitrogen fixed by soil microorganisms, mineralized organic nitrogen, and industrial fixed nitrogen gas (Tisdale *et al*., 1995). One of the most important key findings about nitrogen fertilizers is that nitrogen fertilizers applied to cereals at the recommended time and rate leave virtually no unused fertilizer nitrogen in the soil. In some cases about 1-2% of applied fertilizers nitrogen remains in the soil (Jenkinson, 2001). However, unused fertilizer nitrogen could remain in the soil, if the nitrogen exceeds the requirement of the plant (Mcdonald *et al*., 2002).

Nitrogen is one of the commonly deficient plant nutrients and its deficiency is commonly detected as plant disorder (Doberman and Fairhurst, 2000; Stevens *et al*., 2002). It was reported that, most of the Ethiopian soils are deficit in nitrogen and phosphorus (Tadesse *et al*., 1991; Amsalu and Addisu, 2014). Nitrogen deficiency often occurs at critical plant growth stages such as tiller and panicle initiation, during which the demand for nitrogen is relatively high (Dobermann and Fairhurst, 2000). Large amounts of nitrogen are required to produce amino acid and proteins in the tissues. Nitrogen is easily lost from the soil during wet conditions (Stevens *et al*., 2002). Nitrogen deficiency results in the impediments of synthesis of proteins, enzymes, DNAs and RNAs. These compounds are required in virtually all plant cells for their initial development, sustained growth and for the support of other plant tissues functions. Nitrogen deficiency symptoms are poor tillering, pale leaves stalks, yellowing of lower plant leaves, spindly stems and short heads and failure of formation of complete canopy and poor yield (Stevens *et al*., 2002). Leaves die due to severe nitrogen stress (Dobermann and Fairhurst, 2000). Nitrogen deficiency causes delayed maturity and makes the plant susceptible to disease and pests. Shortage of nitrogen restricts the growth of all plant organs such as roots, stems, leaves, flowers and fruits. Serious deficiency of nitrogen makes the plant-stunted with yellow leaf appearance (Bryson *et al*., 2007). Nitrogen deficient shoots may be reddish or reddish brown, with delayed but heavy flowers bloom. Leaves of nitrogen deficient plants are small and thin and drop early. Shoots are short and smaller in diameter than usual (Barbara, 2007).

2.5.2.2 Phosphorus Requirement

Phosphorus is one of the most important macronutrients for plant growth and the second most essential nutrient after nitrogen. It is an important nutrients limiting agricultural production in many regions of the world. It is known to be involved in many physiological and biological processes of plants, particularly in cell membranes, chloroplasts, mitochondria, in the formation sugar phosphate (ADP, ATP) and nucleic acids. It is a major component of compounds related to growth, root development, flowering and ripening. Phosphorus acts as a structural component of membrane system of cells. Phosphorus is a nutrient that should be available in adequate quantities starting from the early growth stages of the plants (Hu *et al*., 2010). Phosphorus is a component of compounds necessary for protein synthesis and transfer of genetic material (DNA, RNA) (Zhang and Raun, 2006). Phosphorus greatly stimulates root development in the young plant and increase the capacity of the plant to absorb other nutrients from the soil (Dobermann and Fairhurst, 2000). During the ripening phase, phosphorus increases the protein content and overall nutritive value of the grains.

Plants absorb phosphorus in the form of HPO_{4-2} and H_2PO_4. Phosphorus influences plant metabolism through cellular energy transfer, respiration and photosynthesis (Grant *et al.*, 2001). In the case of leguminous plant, phosphorus is involved in the nitrogen fixation process. Application of phosphorous fertilizers positively affects crop yields and enhances the response of plants to other nutrients (Akinrinde and Adigun, 2005). The high requirement of phosphorus by leguminous plants is consistent with the involvement of phosphorus in plant growth as well as in the high rates of energy supply for symbiotic nitrogen fixation and assimilation processes (Grant *et al.*, 2001). Phosphorus deficiency is an attribute for poor nodulation and low yield of leguminous plants on all soil types (Li *et al.*, 2006). Adequate supply of phosphorus is beneficial for better growth, yield, quality and nodule formation (Sammauria *et al.*, 2009). Leguminous plants supplied with adequate phosphorus is characterized by good root system, strong stem, early maturity and high yield. Plants with phosphorus deficiency exhibit retarded and stunted growth, reduced tillering, low shoot to root ratio, poor fruit and seed formation, purple colored leaves and reddish coloration of stem (Uchida, 2000). Leaves of phosphorus deficient plants are narrow, short, very erect and dirt dark green. Stem are thin and spindly (Dobermann and Fairhurst, 2000).

2.5.2.3 Sulfur Requirements

In plants, sulfur is required for proper growth and yield and known to take part in many reactions in all living cells (Sud and Sharma, 2002). Sulfur is a building block of protein and a key ingredient in the formation of chlorophyll. Crops do not reach their full potential in terms of yield and protein content without sulfur (Zhao *et al.,* 1999). Sulfur is required for synthesis of sulfur containing amino acid (cystine, cysteine and methionine). It helps to enhance the uptake of nitrogen, phosphorus, potassium and zinc in plants, resulting in increased crop productivity. Application of sulfur fertilizer appears to suppress the uptake of sodium and chlorine attributed to the antagonistic relationship (Wilkinson *et al*., 2000). Sulfur improves the availability of microelements (Fe, Zn, Mn and Cu) and enhances crop yield characteristics (El-Tantawy *et al*., 2009).

Sulfur deficiency results in low utilization of nitrogen, phosphorous and potash and in significant reduction of catalase activities at all stages of plant growth (Nasreen *et al*., 2003). Sulfur deficiency also results in stunted growth, reduced plant height, tillers, and delayed maturity, decreases in crop yield and deterioration in quality (McGrath, *et al.,* 2003). Insufficient sulfur availability results in poor efficiency of nitrogen conversion into biomass production, which in turn might increase nitrogen losses from cultivated soils (Ceccotti, 2002). Sulfur deficiency has become widespread over the past several decades in agricultural fields at global level, indicating that sulfur is becoming a limiting factor to productivity (SRDI, 1999).

2.5.3. Fertilizer Requirement & Seeding of Field Pea

Field pea is characterized by sensitivity to soil compaction resulting in reduced growth and nitrogen fixation (Siczek *et al.,* 2013). Optimum germination occurs at 15-20 °C and the recommended sowing depth is 2-5 cm (AFF, 2016). Field peas tolerate deep seeding, up to depth of 7.5 cm which, may lead to increased variability in emerging time (Ayaz *et al.,* 2004). The recommended row spacing is 20-50 cm, with 10-20 cm between plants in the row (Elkoca and Kantar, 2006). Recommended seeding rate is about nine plants per square meter or 75-100 kg/ha. Emergence normally takes 10 to 14 days; Field pea matures within 95-100 days and requires 60 days from planting until bloom. (AFF, 2016).

Field pea is considered as one of the highest nitrogen fixing crops, indicating that the plants do not require much addition of nitrogen and over-application of nitrogen increases production costs without raising yield (AFF, 2016). Application of nitrogen reduces nitrogen fixation, but nitrogen application prior to the onset of nitrogen fixation process has been recommended for field pea production, on soils with low nitrogen (Clayton *et al.*, 1998). Fertilizers should be applied just prior to planting with care of preventing direct contact between the seeds and fertilizers, since germinating field peas are extremely sensitive to salt concentrations (AFF, 2016). Sandana and Pinochet (2014) emphasized that phosphorus is required for pea growth and nitrogen fixation. Phosphorus deficiency causes purple color in the leaves. Phosphorus and potassium may be applied during seedbed preparation.

According to Pacyna *et al.* (2006), Sulfur deficiency resulted in decreased nitrogen fixation, while Scherer and Lange, (1996) and Varin *et al.* (2009) reported the importance of Sulfur in legumes due to their high protein concentration. The role of Sulfur in pea cultivation is closely connected with symbiotic nitrogen fixation and nitrogen nutrition. Zhao *et al.* (1999) pointed out that the addition of Sulfur significantly increased seed yield, the total amount of nitrogen in the shoots and double the rate of nitrogen fixation. Cazzato *et al.* (2014) suggested that application of Sulfur fertilization in field pea production increase fatty acid profile and sulfur is required at a relatively high level to ensure adequate nitrogen fixation. Sulfur should be added on the basis of soil test recommendations and application of lime is recommended on fields with a soil pH of 5.2 or lowers (AFF, 2016).

3. MATERIALS AND METHODS

3.1 Description of Study Area

This study was conducted at Jimma University Technology Institute located at 350 km south-west of Addis Ababa. The geographical coordinates of the area are 7°41' N latitude and 36° 48' E longitude. It lies in the climatic zone locally known as "Woyna Daga" or midland ranging from 1,500-2,400 m and the area found at 1850 m above sea level which is considered ideal for agriculture production. The study area is characterized by mean annual maximum and minimum temperature of 30°C and 14°C respectively. The annual rainfall ranges from 1138-1690 mm (Limu G. 2011)

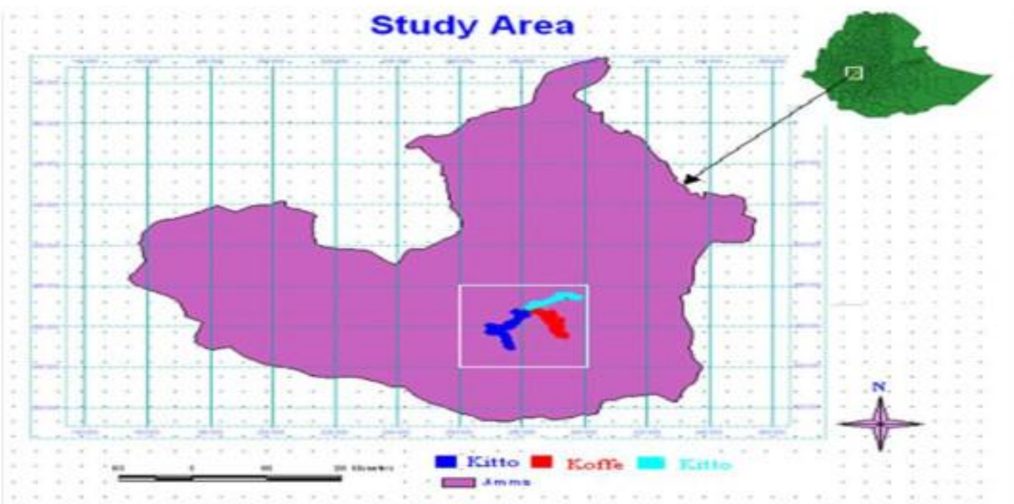

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Figure 1 Map of the study area

3.2 Land Preparation and Planting

A fine seedbed plots were prepared using tractor before the experimental plots were laid out. Each plots were uniformly fertilized with NPS at a rate of 100 kg/ha at the time of sowing by broadcasting. Planting was done in July when continuous rain was assured for successful germination. This was followed by covering the seed by upper soil using hand rakes (Alemu *et al.*, 2007*;* Feyissa, *et al.*, 2008). At an early stage of seedling development, weeds were controlled through manually practice (Aleksandras *et al.*, 2009). The Experimental land was plowed and well prepared at the start of the rainy season.

3.3 Treatments and Experimental Design

This experiment was started on July 2019. The treatments consisted of Oat grass (*Avena sativa* L.) of SRCP X 80 Ab 2291 variety planted as pure stand and intercropped with field pea (*Pisum sativum* L.) as shown in (Table 1). The treatments were randomly assigned to the experimental plots in Randomized Complete Block Design (RCBD) with factorial arrangement replicated three times as shown in (Table 1). Three different levels of nitrogen applications (0, 23 and 46kg/ha) and three different row arrangement (1:1, 1:2 and 2: 1) were used in Oat and field Pea intercropping (Melkamu *et al.*, 2017). Replicated plots of pure oat and pure field pea at three different levels of nitrogen applications (0, 23 and 46 kg/ha) were also included in the factorial treatment combination to be used as negative control treatments as shown in Table 1.

The two species were planted randomly and independently on the rows and simultaneously grown on the same plot. Plot size of 3x2m ($6m^2$), and inter-row spacing of 30 cm recommended by Singh *et al.* (2016) were used. The spacing between the plots and replicates (blocks) were 1 and 1.5m respectively as recommended by (Aklilu and Alemayehu, 2007). Planting rate of 80 and 70kg/ha was used for oat and field pea respectively as suggested by (Altaye, 2018). There were 10 rows per plot and seeds were uniformly drilled into the rows for oat and sown with intra-row spacing of 15 cm for field pea (Bitew *et al.*, 2014). At a time of planting, all the plots received NPS fertilizer at the rate of 100 kg/ha Feyissa, (2009). Half of recommended nitrogen fertilizer was applied at 5 cm distance from the plant base at knee height (Takele *et al.*, 2017). Prior to planting, representative soil samples were taken from the top soil at 0-30 cm depth, combined and thoroughly mixed into a composite sample and kept for laboratory chemical analysis.

Table 1 Experimental layout and treatment combination

Treatments	Treatment Combination	Row Arrangements		N_2 Level
		Oat	Pea	Kg/ha
T1	Oats v Field pea	1:1		0kg
T2	Oats v Field pea	1:1		23kg
T3	Oats v Field pea	1:1		46kg
T4	Oats v Field pea	2:1		0kg
T5	Oats v Field pea	2:1		23kg
T6	Oats v Field pea	2:1		46kg
T7	Oats v Field pea	1:2		0kg
T8	Oats v Field pea	1:2		23kg
T9	Oats v Field pea	1:2		46kg
T10	Oats Sole	-		0kg
T11	Oats Sole	-		23kg
T12	Oats Sole	-		46kg
T13	Field pea sole	-		0kg
T14	Field pea sole	-		23kg
T15	Field pea sole	-		46kg

3.4. Soil Sampling and Laboratory Analysis

Soil samples were collected from each plot at the beginning, before planting/sowing and after harvesting at a depth of 0–30 cm. The sample was collected following a 'zigzag' method across each plot using an auger (Ryan, 2017) and then was bulked to one composite for initial soil samples. The soil samples were air dried, sieved through 2 mm diameter sieve and subjected to laboratory chemical analysis. The particle size distribution (texture) of the soil sample was determined by the Boycouos hydrometric method (Bouyoucos, 1962). Once the percentages of sand, silt, and clay were tested, the textural class of the soil was determined by referring the textural triangle. Soil pH was determined at 1:2.5 soils to water ratio using a glass electrode attached to pH digital meter (Van Reeuwijk, 1992). Soil organic carbon was determined according to wet digestion method as described by (Walkley and Black, 1934) and percent of OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM was composed of 58% carbon (Lennart S. 1957). Available phosphorus and total nitrogen was determined by the Olsen bicarbonate (NaHCO3) extraction method (Olsen *et al.*, 1954) and Kjeldhal method (Jackson, 1964) respectively. CEC was measured by ammonium acetate method after saturating the soil with 1N NH4OAC and displaced by sodium from NaCl solution (Chapman, 1965).

3.5 Data collection

3.5.1 Data collection for performance evaluation of Field pea

Yield and yield indicating data:

The **number of pod per plant** (NPPP) and **number of seed per pod** (NSPP): samples of pods and seed per pod of eight tagged plants were taken randomly from the plot of each treatment in all the replicates. Pods and seed per pod from the samples were counted and the mean was calculated and expressed as number of pods per plant and number of seed per pod.

Thousand seed weight (TSW) (g): thousand seeds were first taken randomly from eight plants from each plot, counted and then weighed. The average values were then recorded and adjusted for field pea.

S**eed yield of field pea (SYP)** (t ha^{-1}) After harvest plants from two rows at center of each plot after maturity, by threshing seed allowed to dry in sun and adjusted at 11% content and converted in tone per ha. Moisture content was adjusted by applying the following formula:

Yield Adjusted = yield measured * $\frac{(100-\text{sample moisture content})}{(100-\text{standard moisture content})}$

3.5.2 Data collection for performance evaluation of Oat

2.5.2.1 Agronomic data collected from Oat forage

Number of tiller per plant and leaf per plant were determined by counting the number of tillers and leave of the oat by taking eight plants from the center of each plot to avoid edge effect. An average result from each measurement was recorded to evaluate the performance (Khan *et al.,* 2014).

Plant height for oat was determined by measuring the height of eight randomly selected plants from ground level to the tip of the main stem by using meter (Tarawali, 1995) when oat reach physiological maturity. The average of eight plants was taken for each plot at 50% flowering stage from each plot (Beyene *et al.,* 2015).

Leaf to stem ratio (LSR) represents relation between mean dry weight of leaf and dry weight of stem. After harvest, fresh biomass yield of every treatment was partitioned into stem and leaf, oven-dried at 65°C overnight to achieve constant weight and dry matter accumulation in leaf and stem. Leaf to stem ratio of oat grass was calculated on total dry matter basis. The leaf to stem ratio was calculated by applying the following formula (Aklilu and Alemayehu, 2007).

$$\textbf{LSR} = \frac{\text{Leaf dry weight (g)}}{\text{Stem dry weight (g)}}$$

2.5.2.2 Biomass, Dry matter and Grain yield of Oat forage

Fresh Biomass of Oat forage was harvested at 50% maturity based on continuous visual observation and harvested fresh weight was recorded immediately in the field using a top loading field balance. Two adjacent rows from the center of each plot were taken at 50% flowering stage for fodder yield evaluation (Akililu and Alemayehu, 2007). Two rows from the center of each plot were cut when oats reach at 50% of the forage at blooming stage on visual observation to estimate fresh biomass yield (Mengistu and Mekasha, 2007). Fresh subsamples were measured from each plot weighed and chopped into short length (2-5cm) for dry matter determination and for further chemical analysis. The weighed subsamples were oven dried at 65°c for 72 hours and the dry weight subsample was measured to estimate the dry matter production.

Dry matter yield of Oat forage (t/ha): DM yield of oat was taken from two rows intercropped and compared with its monocultures (De wit, 1960). The dry matter yield (DMY) was determined after dying the fresh samples in an oven at 70 °C for 48 hours, according to (A.O.A.C, 1995).

The dry matter production was calculated as (Tarawil, 1995):

DM yield (t ha) *= (10*TFW*SSDW)/ (HA*SSFW)*

Where:

10 = Constant for conversion of yields in kg/m2 to t/ha

TFW = Total fresh weight from harvesting area (kg)

HA = harvesting area

SSFW = subsample fresh weight (g)

SSDW = subsample dry weight (g)

Seed yield of Oat was measured after maturity by threshing and adjusted at 12.5% content moisture content was adjusted by applying the following formula:

Yield Adjusted = yield measured * $\frac{(100-\text{sample moisture content})}{(100-\text{standard moisture content})}$

2.5.2.2 Laboratory Chemical Analysis for Oat

Representative plant samples of 250g were taken from each treatments and oven dried at 65 ^{o}C for 72 hrs. The dried samples were grounded to pass through 1 mm sieve and stored in air tight bottles until required for analysis. The Nitrogen and crude protein content was determined using Kjeldahl method, according to (A.O.A.C, 1995). The DM and ash contents were determined by oven drying at 105 °C over-night and by combusting in a muffle furnace at 500°C for 6 hours respectively following the procedure described by (A.O.A.C, 1995). The Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were determined according to the procedures of Van Soest and Robertson (1985). Hemicelluloses were determined by subtracting ADF from NDF and cellulose were determined by subtracting lignin from ADF. The analysis of feed samples was done at JU College of Agriculture and Veterinary medicine in Animal Nutrition Laboratory and CP was analyzed in Post-harvest Lab.

2.5.3. Partial Budget Analysis

Partial budget analysis was performed to evaluate the economic advantage of the different treatments by using the procedure of (CIMMYT, 1988). To estimate the economic parameters, the seed yield of Oat, straw yield of Oat, seed yield of field pea and straw yield of field pea were valued at average open market price. The straw yield of Oat and field pea were obtained by computing 1.5 and 1.2 conversion factor from the grain and seed yield respectively (SSA, 2007). The costs for inorganic fertilizers, seed, labor and transportation of inputs were calculated (ha^{-1}) as Jimma area local market price. Gross field benefit (GFB) determined by multiplying adjusted yield by its corresponding price and total gross field benefit (TGFB) is the sum of all (GFB). The net benefit (NB) was calculated as the difference between the total gross field benefit (GFB) and the total variable cost (TVC). All costs and benefits were based on the average yield of oat and field pea. The cost of cultivation was same under all the treatments. It did not vary because all the operations and inputs used in raising the crop were similar under each treatment. Marginal rate of return (MRR) was calculated as changes in net benefit (upraised benefit) divided by changes in cost (upraised cost). The values of other materials used uniformly for each treatment were not considered in the budget for the partial economic analysis. The dominance analysis was also carried out to select potentially profitable treatments and a percentage marginal rate of return (% MRR) was calculated for the non-dominate treatments CIMMYT, (1988) and Shah *et al*, (2009) suggested minimum rate of return to be 100%, or for technologies requiring a su6bstantial change to a farming system.

All costs and benefits were calculated on hectare basis in Ethiopia birr (ETB ha^{-1}). According to (CIMMYT, 1988) the following concepts used in the partial budget analysis defined as follows:

Gross Average Yield (t/ha) (GAY): An average yield of each treatment (Oat and field pea) converted in tone bases.

Adjusted yield (AJY): Average yield adjusted downward by 10% to reflect the difference between the experimental yield and yield of farmers..

Gross Field Benefit (GFB) (ETB/ha): was computed by multiplying farm gate price (ton /ha) by adjusted yield thus:

GFB = AJY× field/farm gate price

Total gross field benefit (TGFB) is the sum of all gross field benefit **(GFB)**

Total Variable Cost (TVC): is the sum of field cost of fertilizer, cost of seed, cost of input transportation and the cost of fertilizer application

Net Benefit (NB) (ETB/ha): for each treatment is the difference between the gross benefit and the total variable costs thus:

NB = GFB – TVC

Marginal rate of return (MRR %): calculated by dividing change in net benefit by change in total variable cost thus:

MRR (%) = ΔNB /ΔTVC x100

3.7. Statistical Analysis

The data analysis was carried out by using analysis of variance (ANOVA) for Randomized Complete Block Design (RCBD), using the General Linear Models (GLM) procedure (SAS, version 9.3). Means between treatments were compared using least significant difference (LSD) test at 5% level when the significant differences between the treatment mean observed.

The statistical model used to fit the data was:

$$Y_{ijk}=\mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk};$$

Where,

Yijk= measurable variable,

μ=overall mean,

αi =factor (a) nitrogen application

βj = factor (b) row arrangement

(αβ)ij = interaction of the effects,

ε_{ijk}= the residual error

Pearson correlation analysis was used to determine the association among agronomic performance, yield and chemical composition of oat forage.

4. RESULTS AND DISCUSSIONS

4.1 Physico-chemical Characteristics of the Soil

The results of the soil chemical analysis were presented in (Table 2). The results showed that samples of the top soils (0-30 Cm) collected both before and after forage productions were moderately acidic. The mean soil pH was 5.16 before planting (Table 2) indicate adequacy for nutrient availability to plant roots (Marschner, 1995). According to FAO (2000) the soil pH for optimum productivity of most crops range 4-8, indicating that the result of the pH of the soil before planting was within the range of productive soil. The result of overall mean of soil pH after harvesting was found to be 5.62. Even though pH of the soil sample showed moderately acidic after harvesting, there was slightly increase in mean soil pH from 5.16 before planting to 5.62 after harvest. The result showed that there was an increase in the soil pH values of the intercropped systems compared with sole cropping systems. According to Esekhade *et al.* (2003), intercropping lead to reduction in soil acidity compared to sole cropping systems, probably due to higher organic material generation.

The mean organic carbon content of the soil before planting was 3.02%. After harvest, the overall mean of organic carbon content was 2.95 with a range of 2.10 – 4.14% before planting. London (1991), classified soil with organic carbon contents of $\leq$ 4, 4-10 and > 10% as low, medium and high respectively. The result of organic carbon content of the current soil before and after planting was low in accordance with classification of London (1991).

London (1991) classified total nitrogen content of soil of <0.1, 0.1-0.15, 0.15-0.25% and >0.25% as very low, low, medium, and high respectively. The results of total nitrogen content of the experimental soil before planting was 0.25%, the value of which was rated as medium to London (1991). The mean total nitrogen content of the soil after harvest was 0.27% with a range of 0.18-0.35%, the values of which was also rated as high compared to London(1991). An increase in soil total nitrogen was brought as a result of intercropping. As shown in (Table 2) the lowest total nitrogen content of oat forage was recorded after harvest from the treatment consisting pure stand of oat without nitrogen. On the other hand, numerically higher total nitrogen of oats grass was recorded after harvesting the treatment consisting of oat: field pea arrangement of 1:2 with application of 46 kg N_2 ha^1. There is evidence for the positive effects of intercropping of oat and common vetch (grass-legume) on soil fertility and nitrogen content (Yang and Mohamad, 2017).

Mean available phosphorus of 50 ppm and 68.33 ppm (57.04-79.62 ppm) was recorded (Table 2) from the soils before and after planting respectively. The mean available phosphorus of 68.33 ppm recorded from the experimental soil after harvesting was considered as higher than available phosphorus before planting. Olsen *et al.* (1954) classified available phosphorus content of soil as <10, 10-25, 25-50 and >50 as low, medium, high and Excessive. This could be due to organic matter content of experimental soil since the soil studied area not cultivated for longer time.

According to Landon (1991) soil with cation exchange capacity (CEC) values of < 5, 5-15, 15-25, 25-40, and >40 are classified as very low, low, medium, high and very high. According to the result of the current study, the mean cation exchange capacity of the experimental soil was 26.40 cmol/kg before planting and 26.01 cmol/kg after harvesting. These values were classified as high in rate to classification of London (1991) which could be considered as optimum for crop production.

According to the result of the current study, the organic matter of the experimental soil was 5.2% before planting and 5.08% after harvesting. Most soils contain 2-10% OM according to FAO (2005)

Soils particle size fractions of this study before planting was 38% sand, 32% clay and 30% silt and the soil texture class of experimental site was clay loam. Soil particles size proportion after planting was revealed as 27.87% sand, 40.66% clay and 31.47% silt and textural class were clay and clay loam.

Table 2 Physico-chemical Characteristics of Soil Before planting and After Harvesting

parameters	PH (1:2.1 H_2O)	OC%	TN%	P(ppm)	OM%	CEC%
Before planting	5.16	3.02	0.25	50	5.20	26.40
After Harvesting						
Row Arrangement						
1:1	5.56±0.18[a]	2.83±0.21	0.26±0.01[b]	69.69±1.25[ab]	4.79±0.29	25.19±0.47[c]
2:1	5.82±0.06[a]	3.04±0.20	0.25±0.01[c]	70.16±2.33[a]	5.25±0.53	26.63±0.34[ab]
1:2	5.77±0.03[a]	3.20±0.25	0.31±0.02[a]	69.34±2.01[ab]	5.80±0.48	27.86±0.51[a]
Sole oat	5.27±0.02[b]	2.81±0.22	0.23±0.02[d]	64.77±1.09[c]	4.57±0.34	26.09±0.68[bc]
Sole pea	5.68±0.07[a]	2.87±0.24	0.28±0.01[b]	67.69±0.44[b]	5.01±0.53	25.66±0.57[bc]
P- value	**0.01**	**0.19**	**0.01**	**0.01**	**0.13**	**0.02**
Nitrogen Level						
0	5.52±0.12	2.69±0.12[b]	0.24±0.01[b]	69.34±1.45[a]	4.52±0.25[b]	25.61±0.58[b]
23	5.62±0.06	2.80±0.16[b]	0.28±0.01[a]	69.29±1.39[a]	5.80±0.34[a]	26.26±0.36[ab]
46	5.73±0.06	3.36±0.18[a]	0.29±0.01[a]	66.36±0.73[b]	4.94±0.38[b]	27.00±0.31[a]
P- value	**0.15**	**0.01**	**0.01**	**0.02**	**0.01**	**0.03**
Interaction						
1:1 * 0	5.43±0.62	2.45±0.18[fgh]	0.25±0.01[bc]	73.60±1.56[b]	4.20±0.75[de]	23.52±0.70[e]
1:1 * 23	5.60±0.03	3.17±0.50[cde]	0.27±0.03[bc]	66.30±1.27[cde]	5.46±0.13[abcd]	24.94±0.52[cde]
1:1 * 46	5.67±0.01	2.88±0.29[def]	0.26±0.01[bc]	69.17±1.15[c]	4.70±0.24[cde]	26.23±0.27[bcd]
2:1 * 0	5.72±0.12	2.68±0.02[efgh]	0.24±0.01[c]	64.37±1.54[de]	4.68±0.81[cde]	25.41±0.45[cde]
2:1 * 23	5.75±0.02	2.58±0.01[efgh]	0.26±0.01[bc]	78.95±0.73[a]	4.45±0.87[cde]	25.55±0.68[cde]
2:1 * 46	5.99±0.01	3.85±0.02[ab]	0.27±0.01[bc]	67.18±1.63[cde]	6.63±0.75[ab]	26.93±0.19[bc]
1:2 * 0	5.75±0.05	2.48±0.01[fgh]	0.25±0.01[c]	76.83±1.01[ab]	4.29±0.57[cde]	29.23±0.46[a]
1:2 * 23	5.88±0.02	4.14±0.02[a]	0.33±0.01[a]	66.40±1.45[cde]	7.14±0.26[a]	26.62±0.75[bc]
1:2 * 46	5.69±0.03	2.97±0.01[cdef]	0.35±0.01[a]	64.78±1.59[de]	5.95±0.60[abc]	26.74±0.44[bc]
Sole oat * 0	5.22±0.01	2.78±0.01[defg]	0.18±0.01[d]	64.16±2.46 [de]	4.79±0.42[cde]	24.41±0.60[de]
sole oat * 23	5.25±0.01	3.56±0.01[abc]	0.27±0.01[bc]	66.71±1.95[cde]	5.31±0.64[bcde]	25.80±1.00[bcd]
sole oat * 46	5.35±0.01	2.10±0.14[h]	0.26±0.01[bc]	63.44±1.22[e]	3.61±0.15[e]	27.74±1.21[ab]
Sole pea * 0	5.48±0.01	3.07±0.58[cdef]	0.26±0.01[bc]	67.75±0.91[cd]	4.62±0.64[cde]	24.25±0.61[de]
sole pea * 23	5.62±0.02	3.36±0.02[bcd]	0.29±0.01[b]	68.08±0.77[cd]	6.63±0.60[ab]	26.72±1.06[bc]
sole pea * 46	5.94±0.05	2.19±0.01[gh]	0.29±0.01[b]	67.23±0.81[cde]	3.78±0.66[de]	26.01±0.87[bcd]
Mean±SE	**5.62±0.07**	**2.95±0.12**	**0.27±0.01**	**68.33±1.34**	**5.08±0.54**	**26.01±0.65**
P- value	**0.86**	**0.03**	**0.02**	**0.01**	**0.02**	**0.01**

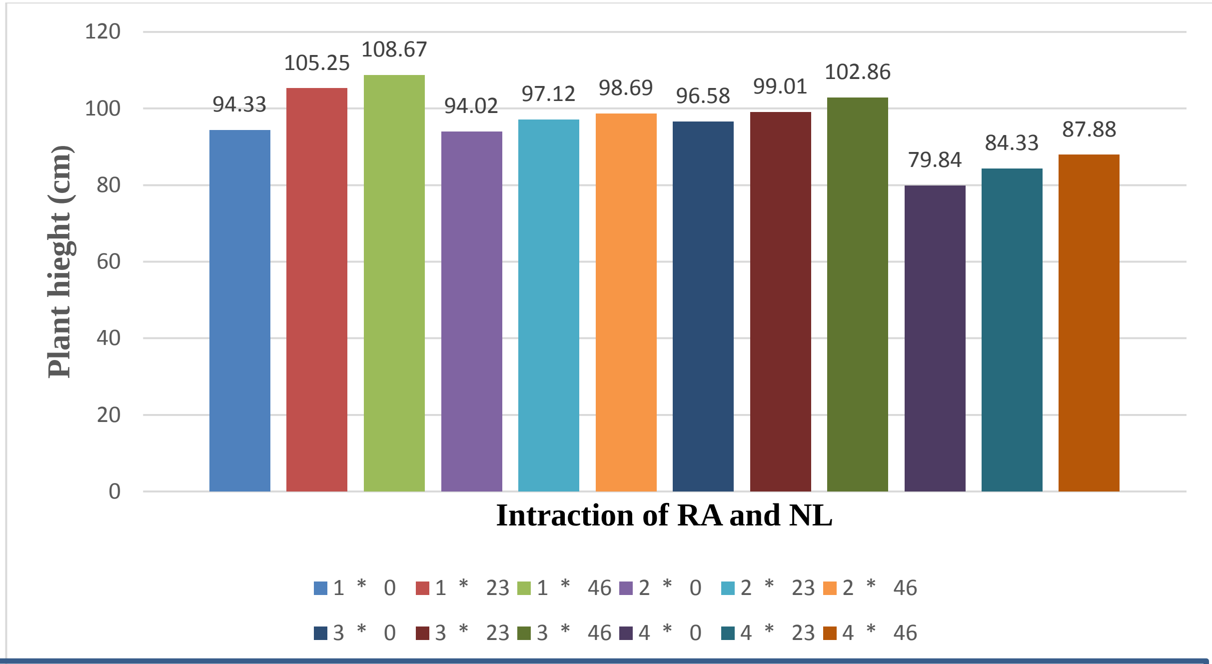
CEC=cation exchange capacity; OM=Organic matter; OC= organic carbon; TN= total Nitrogen; P= Available phosphorus

4.2. Agronomic Attributes and Yield of Oat

4.2.1 Plant height

The result of the plant height (PH) and related agronomic characteristics was presented in (Table 3). There was significant difference between different treatments on plant height ($P<0.05$). There was statistically significant interaction between row arrangement and different level of nitrogen application on plant height ($P<0.05$). The result showed that significantly taller plants ($P<0.05$) were observed from the treatment containing oat: field pea at 1:1 row arrangement which received 46 Kg N_2 ha^{-1} 108.67cm as shown in (Figure 2). The significantly shorter plant was observed from the treatment containing pure stand oat without nitrogen application i.e 0 Kg N_2 ha^{-1} 79.84cm. The results obtained indicated that there was significant ($P<0.05$) increase in plant height as a result of intercropping of oat with field pea and application of nitrogen fertilizer. Maximum plant height was attained at 1:1 row arrangement and nitrogen application of 46 Kg N_2 ha^{-1} at 50% of flowering stage (Table 3). Lengthening on plant height could be due to the higher competition between oat and field pea to reach and capture sunlight as suggested by (Ofori and Stern, 1987). According to Shaalan, (2005), the reason for increase in PH in response to row arrangement and levels of nitrogen fertilizer application might be due to secretion of plant growth promoting hormones like auxin, gibberellin and cytokinins by oat grass, which increase the rate of nutrient uptake and nitrogen availability.

The result of the current study was in agreement with that of Dubey *et al*. (2013), Abate and Wegi (2014), Takele *et al*. (2017) and Tamiru (2014) they reported that an increased plant height with increasing levels of nitrogen application and intercropping. They also indicated that the highest plant height was recorded at the higher level of nitrogen fertilizer application and significantly shorter ($P<0.05$) plant height was recorded at 0 level of nitrogen fertilizer application. This implies that the increment on plant height in response to the applied treatment contribute to an increase on forage dry matter yield which is the ultimate goal of the smallholder farmers.



RA= Row Arrangement; NL= Nitrogen level cm= centimeter

1*0 = 1:1 RA without nitrogen	3*0 = 1:2 RA without nitrogen
1*23 = 1:1 RA interaction with 23 kg N_2 ha^1	3*23 = 1:2 RA interaction with 23 kg N_2 ha^1
1*46 = 1:1 RA interaction with 46 kg N_2 ha^1	3*46 = 1:2 RA interaction with 46 kg N_2 ha^1
2*0 = 2:1 RA without nitrogen	4*0 = Sole oat without nitrogen
2*23 = 2:1 RA interaction with 23 kg N_2 ha^1	4*23 = Sole oat interaction with 23 kg N_2 ha^1
2*46 = 2:1 RA interaction with 46 kg N_2 ha^1	4*46 = Sole oat interaction with 46 kg N_2 ha^1

Figure 2 plant height

4.2.2. Number of tiller per plant

The results of number of tillers per plant are shown in (Table 3). The results showed that the number of tillers per plant of oat forage was significantly affected by row arrangement, application levels of nitrogen and interaction between row arrangement and level of nitrogen application ($P < 0.05$). The maximum number of tillers per plant 9.92 was recorded from experimental plot oat: field pea row arrangement of 1:1,received 46 Kg N_2 ha^{-1} , followed by oat: field pea row arrangement of 1:2 received 46 Kg of N_2 ha^{-1} produced 8.75. The increase in number of tillers per plant might be due to nitrogen fixing capacity of leguminous field pea plus adequate fertilizer application has increased nitrogen availability, which in turn enhanced the production of more number of tillers per plant as reported by Nowak, J. (2011). Significantly lower ($P<0.05$) number of tillers per plant of 5.00 was recorded from oat pure stand without nitrogen fertilizer (0 Kg of N_2 ha^{-1}).

Table 3 Agronomic Attributes and Yield of Oat

Source of Variation		TL	LC	PH	FBY	DMY (t ha^{-1})	SYO(t ha^{-1})	LSR
RA	1:1	7.56±0.64^{a}	6.16±0.20^{b}	102.75±2.22^{a}	39.63±0.70^{a}	6.97±0.36^{a}	3.96±0.18^{b}	1.03±0.008^{b}
	2:1	6.20±0.30^{b}	5.93±0.10^{c}	96.61±0.80^{b}	37.73±0.67^{b}	6.23±0.35^{b}	3.51±0.11^{c}	1.02±0.009^{b}
	1:2	7.77±0.35^{a}	6.47±0.11^{a}	99.49±1.11^{c}	40.37±0.62^{a}	7.42±0.47^{a}	4.75±0.19^{a}	1.05±0.008^{a}
	Sole Oat	5.36±0.18^{c}	5.57±0.09^{d}	84.02±1.45^{d}	33.89±1.06^{c}	5.22±0.35^{c}	2.95±0.13^{d}	0.97±0.012^{c}
	Mean±SE	**7.17±0.43**	**6.19±0.14**	**99.62±1.38**	**39.24±0.66**	**6.46±0.38**	**4.06±0.16**	**1.03±0.01**
	cv%	**9.05**	**5.74**	**1.23**	**2.30**	**8.30**	**5.34**	**9.80**
	P-value	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
NL kg/ha	0	5.81±0.24^{c}	5.68±0.12^{c}	91.19±2.06^{c}	35.62±1.06^{c}	5.32±0.26^{c}	3.36±0.21^{c}	0.99±0.012^{c}
	23	6.47±0.34^{b}	6.11±0.10^{b}	96.43±2.39^{b}	38.02±0.67^{b}	6.39±0.33^{b}	3.73±0.17^{b}	1.02±0.010^{b}
	46	7.88±0.50^{a}	6.32±0.15^{a}	99.53±2.32^{a}	40.08±0.76^{a}	7.67±0.30^{a}	4.29±0.24^{a}	1.04±0.011^{a}
	Mean±SE	**6.72±0.36**	**6.04±0.12**	**95.72±2.26**	**37.90±0.83**	**6.46±0.30**	**3.79±0.21**	**1.02±0.01**
	cv%	**8.93**	**5.74**	**1.57**	**2.40**	**10.45**	**5.34**	**9.80**
	P-value	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
INT	1:1 * 0	5.71±0.18^{fg}	5.46±0.21^{fg}	94.33±0.86^{d}	37.69±0.63^{cd}	5.94±0.44	3.31±0.07^{de}	1.00±0.003
	1:1 * 23	7.04±0.48^{cd}	6.36±0.07^{bc}	105.25±1.29^{ab}	39.10±0.58^{bc}	6.95±0.48	4.05±0.03^{c}	1.03±0.003
	1:1 * 46	9.92±0.22^{a}	6.67±0.11^{ab}	108.67±0.66^{a}	42.09±0.17^{a}	8.02±0.29	4.51±0.04^{b}	1.05±0.007
	2:1 * 0	5.63±0.07^{fg}	5.79±0.04^{def}	94.02±0.36^{d}	36.70±0.63^{de}	5.34± 0.38	3.19±0.06^{de}	0.99±0.009
	2:1 * 23	6.09±0.65^{def}	5.96±0.15^{de}	97.12±1.11^{cd}	37.03±1.02^{de}	6.10±0.47	3.45±0.09^{d}	1.01±0.003
	2:1 * 46	6.88±0.52^{cde}	6.04±0.27^{cde}	98.69±0.79^{c}	39.46±1.29^{bc}	7.24±0.46	3.90±0.10^{c}	1.05±0.010
	1:2 * 0	6.92±0.48^{cde}	6.17±0.08^{cd}	96.58±1.82^{cd}	38.25±0.62^{cd}	5.83±0.17	4.45±0.10^{b}	1.03±0.009
	1:2 * 23	7.63±0.38^{c}	6.42±0.11^{bc}	99.01±0.98^{c}	40.64±0.28^{ab}	7.48±0.35	4.41±0.10^{b}	1.05±0.009
	1:2 * 46	8.75±0.50^{b}	6.84±0.04^{a}	102.86±0.61^{b}	42.22±0.28^{a}	8.94±0.24	5.41±0.32^{a}	1.08±0.009
	Sole oat * 0	5.00±0.12^{g}	5.29±0.15^{g}	79.84±1.02^{g}	29.83±0.61^{f}	4.16±0.29	2.50±0.08^{ef}	0.95±0.032
	sole oat * 23	5.13±0.07^{fg}	5.71±0.04^{ef}	84.33±2.48^{f}	35.31±0.45^{e}	5.01±0.18	3.00±0.08^{e}	0.97±0.010
	sole oat * 46	5.96±0.32^{efg}	5.71±0.08^{ef}	87.88±1.30^{e}	36.53±0.35^{de}	6.48±0.13	3.35±0.06^{d}	0.99±0.009
	Mean±SE	**6.72±0.33**	**6.04±0.11**	**95.72±1.11**	**37.90±0.58**	**6.49±0.40**	**3.79±0.09**	**1.02±0.01**
	cv%	**9.86**	**3.83**	**2.24**	**2.98**	**11.31**	**5.34**	**2.02**
	P-value	**0.007**	**0.025**	**0.009**	**0.012**	**0.416**	**0.027**	**0.959**

TL = tiller; PH=Plant height; LC=leaf count; FBY=Fresh biomass yield; DMY=Dry matter yield; SYO= seed *yield of oat; LSR= Leaf Stem Ratio; CV = coefficient of variance; SE = standard error; RA=row arrangement NL= Nitrogen level INT=interaction abc… means with different superscripts within a column are significantly d/t (P<0.05)*

The result obtained indicated that there was an increase in number of tiller per plant with the increased proportion of legume within the row arrangement and level of application of nitrogen. The result of the number of tiller per plant obtained in the current study 9.92 was in agreement with that of Kassa *et al.* (2019), Hasan and Shah (2000), Yang and Mohamed (2017) and Singh *et al.* (2002) reported that the number of tillers per plant improved with increasing levels of nitrogen on oat forage and intercropping. This suggesting that the studied factor could increases dry matter and fresh biomass yield of forage oat ha^{-1} and improve feed shortage in quantity.

4.2.3. Number of leaf per plant

There was significant ($p < 0.05$) difference between the treatments in number of leaves per plant at 50% flowering (Table 3). The number of leaves per plant at 50% flowering was significantly ($P<0.05$) higher for the treatment containing oat: field pea row arrangement of 1:2 received 46 Kg N_2 application ha^{-1}. Significantly higher mean number of leaves per plant 6.84 was recorded from the treatment containing oat: field pea row arrangement of 1:2 received 46 kg N_2 ha^{-1}, followed by that 6.67 of the treatment containing oat: field pea row arrangement of 1:1 received 46 kg N_2 ha^{-1}. The higher number of leaves per plant could be due to the higher level of nitrogen content of the plants which ultimately helped to increase vegetative growth and efficient leaves formation. On the other hand, significantly lower ($P<0.05$) number of leaves per plant 5.29 was recorded from the experimental plots containing pure stand oat grown without nitrogen fertilizer (0 kg N_2 ha^{-1}).

The results of this experiment clearly showed that there was an increase in number of leaves per plant with increased proportion of field pea in the row arrangement and increased level of nitrogen application. According to Muthoni and Kabira (2011) an increase on the number of leaves per plant could be attributed to increased nitrogen uptake which brought about the production of extra leaves and branches with adequate expansion of leaf area. The results of the current study was in line with that of Rana (2009), Godara *et al.* (2016), Rawat and Agarwal (2010), Sher A. *et al.* (2016) and Nyagari (2016) reported the total number of leave per plant increases in response to increased level of nitrogen application and intercropping. Regardless to N_2 application, N_2 dosage positively affected number of leaves. According to these studies all growth parameters of oat forage were influenced significantly by increasing levels of nitrogen. Application of nitrogen significantly increased the growth and yields of fodder oat. They reported that maximum number of leaves per plant was recorded with higherN_2 rate. An increase in number of leaves plant^{-1} on maize and sorghum with N_2 application has also been reported by Akram *et al.* (2010), Khalid *et al.*(2010) and Amin (2011). This implies that increase in number of leaves plant^{-1}improves the feed quality and could increase animal production traits.

4.2.4. Fresh Biomass Yield of Oat

The result of the biomass and related yield parameters are shown in (Table 3). There was significant difference ($P<0.05$) and interaction (RA*NL) between the treatment plots in fresh biomass yield ($t \cdot ha^{-1}$) of the forage at 50% flowering. The results obtained indicated that significantly ($P<0.05$) higher mean fresh biomass forage of 42.09 and 42.22 t ha-^{1} was harvested from the experimental plots containing oat: field pea row arrangement of 1:1 and 1:2 respectively with application of 46 kg of nitrogen ha^{-1}. The better mean green forage yield of these experimental plots might be due to the better supply of nitrogen through nitrogen fixation capacity of the relatively high population of field pea and nitrogen fertilizer application resulting in increased total available nitrogen, which activated vegetative growth and increase in mean green forage yield. There was no significant ($P>0.05$) difference in mean fresh biomass forage production between experimental plot containing oat: field pea 1:1 and 1:2 row arrangement with 46 kg of nitrogen ha^{-1} both of which were significantly higher than the others. Significantly lower ($P<0.05$) mean fresh biomass forage 29.83 t ha-^{1} was harvested from the treatment plots containing pure stand oat received 0 kg N_2 ha^{-1}.

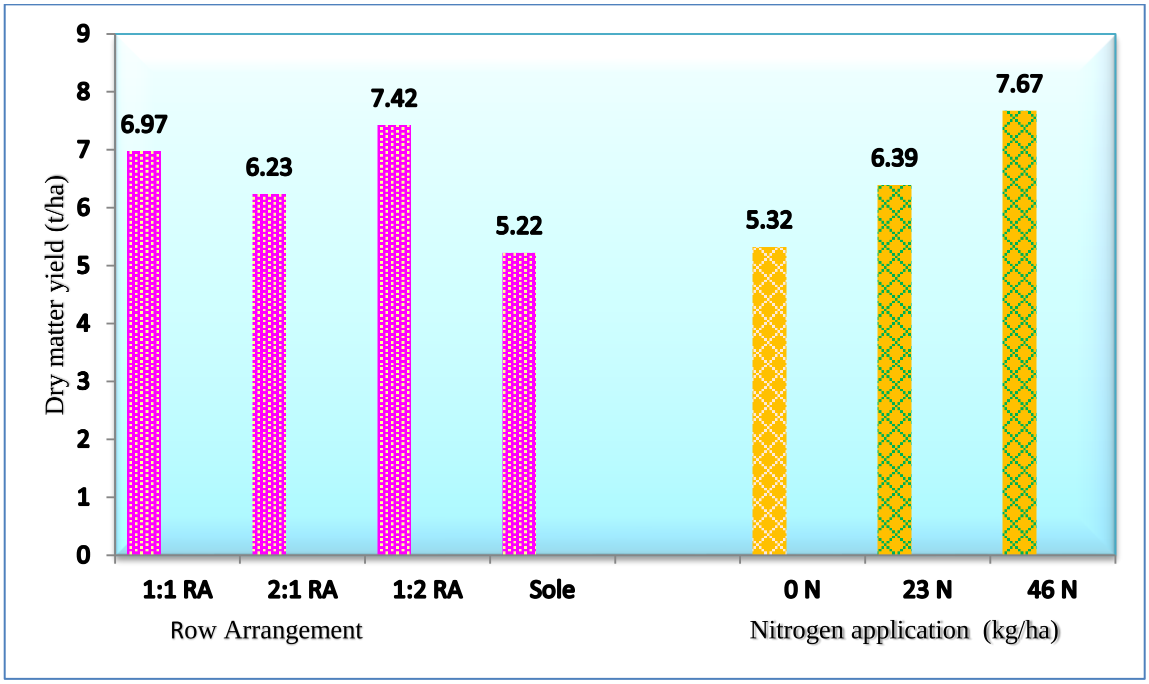
Studies conducted by Kassa *et al.* (2019), Olanite *et al.* (2010), Lodhi *et al.* (2009), Muhammad *et al.* (2011) and Unathi *et al.* (2018) corresponded to the current result in green biomass yield at 50% flowering stages those reported that higher level of nitrogen and intercropping contributed to progressive increase in biomass of the forage. Lower than the value of fresh biomass yield reported by Beyene *et al.* (2015). The differences observed could be the differences in soil related factors, climate and probably the physiological stage of the plant at harvest. This suggesting that the studied forage could increases feed quantity ha^{-1} and alleviate feed shortage of small holder farmers

4.2.5. Total Dry Matter Yield

The result of herbage dry matter yield of the current study was presented in (Table 3 and Figure 3). As presented in (Figure 3), the mean total dry matter ranged between 5.22 and 7.42 $t \cdot ha^{-1}$. Significantly higher ($P<0.05$) mean total dry matter yield of 7.42 t ha^{1} was harvested from experimental plots containing oat: field pea row arrangement of 1:2, which is similar to the mean total dry matter yield of 6.97 $t \cdot ha^{-1}$ harvested from the experimental plot containing oat: field pea at 1:1 row arrangement. The mean total dry matter yield harvested from the experimental plot planted to pure stand oat was 5.22 $t \cdot ha^{-1}$, the value of which was significantly ($P<0.05$) lower than the mean total dry matter harvested from the others.

The significantly higher ($P<0.05$) mean dry matter yield recorded from the experimental plots with oat: field pea row arrangement of either 1:2 or 1:1 might be due to nitrogen fixing capacity of the relatively higher population of leguminous field pea . The adequate nitrogen supply achieved through atmospheric nitrogen fixation seems to have promoted better mean dry matter yield. On the contrary, significantly lower ($P<0.05$) mean dry matter yield recorded from the experimental plots containing oat-field pea row arrangement of 2:1 might be due to the sever competition for nutrients and moisture exerted by relatively high population of oats (Table 3). The results of the current study was in agreement to Whitehead, (1995), Eskandari *et al.* (2009) and Sima *et al.* (2010) those reported that higher DM yield of intercropped grass-legume over grass-legume monocultures in which the legumes cover the nitrogen demand of grasses through atmospheric nitrogen fixation.

Significantly higher ($P<0.05$) mean total dry matter yield of 7.67 $t \cdot ha^{-1}$ was harvested from experimental plots received 46 kg N_2 ha^{-1} , whereas the minimum mean total dry matter yield of 5.32 t $ha\text{-}^{1}$ was recorded from the treatment plots received 0 kg N_2 $ha\text{-}^{1}$ (control treatment). The results obtained indicated that mean total dry matter yield of oat showed significant variation in mean dry matter yield with different oat: field pea row arrangement and application of different levels of nitrogen ha^{-1} (Table 3). An increase on mean total dry matter yield could be due to nitrogen fixing capacity of field pea which in turn increased dry matter yield through increasing nitrogen availability and plant dry matter accumulation. Also this finding in line with that of Kebede *et al.* (2017), Yidersal *et al.* (2020), Kumar (2005), Sharma *et al* (2009) and Rasheed *et al.* (2005) those suggested that nitrogen fertilizer application greatly increased the accumulation of the dry matter yield of oat over control. Generally, on increasing on dry matter yield per unit area could suggest that an ability of intercropping to improve feed shortage of small holder farmers.



RA= Row Arrangement; N=nitrogen

Figure 3 Dry matter yields of Oat

4.2.6 Seed Yield of Oat

The result of seed yield of oat was presented in (Table 3). It was observed that application of different levels of nitrogen and intercropping of oat: field pea at different row arrangement resulted in significant increase in seed yield of oat. Moreover, significantly higher ($P<0.05$) and maximum grain yield of 5.41 $t{\cdot}ha^{-1}$ of oat seed was harvested from experimental plots received 46 kg of N_2 ha^{-1} with oat: field pea row arrangement of 1:2 followed by seed yield of (4.51 $t{\cdot}ha^{-1}$) harvested from plots received 46 kg N_2 ha^{-1} with oat: field pea row arrangement of 1:1 (Table 3). The minimum mean seed yield of 2.50 t ha^{-1} was recorded from the experimental plots containing pure stand oat received 0 kg N_2 ha^{-1}

(control treatment). This indicated that existence of positive interaction between nitrogen application and row arrangement. The result of the current study was lower than that of Kassa *et al*. (2019) who reported 6.57 t·ha^{-1} of oat seed from variety trials conducted with the use of irrigation. The current result was higher than that of Abate and Wegi (2014) who reported mean total grain yield of 4.48 t·ha^{-1}. But this result was in agreement with Devi *et al.* (2019) who reported that nitrogen application, gave significant seed yield resulting from nitrogen application. The differences observed could be the differences in soil related factors, climate etc.

4.2.7 Leaf to Stem Ratio (LSR)

The result of leaf to stem ratio presented in (Table 3) showed that there was no interaction but significant ($P<0.05$) difference between different oat: field pea row arrangement and different levels of nitrogen application in leaf to stem ratio. Significantly higher ($P<0.05$) mean leaf to stem ratio of 1.05 was obtained from the experimental plots with oat: field pea row arrangement of 1:2 and significantly lower ($P<0.05$) mean leaf to stem ratio of 0.97 was recorded from the treatment plots containing pure stand oat plantation.

Mean leaf to stem ratio of 1.04 was recorded from the experimental plots received 46 kg N_2 ha^{-1}, the value of which was significantly higher than the other levels of nitrogen application ($P<0.05$). The results obtained indicated that there was increase in leaf to stem to ratio with increase in nitrogen availability which initiated the development of more number of leaves per tiller and more fresh weight of leaves as compared to the plots receiving control treatment. Significantly lower ($P<0.05$) mean leaf to stem ratio of 0.99 was recorded from the control treatment (0 kg N_2 ha$^{-1)}$.

The results of the current study was in line with that of Abate and Wegi (2014) who reported that the maximum number of leaf to stem ratio was recorded for the maximum nitrogen fertilizer rate application. Leaf to stem ratio was increased for treatments received nitrogen fertilizer as compared to treatments without nitrogen fertilizer. This indicates that fertilizer contributes for the increment of leaf to stem ratio of fodder oat. Similar results reported by (Piri and Tavassoli 2012, Abate and Wegi 2014 and Abd El-Aziz, 2002) indicated that nitrogen fertilization significantly increase leaf to stem ratio. Yeshambel *et* *al.* (2018) reported that leaf-stem ratio was significantly increased in oat-vetch mixtures (intercropping at different harvesting stage. An increase in leaf to stem ratio with increased level of nitrogen application and proportion of legume might be attributed to an increase on number of leaves per tiller and fresh weight of leaves as compared to the control treatment plots. An increase in the proportion of leaves due to adequate nitrogen application and intercropping might have ultimately resulted in higher photosynthetic activities which in turn brought improvement in growth and yield attributes (Table 3). Nitrogen is the main component of protein and stimulates cell division and elongation, resulting in better yielded response of forage (Midha *et al.* 2015, Godara *et al.* 2016, Ratan *et al*. 2016). This implies that increase in leaf to stem ratio improve the feed quality and could increase animal production at farmer level since leaf contain considerably high percentage of protein and other essential nutrient.

4.3. Yield and Yield Attributes of Field pea

4.3.1. Number of seed per pod

The result of number of seeds per pod of field pea was presented in (Table 4). There was significant ($P<0.05$) difference and interaction between experimental plots containing different row arrangement with different levels of nitrogen application in number of seeds per pod (Appendix 2). Significantly higher (P<,0.05) mean number of seed per pod of 7.25 was obtained from the application of 46 kg N_2 ha^{-1} with oat : field pea row arrangement of 1:2 followed by mean number of seed per pod of 5.92 obtained from the application of 46 kg N_2 ha^{-1} with oat: field pea 1:1 row arrangement. On the contrary, lowest mean number of seed per pod of 3.46 was recorded from the experimental plots containing pure stand oat received 0 kg N_2 ha-^{1} (Table 4). The results indicate that mean number of seed per pod responded positively to both nitrogen application and row arrangement during the trials period.

The results of the current study was in line with that of Lai (2004) who reported that the application of different level of nitrogen showed an improved seed yield and number of seeds per pod. There was increased in the values of response characters studied with increasing N_2 application from 0 to 46 kg N_2 ha^{-1} which indicates nitrogen as an essential nutrient for field pea. Higher values obtained from plot treated with 46 kg N_2 ha-^{1} which shows that increased rate of nitrogen leads to better and efficient nodulation which resulted in an increased, well filled pods and higher yield. Sing and Verma (2002), Tewari *et al*. (2000) also observed the similar results in bush bean. An increase on number of seeds per pod in response to row arrangement and nitrogen rate implies that the rise on production of field pea per unit area which is better solution for low productivity in small-scale farm.

4.3.2. Number of pod per plant

The result of number of pods per plant of field pea was presented in (Table 4). Statistical analysis of variances revealed that the main effect of Row arrangement (RA) and Nitrogen level (NL) as well as their interactions (RA*NL) had highly significant ($p < 0.05$) effect on number of pods per plant (NPPP) (Appendix 2). Based on the mean performance of the interaction between RA*NL field pea grown at the 1:2 RA received 46 kg N_2 ha^{-1} produced maximum number of pods per plant 27.50 followed by 1:1 RA received 46 kg N_2 ha^{-1} which produced 26.13. The minimum number of pods per plant 18.00 was recorded from sole field pea without (0 kg N_2 ha^{-1}) as shown in (Table 4). The maximum number of pods per plant was recorded from higher dose of nitrogen and at higher share of legume in cropping system and the minimum number of pods per plant was recorded from lower dose of nitrogen with sole oat forage. Number of pods per plant showed direct relationship with level of nitrogen and number of rows of legume in the cropping system. As the level of nitrogen and number of rows of field pea reduce there was reduction on the number of pods per plant.

An increase in the number of pods per plant with increasing rate of nitrogen and number of rows of legume in the cropping system could be due to the amount of N_2 applied and fixed by legume plant respectively. Reduction in N_2 rate and number of rows of legume result in reduction of the number of pods per plant and this might be due to good supply of N_2 to the plant encouraging the uptake of the other nutrients and visa verse (FAO, 2002), Mozumder *et al*. 2003). Moreover Achakzai & Bangulzai, (2006) and Kakar *et al.* (2002) reported that the number of pods per plant significantly increases with progressive increase in applied nitrogen fertilizer, and a maximum number of pods per plant was recorded in (100 kg ha^{-1})

dose of fertilizer. This increased number of pods per plant under higher fertilizer levels was mainly linked with increased plant height, which was the result of nitrogen availability in the soil in adequate quantities from external sources that were applied and from nitrogen fixation. This result was in agreement with the study of (Tuna and Orak, 2007) who reported that number of pods per plant was affected by the legume in the intercropping. Number of pods per plant reduced with reduction on legume ratio in the intercropping due to dominant stands of oat grass. This result was in line with Bitew *et al.* (2014) who obtained higher number of pods per plant in response to nitrogen rate.

4.3.3 Thousand seed weight

The response of 1000 seed weight of field pea to application of nitrogen rate and row arrangement was presented in (Tables 4). The table indicated that increase in application of nitrogen from 0 to 46 kg ha^{-1} at row arrangement (1:1, 2:1, 1:2 & sole) resulted in significant at the probability level ($P < 0.05$) on the main factor and their interaction effect (Appendix 2). Significantly higher values 224.67 g of measured characters were obtained from the interaction ($P < 0.05$) of 1:2 row arrangement with 46 kg N_2 ha^{-1} followed by 223.67g at 1:1 row arrangement with 46 kg N_2 ha^{-1} which was statistically similar and the least value 200.33g was recorded for sole oat without nitrogen (0 kg N_2 ha^{-1}). An increase in the values of traits studied with increasing nitrogen application indicates that the beneficial of nitrogen as a vital nutrient for field pea.

The result was in agreement with the findings of (Achakzai and Bangulzai 2006) who reported that increasing rate of nitrogen to field pea resulted in a corresponding increase in 1000 grain weight. This result was in line to (Mogiso, 2017) who founds 227g trail carried out for variety adaptation and evaluation. Saeed *et al.* (2004), Islam *et al.* (2006) and Shah *et al.* (2016) reported that there was significant variation among nitrogen fertilizer levels 1000-grain weight (g) of Chickpea. Higher dose nitrogen application has exhibited higher 1000-grain weight and significantly the lowest 1000-grain weight was observed in control treatment.

4.3.4 Seed yield of field pea

The results of seed yield of field pea were presented in Table 4. The result from analysis of variance revealed that the main effect of row arrangement, level of Nitrogen application and their interaction showed significant ($P < 0.05$) effect on seed yield of field pea (Appendix 2). Significantly ($P<0.05$) higher mean value of 3.98 t ha^{-1} and 3.96 t ha^{-1} of seed yield of field pea was harvested from the treatment plots containing oat: field pea row arrangement of 1:2 and 1:1 respectively with the addition of 46 kg N_2 ha^{-1}. On the contrary, significantly ($P<0.05$) lower mean seed yield of 2.98 t ha^{-1} was recorded from the treatment plots planted to pure oat without nitrogen fertilizer application (0 kg N_2 ha^{-1}). The increase in seed yield of field pea could be due to intercropping with oat (grass) which provided an upright standing support to field pea, avoiding reductions in seed yield due to severe lodging after flowering.

The result of this investigation agree with Lai (2004) who found that the application of nitrogen at (0, 20, 40 and 60 kg N ha^{-1}) on seed yield of field pea and bean resulted on an increased seed yield kg ha-^{1}. This result was in line with Mogiso, (2017) who reported (4.17 t ha^{-1}) a trail conducted for variety adaptation and evaluation. Borhan *et al.* (2014) reported that application of nitrogen fertilizer contributed for significant increase on grain yield of field pea in combination with phosphorus fertilizer.

Table 4 Agronomic Attributes and Yield of Field Pea

Source of Variation		NSPP	TSW	NPPP	SYP (t ha^{-1})
RA	1:1	5.15±0.23^{b}	215.67±2.12^{b}	23.56±0.83^{b}	3.66±0.113^{ab}
	2:1	4.89±0.22^{b}	213.00±1.42^{bc}	22.67±0.59^{c}	3.61±0.089^{b}
	1:2	5.93±0.41^{a}	223.67±1.04^{a}	24.56±1.04^{a}	3.72±0.085^{a}
	Sole oat	3.92±0.15^{c}	211.33±3.07^{c}	19.41±0.45^{d}	3.13±0.066^{c}
	Mean±SE	**5.32±0.29**	**217.45±1.53**	**23.60±0.82**	**3.66±0.096**
	CV%	**10.06**	**0.64**	**3.76**	**8.50**
	P-value	**0.01**	**0.01**	**0.01**	**0.01**
NL(kg)	0	4.22±0.17^{c}	211.17±2.73^{b}	19.90±0.34^{c}	3.23±0.05^{c}
	23	4.889±0.24^{b}	216.50±1.63^{a}	22.99±0.72^{b}	3.57±0.09^{b}
	46	5.81±0.31^{a}	220.08±1.28^{a}	24.75±0.74^{a}	3.79±0.08^{a}
	Mean±SE	**4.97±0.24**	**215.92±1.88**	**22.55±0.60**	**3.53±0.07**
	CV%	**9.86**	**0.63**	**3.44**	**7.50**
	P-value	**0.01**	**0.01**	**0.01**	**0.01**
Interaction	1:1 * 0	4.50±0.29^{def}	212.00±4.73^{cd}	20.50±0.14^{fg}	3.24±0.04^{ed}
	1:1 * 23	5.04±0.11^{cd}	216.00±3.46^{bcd}	24.04±0.11^{d}	3.76±0.07^{bc}
	1:1 * 46	5.92±0.04^{b}	219.00±2.65^{abc}	26.13±0.29^{b}	3.98±0.04^{a}
	2:1 * 0	4.21±0.04^{ef}	209.67±2.03^{d}	20.46±0.29^{g}	3.30±0.05^{d}
	2:1 * 23	4.80±0.06^{de}	213.33±2.40^{cd}	23.21±0.34^{e}	3.63±0.05^{c}
	2:1 * 46	5.67±0.11^{bc}	216.00±2.08^{bcd}	24.33±0.17^{d}	3.89±0.04^{ab}
	1:2 * 0	4.71±0.29^{de}	222.67±2.60^{ab}	20.63±0.26^{fg}	3.40±0.05^{d}
	1:2 * 23	5.84±0.53^{b}	223.67±1.45^{a}	25.54±0.29^{c}	3.79±0.02^{bc}
	1:2 * 46	7.25±0.07^{a}	224.67±1.76^{a}	27.50±0.40^{a}	3.96±0.04^{a}
	Sole oat * 0	3.46±0.11^{g}	200.33±2.03^{e}	18.00±0.07^{i}	2.98±0.04^{f}
	Sole oat * 23	3.88±0.14^{fg}	213.00±1.15^{cd}	19.17±0.11^{h}	3.08±0.08^{ef}
	Sole oat * 46	4.4±0.08^{def}	220.67±1.45^{ab}	21.04±0.04^{f}	3.33±0.10^{d}
	Mean±SE	**4.97±0.16**	**215.92±2.32**	**22.55±0.21**	**3.53±0.05**
	CV%	**7.49**	**2.01**	**1.83**	**2.70**
	P-value	**0.005**	**0.045**	**0.001**	**0.020**

NSPP= Number of seed per pod; TSW= Thousand seed weight; NPPP= Number of pod per plant; SYP= Seed yield of pea; CV = coefficient of variance; SE = standard error; RA=row arrangement NL=nitrogen level abc… means with different superscripts within a column are significantly different (P<0.05)

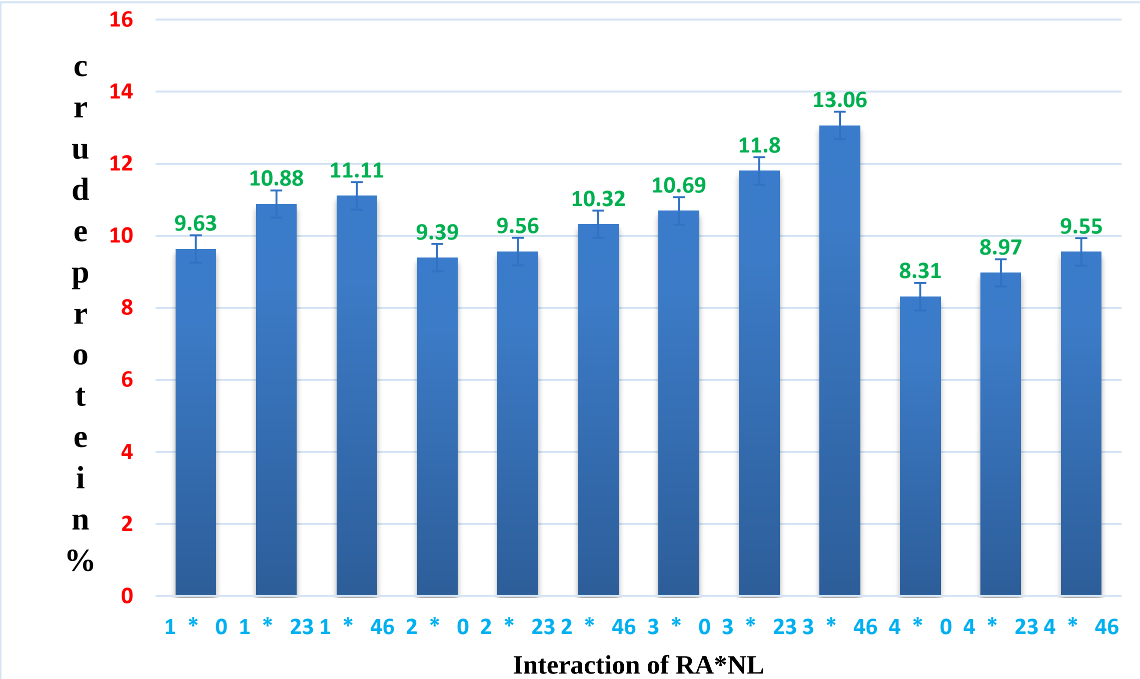
4.4. Chemical Composition of Oat Forage

4.4.1 Crude protein

The result of the laboratory chemical analysis of oat forage at 50% flowering stage was presented in (Table 5 and Figure 4). There was statistically significant interaction between row arrangement and level of nitrogen application ($P<0.05$) on crude protein content of oat forage. Significantly higher ($P<0.05$) crude protein content of 13.06% was recorded from forage materials harvested from the experimental plots received 46 kg N_2 ha^{-1} with oat: field pea at 1:2 row arrangement followed by 11.80% which harvested from the experimental plots received 23 kg N_2 ha^{-1} with oat: field pea at 1:2 row arrangement. This could be due to share of field pea in the row, the fact that field pea is nitrogen fixing legume which may increase nitrogen availability and transfer nitrogen to nearby forage grass and nitrogen is the basic constituent of amino acids that form protein. Significantly lower ($P<0.05$) crude protein content of 8.31% was recorded from oat pure stand received 0 kg N_2 ha^{-1}. The significantly higher crude protein content of the oat forage harvested from the treatment containing oat: field pea row arrangement of 1:2 receiving nitrogen fertilizer of either 23 or 46 kg N_2 ha^{-1} could mainly be attributed to the atmospheric nitrogen fixation capacity of the dominating population of field pea supported by the applied nitrogen fertilizer, both of which could be synthesized into crude protein.

The result of the current study was similar to that of Owens *et al.* (2007) and Galindo, (2019) those reported that oat grown in combination (intercropped) with peas as well as an increase on level of nitrogen application provides high-quality forage in crude protein concentration of harvested oat forage. Haq *et al*. (2018) reported that the CP content of oat-vetch and oat-pea combination was higher than that of oat grown alone. Sturludottir *et al.* (2014) reported that grass-legume intercropping increase the yield, quality, crude protein and amino acid content of the intercrop as compared with either of the two mono-cropping alone. The CP content increased with increasing share of legume in the intercropping compared to the crude protein content of the grass in the control experimental plots.

The review conducted by Adugna and Said (1994) indicated that crude protein content of less than 7.5% inhibits intake, digestibility and proper utilization of feeds. The CP content from all experimental plots of the plant materials obtained from intercropping in the current study was above the minimum level required for optimum rumen function (Van Soest, 1982), suggesting that the studied forage could properly support production functions of the animals.



RA= Row Arrangement; NL= Nitrogen application; CP= crude protein

Figure 4: Crude protein (CP %)

4.4.2 Total Ash

The result of laboratory chemical analysis for total ash content of oat forage at 50% flowering stage was presented in (Table 5). There was statistically significant interaction between row arrangement and level of nitrogen application ($P<0.05$) on total ash content of oat forage. The current study revealed that significantly higher ($P<0.05$) mean total ash content of 11.36% was recorded for the plant materials harvested from experimental plots containing pure stand oat grown with the application of 0 kg N_2 ha^{-1} (control) at 50% flowering stage (Table 5) . This was followed by mean total ash content of 10.20% recorded for the plant materials harvested from experimental plots containing oat: field pea at 2:1 row arrangement with 0 kg N_2 application ha^{-1} at 50% flowering stage. Minimum value of mean total ash of 7.16% was recorded for the plant materials harvested from experimental plots containing oat: field pea at 1:2 row arrangement with the application of 46 kg N_2 ha^{-1} at 50% flowering stage.

The result of the current study was in line with that of Kassa *et al.* (2019) who reported mean total ash of oats grass 9.99 % and Dereje (2016) who reported mean total ash of oats 12.30%. This result was also in line with that of Sarkar *et al.* (2004) who reported that there was significantly reduction on total ash continent of grass at increasing doses of nitrogen fertilizer could be due to increase on soil organic matter content. The results are inconsonance with the findings of Safdar (1997) who reported that total ash contents were increased with nitrogen rates in maize and similarly Tariq (1998) reported that in fodder maize, by increasing nitrogen levels; ash contents were increased. Kebede *et al.* (2014) and McDonald *et al.* (2002) reported that variation in concentration of total ash might be affected by factors like varieties, growth stage, morphological fractions, climatic conditions, soil characteristics, seasonal conditions and fertilization regime. The differences observed between the investigation results, could be impact of the above differences.

4.4.3 Total Dry Matter Content

The result of laboratory chemical analysis for total dry matter percentage of oat forage at 50% flowering stage was presented in (Table 5). The current result revealed that total dry matter content was significantly ($P<0.05$) affected by row arrangement and nitrogen application but their interaction did not show significant differences (Appendix 3). According to the data presented in (Table 5), mean total dry matter content of 92.95% was recorded from experimental plots containing oat: field pea at 1:2 row arrangement followed by mean total dry matter percentage of 91.89% recorded from experimental plots containing oat: field pea at 1:1 row arrangement. The lowest mean total dry matter percentage of 88.55% was recorded from experimental plots containing oat: field pea at 1:1 row arrangement. The highest mean total dry matter percentage of 93.26% was recorded for application of 46 kg N_2 ha^{-1} whereas the low mean total dry matter content 88.34% % was recorded from control treatment.

This result was in agreement with that of Kassa *et al.* (2019) who reported mean total dry matter content of 93.3% and Dereje (2016.) who reported mean total dry matter 93.76% on

Oats forage. Percentage of dry matter, hemicellulose, cellulose and lignin increases with advancement in stage of maturity (Yeshambel *et al.* 2018). They indicated that both intercropping and nitrogen level affect dry matter content of plant materials.

4.4.4. Neutral Detergent Fiber (NDF)

The result of laboratory chemical analysis for neutral detergent fiber content of oat forage at 50% flowering stage was presented in (Table 5). The current result revealed that neutral detergent fiber content was significantly ($P<0.05$) affected by row arrangement and nitrogen application but their interaction did not show significant differences (Appendix 3). The highest mean NDF content of 56.48% was recorded from the experimental plots received 0 kg N_2 ha^{-1} and the lowest mean NDF content of 51.94% was recorded from the experimental plots received 46 kg N_2 ha^{-1}. The results obtained showed that NDF content of the forage materials increased with reduction in level of nitrogen fertilizer application. The results of the current study were in line with those of Dereje (2016), Muhammad *et al.* (2011) and Ahmad *et al.* (2013) who reported 60, 56 and 59.70% of NDF on oat forage respectively. The result of the NDF concentration obtained in the current study was in agreement with that of Viana *et al. (2011) and* Dupas *et al.* (2010) those reported reduction in NDF concentration with increase in level of nitrogen fertilizer application. Since nitrogen fertilizer promotes the growth of new leaves and shoots resulting in low NDF.

Significantly higher ($P<0.05$) mean NDF of 57.58% was recorded for forage materials harvested from the experimental plots grown to pure oat stand. On the other hand significantly lower ($P<0.05$) mean NDF of 50.95% was recorded for forage materials harvested from the experimental plots containing oat: field pea at 1:2 row arrangement. Negash *et al.* (2017) reported that the contents of NDF, ADF and ADL appeared to increase with increasing proportion of oats in the mixture.

Geleti **(**2000) indicated that NDF contents above the critical value 60%, results in decreased voluntary feed intake, feed conversion efficiency and longer rumination time. An increased NDF% most often has a negative impact on the amount of dry matter consumed (Allen, 2000). According to Van Soest (1965), the critical level of NDF which limits intake was reported to be 55%. Singh and Oosting (1992) reported that NDF below 45% are generally considered to be high quality feeds. The NDF% obtained from the current study was within the range of 45 and 60% indicating the good nutritional value of the forages, with the exception of sole stand oat without nitrogen fertilizer application. It was reported that the concentration of NDF diminished because of an increase in the crude protein and other soluble contents (Peyraud and Astigarraga, 1998).

4.4.5. Acid Detergent Fiber (ADF)

The ADF result of the current study was presented in (Table 5). The current result showed that acid detergent fiber content was significantly ($P<0.05$) affected by row arrangement and nitrogen application but their interaction did not show significant differences (Appendix 3). The result showed that significantly higher ($P<0.05$) ADF content of 39.67% was recorded from pure stand grown oat. On the contrary, significantly lower ($P<0.05$) ADF content of 35.10% was recorded from the experimental treatment containing oat: field pea at1:2 row arrangement. The highest mean value of 38.91% ADF was recorded without nitrogen application, whereas the minimum mean value 36.45% was recorded for experimental plots received 46 kg N_2 ha^{-1}.

The result of this study was in line with that of Vern S. Baron *et al*. (2004) who reported that increasing the legume proportion resulted in decreased ADF and NDF concentrations for the legume grass intercropping. The ADF value in the current study was in line with that of Alemu *et al.* (2007) who reported 40.68% ADF from oat and vetch intercropping at different harvesting date. The percentage composition of ADF decreased significantly and linearly with increased level of nitrogen fertilizer application ($P < 0.05$). These changes in ADF probably occurred because of dilution of the cell wall since nitrogen fertilizer promotes the growth of new leaves and shoots resulting in low ADF (Yidersal *et al.* 2020).

Kellems and Church (1998) classified forage with less than 40% ADF as high quality and ADF > 40% as low quality forage. According to the results of the current study, ADF content of < 40% was recorded from all the experimental plots, this indicating that the higher digestibility and nutritive value of oat forage on present evaluation. The general tendency showed that there was decrease in ADF content of the forage harvested with increasing proportion of legume in row arrangement and at different rate of nitrogen fertilizer application.

Table 5 Chemical Composition of Oat

Source of Variation		DM%	CP%	ASH %	NDF%	ADF%	ADL%	HC%	CELU%
RA	1:1	91.89±0.87^{ab}	10.54±0.23^{b}	9.56±0.17^{b}	53.31±0.78^{c}	37.85±0.46^{b}	10.16±0.24^{a}	15.46±0.49^{b}	27.69±0.30^{b}
	2:1	90.70±0.78^{b}	9.76±0.16^{c}	9.72±0.19^{ab}	55.44±0.53^{b}	38.17±0.44^{ab}	8.91±0.30^{b}	17.27±0.29^{a}	29.26±0.38^{a}
	1:2	92.95±0.97^{a}	11.85±0.38^{a}	8.64±0.41^{c}	50.95±1.43^{d}	35.10±1.09^{c}	9.04±0.40^{b}	15.85±0.52^{b}	26.06±0.80^{c}
	Sole oat	88.55±0.81^{c}	8.95±0.21^{d}	10.12±0.34^{a}	57.58±0.79^{a}	39.67±0.60^{a}	10.44±0.16^{a}	17.91±0.49^{a}	29.34±0.50^{a}
	Mean±SE	**91.85±0.87**	**10.72±0.26**	**9.31±0.26**	**53.23±0.91**	**37.04±0.66**	**9.37±0.31**	**16.19±0.43**	**27.67±0.49**
	CV%	**1.02**	**4.87**	**5.56**	**1.73**	**2.14**	**5.50**	**4.04**	**2.49**
	p-value	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
NL	0	88.34±0.55^{c}	9.51±0.28^{c}	10.34±0.22^{a}	56.48±0.69^{a}	38.91±0.42^{a}	10.21±0.23^{a}	17.57±0.44^{a}	28.79±0.36^{a}
	23	91.46±0.69^{b}	10.30±0.35^{b}	9.45±0.12^{b}	54.54±0.93^{b}	37.73±0.79^{ab}	9.45±0.33^{b}	16.81±0.39^{b}	28.28±0.6^{ab}
	46	93.26±0.67^{a}	11.01±0.40^{a}	8.74±0.30^{c}	51.94±1.15^{c}	36.45±0.86^{b}	9.25±0.32^{b}	15.49±0.42^{c}	27.20±0.69^{b}
	Mean±SE	**91.02±0.64**	**10.27±0.34**	**9.51±0.21**	**54.32±0.92**	**37.70±0.69**	**9.64±0.29**	**16.62±0.42**	**28.09±0.55**
	CV%	**0.88**	**5.68**	**4.82**	**1.77**	**2.20**	**5.58**	**3.90**	**2.64**
	p-value	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**
RA*NL	1:1 * 0	88.90±0.94	9.63^{e}±0.12^{e}	9.91±0.21^{bc}	54.90±0.25	38.67±0.57	10.60±0.41	16.23±0.82	28.07±0.19
	1:1 * 23	92.67±0.86	10.88±0.08^{cd}	9.54±0.18^{bcd}	53.78±1.68	38.01±0.71	10.24±0.06	15.77±0.98	27.78±0.74
	1:1 * 46	94.10±0.52	11.11±0.07^{c}	9.24±0.38^{cd}	51.26±0.96	36.87±0.96	9.65±0.55	14.39±0.58	27.22±0.55
	2:1 * 0	88.54±1.22	9.39±0.02^{e}	10.20±0.36^{b}	56.68±0.16	39.21±0.37	9.65±0.62	17.47±0.48	29.56±0.27
	2:1 * 23	91.27±0.84	9.56±0.08^{e}	9.68±0.17^{bc}	55.33±1.25	37.73±0.73	8.56±0.27	17.61±0.56	29.17±0.99
	2:1 * 46	92.28±1.20	10.32±0.26^{d}	9.29±0.28^{cd}	54.30±0.63	37.58±0.93	8.53±0.46	16.72±0.49	29.05±0.75
	1:2 * 0	89.66±0.86	10.69±0.42^{cd}	9.87±0.09^{bc}	55.02±1.16	37.95±0.89	10.31±0.55	17.07±0.55	27.64±0.82
	1:2 * 23	93.33±0.59	11.80±0.40^{b}	8.88±0.13^{d}	51.25±1.40	35.02±2.05	8.49±0.57	16.22±0.65	26.53±1.57
	1:2 * 46	95.87±0.75	13.06±0.11^{a}	7.16±0.29^{e}	46.57±1.78	32.32±1.16	8.31±0.19	14.25±0.69	24.01±1.00
	Sole oat * 0	86.28±0.63	8.31±0.28^{f}	11.36±0.35^{a}	59.31±1.65	39.81±1.29	10.27±0.15	19.50±0.50	29.88±0.53
	Sole oat * 23	88.57±1.37	8.97±0.24^{ef}	9.72±0.16^{bc}	57.80±1.11	40.17±1.36	10.53±0.43	17.64±0.60	29.63±1.14
	Sole oat * 46	90.81±0.63	9.55±0.12^{e}	9.28±0.22^{cd}	55.61±0.41	39.02±0.71	10.51±0.30	16.59±0.32	28.52±0.96
	Mean±SE	**91.02±0.87**	**10.27±0.18**	**9.51±0.24**	**54.32±1.04**	**37.70±0.98**	**9.64±0.38**	**16.62±0.60**	**28.09±0.79**
	CV%	**1.74**	**3.75**	**4.60**	**3.73**	**4.90**	**7.54**	**6.49**	**5.38**
	p-value	**0.853**	**0.038**	**0.003**	**0.277**	**0.376**	**0.182**	**0.549**	**0.648**

CP=Crude protein; DM=Dry matter; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; ADL=Acid detergent lignin; HC= Hemicellulose; CELU= Cellulose; CV=coefficient of variance; SE=standard error; RA=row arrangement NL=nitrogen level
abc… means with different superscripts within a column are significantly different (P<0.05)

4.4.6. Acid Detergent Lignin (ADL)

The result of ADL content observed in the current study was presented in (Table 5) showed that there was no interaction but significant (P<0.05) difference between the main factors. There was no significant difference (P<0.05) between the treatments containing pure oat stand and oat: field pea with row arrangement of 1:1 in composition of ADL as shown in (Appendix 3). Significantly higher (P<0.05) mean ADL content of 10.44% and significantly lower mean content of ADL of 8.91% were recorded for sole oat plantation and oat: field pea row arrangement of 2:1 respectively. Similarly significantly higher (P<0.05) ADL content of 10.21% and significantly lower (P<0.05) ADL content of 9.25% was recorded for experimental plots received 0 and 46 kg N_2 fertilizer ha^{-1} respectively.

The present result was in line with that of Dereje (2016) and Negash *et al.* (2017) those reported that 10.47% & 11.20% of ADL from oat forage at Oats and Vetch Mixtures (intercropping) respectively. The current study was similar Sisay *et al.* (2015) reported as the urea fertilizer level increase, the ADL content decrease. This is because the urea fertilizer promotes the growth of new leaves and shoots resulting in low lignin, which compensates the increase in lignin content of other tissues. Lower lignin has always produce a marked increase in the digestibility of the plants and lignin are highly resistant to chemical and enzymatic degradation and are not appreciably broken down by the micro flora in the ruminant digestive tract Ranjhan (1993).

The general trend of the result of the current study on ADL content were showed that there was reduction in ADL content of the forage with increasing level of nitrogen fertilizer application and increased proportion of legume in the cropping system. This could be due to decrease in the CP% and other soluble contents in the cell wall of the forage (Peyraud and Astigarraga 1998). Generally ADL content of oat forage affected to nitrogen rate and proportion of legume in the cropping system. The result of the current study showed lower lignin content which implies that better digestibility of the oat forage on the present evaluation.

4.4.7. Hemicellulose and Cellulose

Row arrangement and nitrogen level significantly (P < 0.05) affected the hemicellulose and cellulose content of oat forage. However, their interactions did not show significant difference

(Table 5). Significantly higher (P <0.05) mean hemicellulose content of 17.91% was recorded for sole oat forage and significantly lower (P<0.05) mean hemicellulose content of 15.85% was recorded from both experimental plots containing oat: field pea with 1:1 and 1:2 row arrangement. There was no significant difference between the experimental plots containing pure oat plantation and the experimental plots containing oat: field pea at 2:1 row arrangement of in composition of hemicellulose (Appendix 3). Similarly significantly higher (P<0.05) hemicellulose content of 17.57% and significantly lower (P<0.05) hemicellulose content of 15.49% was recorded from the experimental plots received 0 and 46 kg N_2 ha^{-1} respectively.

On other hand, higher mean cellulose content of 29.34 and 26.06% was recorded for pure stand oat plantation and from oat: field pea at 1:2 row arrangements. Similarly higher mean cellulose content of 28.79% was recorded from the experimental plots received 0 kg N_2 ha^{-1}(control). This result revealed that the hemicellulose and cellulose composition were significantly affected by levels of nitrogen fertilizer application and increased proportion of legume in the row arrangement. The high proportion of leaves apparently had more influence on the decrease of hemicellulose and cellulose composition of the whole plant receiving nitrogen fertilizer, whereas, the proportion of stems is the dominant factors involved in an increase of hemicellulose & cellulose composition of the whole plant with advancement in stage of maturity. This finding was in agreement to that of Ciepiela (2016), Gasim SH. (2003) and Kumar *et al.* (2001) those concluded that increasing in level of nitrogen application significantly decreased cellulose, hemicellulose, lignin and structural carbohydrate contents of forages.

4.5 Correlation of Agronomic, Yield and Composition of oat forage

The correlation analysis among agronomic, yield and chemical composition parameters of oat forage was presented in (Table 6). The correlation analysis revealed that there was a significant (P < 0.05) and positive correlation between number of tiller per plant with number of leaf per plant (NLPP) (r = 0.80*), dry matter yield (DMY (r = 0.77*)), seed yield of oat (SYO (r = 0.78*)), leaf stem ratio (LSR (r = 0.71*)), fresh biomass yield (FBY (r = 0.78*)) and crude protein (CP (r = 0.77*)). The association of NTPP with fiber contents neutral detergent fiber NDF (r = -0.72*), acid detergent fiber ADF (r = -0.59*) and acid detergent lignin ADL (r = -0.39*) showed significant but inversely correlated which might be because leaves have contain more organic matter. This finding was in line with Nidhi *et al.* (2015) who reported number of tiller per plant was strong association with NLPP, LSR, FBY and DMY of oat fodder.

Plant height (PH) was correlated significantly and positively with NLPP (r = 0.76*), LSR (r = 0.82*), dry matter (DM) (r = 0.77*), fresh biomass yield (FBY) (r = 0.86*), grain yield of oat, number of tiller per plant (NTPP) and Crude protein CP (r = 0.75*) content, which suggested that significant contribution of PH to agronomic, yield and yield components of oat forage. The current finding is in agreement with Amir *et al.* (2016) who reported that PH positive association with leaves, tiller and forage yields. Thus, the improvements in response variable such as PH, DMY, FBY and NTPP will help to improve fodder yield directly and indirectly.

The finding obtained from the present study confirm dry matter content (DMC) and dry matter yield (DMY) oat forage were positively correlated with agronomic parameters (NTPP, NLPP, PH, LSR), yield and quality indicator of oat. The current finding was in relation to Atman *et al.* (2018) who reported that DMY of oat exhibited direct and positive relation to NTPP, FBY and PH on DMY. This indicated that NTPP and PH were the important traits as far as their association with dry matter yield is concerned.

The results of current study indicated that there was strong relationship between CP and agronomic parameters but negatively correlated with ash and fiber contents. The fiber contents (NDF, ADF and ADL) of oat forage were positively correlated with each other's. The result in agreement with Daulat *et al*., (2010) who reported that crude protein showed a highly significant and positive association with NLPP and LSR. The result of the current study revealed that all the characters observed were highly significant, thereby showing that there were enough association among the parameters studied.

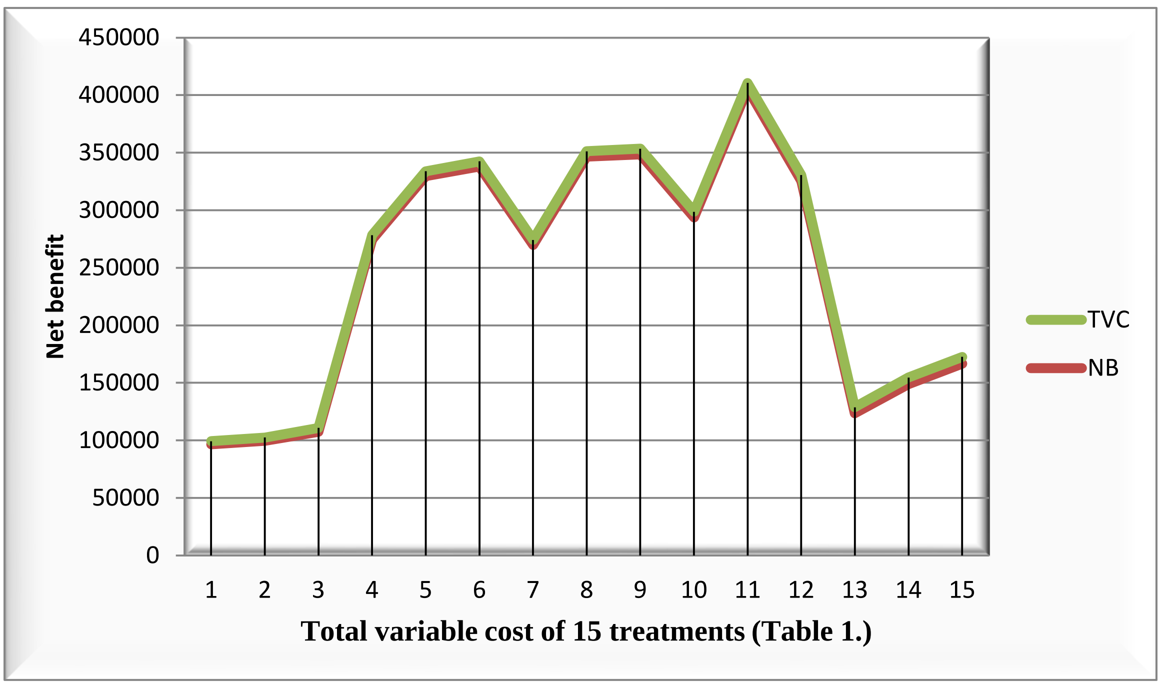
Table 6 Correlation of Agronomic, Yield and Composition of oat forage

	NTPP	NLPP	PH(cm)	LSR	DMY(t/ha)	SYO(t/ha)	CP%	ASH%	FBY(t/ha)	NDF%	ADF%	ADL%
NTPP	1.00	0.80*	0.79*	0.71*	0.77*	0.78*	0.77*	-0.55*	0.78*	-0.72*	-0.59*	-0.34*
NLPP		1.00	0.76*	0.74*	0.76*	0.86*	0.83*	-0.64*	0.78*	-0.71*	-0.57*	-0.37*
PH(cm)			1.00	0.82*	0.77*	0.77*	0.75*	-0.54*	0.86*	-0.70*	-0.56*	-0.37*
LSR				1.00	0.78*	0.85*	0.83*	-0.65*	0.84*	-0.74*	-0.67*	-0.51*
DMY(t/ha)					1.00	0.83*	-0.83*	-0.79*	0.83*	-0.84*	-0.65*	-0.41*
SYO(t/ha)						1.00	0.91*	-0.76*	0.82*	0.82*	-0.70*	-0.41*
CP%							1.00	-0.80*	0.84*	-0.87*	-0.80*	-0.50*
ASH%								1.00	-0.72	-0.82*	-0.74*	-0.46*
FBY(t/ha)									1.00	-0.77*	-0.60*	-0.41*
NDF%										1.00	0.91*	0.54*
ADF%											1.00	0.66*
ADL%												1.00

*Level of significance: *= P < 0.05; NTPP = number of tiller per plant, PH=Plant height, NLPP=number leaf per plant, DMY=Dry matter yield, SYO=* seed *yield of oat, LSR= Leaf Stem Ratio, CP=Crude protein, FBY=fresh biomass yield; NDF=Neutral detergent fiber, ADF=Acid detergent fiber, ADL=Acid detergent lignin.*

4.6. Partial Budget Analysis

The result of the partial budget analysis on yield of oat and field pea presented in terms of cost of inputs, total gross field benefit (TGFB), net benefit (NB) and marginal rate of return (MRR) were given in (Table 7). Since the quantity of economic produce (seed and straw yield) was varied due to application of different treatment, hence TGFB, NB and MRR also differed with these treatments. Thus, the result of this study indicated that the highest **TGFB** was attained from interaction of 1:2 row arrangement (RA)*46 kg nitrogen (N_2) ha^{-1} (410,618.25 ETB ha^{-1}) followed by 1:2 RA*23 kg N_2 ha^{-1} (353,432.25 ETB ha^{-1}) and 1:1 RA*46 kg N_2 ha^{-1} (351,173.25 ETB ha^{-1}) whereas the lowest TGFB obtained from sole field pea without nitrogen (99,234.00 ETB ha^{-1}).



RA= Row Arrangement; N_2= Nitrogen

1 = 1:1 RA without nitrogen
2 = 1:1 RA interaction with 23 kg N_2 ha^{1}
3 = 1:1 RA interaction with 46 kg N_2 ha^{1}
4 = 2:1 RA without nitrogen
5 = 2:1 RA interaction with 23 kg N_2 ha^{1}
6 = 2:1 RA interaction with 46 kg N_2 ha^{1}
7 = 1:2 RA without nitrogen
8 = 1:2 RA interaction with 23 kg N_2 ha^{1}
9 = 1:2 RA interaction with 46 kg N_2 ha^{1}
10 = Sole oat without nitrogen
11 = Sole oat interaction with 23 kg N_2 ha^{1}
12 = Sole oat interaction with 46 kg N_2 ha^{1}
13 = Sole field pea without nitrogen
14 = Sole field pea interaction with 23 kg N_2 ha^{1}
15 = Sole field pea interaction with 46 kg N_2 ha^{1}

Figure 5 Partial budget analysis

Net returns from different oat-field pea intercropping systems were worked out to evaluate the profitability of different combinations of oat-field pea row arrangement. The data presented in (Table 7 and Fig. 5) revealed that all the oat-field pea at interaction of 1:2 RA*46 kg N_2 ha^{-1}, 1:2 RA*23 kg N_2 ha^{-1} and 1:1 RA*46 kg N_2 ha^{-1} treatments had been responsible for a net benefit of (405,477.44 ETB ha^{-1}), (348,639.77 ETB ha^{-1}) and (346,484.09 ETB ha^{-1}) respectively. The findings was in line with Dhakad *et al.* (2005) who reported that net return were significantly higher for intercropping than sole cropping.

In most cases, farmers prefer the highest profit with low cost (high income). For this purpose it is necessary to conduct dominated treatment analysis. The dominant (undominated) treatments were ranked from the lowest to the highest costs that vary. The dominant analysis showed that the net benefit of dominant treatments were at 2:1 RA* 0 kg N_2 ha^{-1} created (269,808.02 ETB ha^{-1}) NB, 2:1 RA* 23 kg N_2 ha^{-1} created (293,845.19 ETB ha^{-1}) NB, 2:1 RA* 46 kg N_2 ha^{-1} created (325,341.11 ETB ha^{-1}) NB, Sole oat * 0kg N_2 ha^{-1} created (123,462.50 ETB ha^{-1}) NB. This indicates that the net benefit was decreased as the total cost that varies increased beyond undominated treatments and as yield per unit area decreased.

The process of calculating **marginal rates of return** of alternative treatments, proceeds steps from the least costly treatment to the most costly and resolves if they are acceptable to farmers, which is called marginal analysis (CIMMYT, 1988). Marginal rate of return measure the increase in net income (ΔNI) and the effect of additional investment in a new knowledge on additional expenditures (ΔTVC). Thus, among the treatments 1:2 RA * received 46 kg N_2 ha^{-1} had more net return as well as more potential for profitability. The best recommendation for treatments based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit together with an acceptable MRR becomes the finest recommendation (CIMMTY, 1988). The minimum acceptable marginal rate of return used in this study was assumed to be 100% for farmers' recommendation. Finally, the row arrangement and nitrogen levels that gave the maximum net benefit with acceptable marginal rate of return were selected. Thus, on the basis of marketable yield, net benefit and MRR, it could be concluded that most of the yield and yield components were significantly improved at interaction of 46 kg N_2 ha^{-1} at1:2 RA. Greater economic returns were reported in cereal–legume intercropping systems (Workayehu and Wortmann, 2011).

This result was similar with a finding obtained from a study on total productivity and net returns of different sorghum-legume intercropping system under varying N levels Waghmare, and Singh, (2012).

Therefore, in this study, the economic analysis indicated that the interaction of 46 kg N_2 ha^{-1} at1:2 RA produced net benefit of 405,477.44 ETB ha^{-1} with MRR of 32,286.98%, which was superior in most of yield parameters. Accordingly, this treatment could be recommended as profitable treatment to Oat-field pea producing farmers in the study area and similar agro ecology and soil type.

Table 7 Partial budget analysis

Treatment	TVC	GAY				AJY				TGFB (ETB)	NB (ETB)	MRR
		Oat		Field Pea		Oat		Field Pea				
		OS t/ha	OG t/ha	PS t/ha	PSD t/ha	OS t/ha	OG t/ha	PS t/ha	PSD t/ha			
SP * 0	2635.00	0	0	3.576	2.98	0	0	3.218	2.682	99,234.00	96,599.00	
SP * 23	2983.33	0	0	3.696	3.08	0	0	3.326	2.772	102,564.00	99,580.67	855.99
SP * 46	3331.66	0	0	3.996	3.33	0	0	3.596	2.997	110,889.00	107,557.34	2,289.98
1:1 * 0	3992.50	4.965	3.31	3.888	3.24	4.469	2.979	3.499	2.916	278,439.75	274,447.25	25,254.21
1:1 * 23	4340.83	6.075	4.05	4.512	3.76	5.468	3.645	4.061	3.384	333,884.25	329,543.42	15,817.23
1:2 * 0	4444.15	6.675	4.45	4.08	3.40	6.008	4.005	3.672	3.060	342,506.25	338,062.10	8,244.95
2:1 * 0	4446.73	4.785	3.19	3.96	3.30	4.307	2.871	3.564	2.970	274,254.75	269,808.02	D
1:1 * 46	4689.16	6.765	4.51	4.776	3.55	6.089	4.059	4.298	3.195	351,173.25	346,484.09	31,628.13
1:2 * 23	4792.48	6.615	4.41	4.548	3.79	5.954	3.969	4.093	3.411	353,432.25	348,639.77	2,086.41
2:1 * 23	4795.06	5.175	3.45	4.356	3.63	4.658	3.105	3.920	3.267	298,640.25	293,845.19	D
1:2 * 46	5140.81	8.115	5.41	4.752	3.96	7.304	4.869	4.277	3.564	410,618.25	405,477.44	32,286.98
2:1 * 46	5143.39	5.85	3.90	4.668	3.89	5.265	3.51	4.201	3.501	330,484.50	325,341.11	D
SO * 0	5350.00	3.75	2.50	0	0	3.375	2.25	0	0	128,812.50	123,462.50	D
SO * 23	5698.33	4.5	3.00	0	0	4.05	2.7	0	0	15,4575.00	148,876.67	7,296.00
SO * 46	6046.66	5.025	3.35	0	0	4.523	3.015	0	0	172,608.75	166,562.09	5,077.20

GAY = Gross average yield; OS = Oat straw OG = Oat grain (seed)*; PS = pea straw; PSD = pea seed; MRR = marginal rate of return; ETB = Ethiopian Birr; NB = net return; TVC = total variable cost; TGFB = total gross field benefit; SP = sole pea; SO = sole oat*

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The results of the current study showed that both legume inclusion and nitrogen application had a positive effect on overall dry matter production and chemical composition of oat forage, yield and economic feasibility of oat with field pea intercropping. Oat-pea (feed–food) intercrops with application of nitrogen produced high crude protein (CP), fresh biomass yield (FBY), dry matter yield (DM) of oat, seed yield and higher net benefit and marginal rate of return in comparison to the control. This confirms that intercropping oat with field pea provides superior forage both in quality and quantity as well as economically feasible. The results of the current study indicated that the treatment containing oat: field pea at interaction of 1:1 and 1:2 RA received 46 kg N_2 ha^{-1} gave maximum mean FBY forage production. The higher ($P<0.05$) mean total DMY was harvested from experimental plots at 1:2 RA and are likely to play a crucial role in providing quality and quantity feed. As far as nitrogen fertilizer concerned the higher ($P<0.05$) mean total DMY was harvested from experimental plots received 46 kg N_2 ha^{-1}. The highest mean SYP was recorded at interaction of 1:2 and 1:1 RA received 46 kg N_2 ha^{-1}. The higher ($P<0.05$) crude protein content was recorded from plant materials harvested from the experimental plots at interaction of 1:2 RA received 46 kg N_2 ha^{-1}. The highest mean NDF content was recorded from the experimental plots received 0 kg N_2 ha^{-1} at 50% flowering.

The economic efficiency was obtained with 46 kg nitrogen ha^{-1}, which represents an optimal dose for the yield and chemical composition with inclusion of legume at 1:2 row arrangements. Low nutrient content and dry matter yield of oat grass obtained from the control plot suggest that incorporating forage legumes into grasses is crucial to ensure the provision of quality nutrient that is essential for ruminant animals.

Therefore, from the current study it could be concluded that oat-field pea intercropping with nitrogen fertilizer application could be better option to utilize per unit area of land for a maximum DM harvest, improving the feed quality issue and the potential to attain an increased forage DM yield that could address the situation of mitigating feed shortage and provide profitable net income.

5.2. Recommendation

Based on the result generated in this study from the above discussion and keeping in view over all the performance, the following recommendations were forwarded:

For better biomass yield with improved dry matter yield and maximum crude protein content, for higher grain yield and economic feasibility 1:2 RA with 46 Kg N_2 ha^{-1} could be recommended for use by farmers and livestock enterprise in study area and other areas having similar agro-ecologies and soil type. Further research on effect of nitrogen rate and row arrangement on dry matter and chemical composition of oats and seed yield for its performance over years, across diverse agro-ecologies is also vital to more fine-tuned recommendation.

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7. APPENDIX

Appendix 1 The results of ANOVA for agronomic attributes and yield of oat

Source of variation	Mean squares							
	DF	**TILLER**	**LC**	**PH**	**FBY**	**DMY**	**SYO**	**LSR**
RA	3	11.728*	1.303*	604.091*	75.619*	8.328*	5.220*	0.012*
NL	2	13.313*	1.273*	212.899*	59.702*	16.672*	2.627*	0.007*
RA*NL	6	1.708*	0.160*	17.042*	4.129*	0.246^{ns}	0.121*	0.001^{ns}
Error	24	0.439	0.054	4.585	1.274	0.356	0.041	0.003
LSD(0.05)		*1.003*	*0.394*	*3.427*	*1.989*	*ns*	*0.330*	*ns*

DF= degree of freedom; *LC=leaf count; PH= Plant height; FBY=Fresh biomass yield; DMY= Dry matter yield; GYO= Gain yield of oat; LSR= Leaf Stem Ratio;* RA= Row Arrangement; NL= Nitrogen application; *LSD*= least significant difference

Appendix 2 The results of ANOVA for yield and yield indicators of field pea

Source of variation	Mean squares				
	DF	**NPPP**	**NSPP**	**TSW**	**SYP**
RA	3	44.844*	6.223*	268.917*	0.647*
NL	2	72.491*	7.698*	241.583*	0.956*
RA*NL	6	2.811*	0.340*	48.361*	0.029*
Error	24	0.170	0.132	18.778	0.009
LSD(0.05)		*0.554*	*0.631*	*7.161*	*0.155*

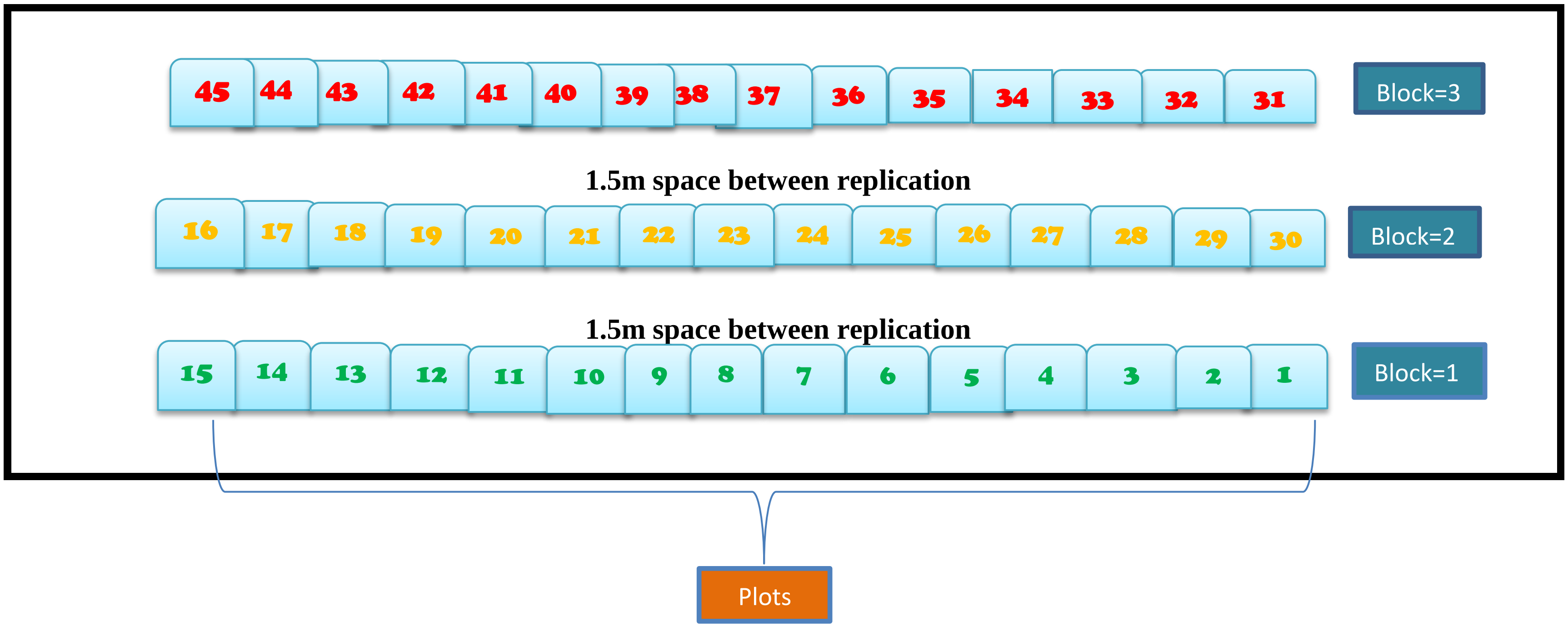
DF= degree of freedom; *NPPP= Number of pod per plant; NSPP= Number of seed per pod; TSW= Thousand seed weight; SYP= Seed yield of pea;* RA= Row Arrangement; NL= Nitrogen application; *LSD*= least significant difference

Appendix 3 The results of ANOVA for chemical composition of oat

source of variation	Mean squares								
	DF	CP%	ASH%	DM%	NDF%	ADF%	ADL%	HC%	CELU%
RA	3	13.765*	3.552*	32.055*	72.752*	32.633*	5.401*	12.041*	21.629*
NL	2	6.810*	7.631*	74.335*	62.286*	18.190*	3.044*	13.289*	7.893*
RA*NL	6	0.400*	0.861*	1.056^{ns}	5.507^{ns}	3.848^{ns}	0.863^{ns}	0.983^{ns}	1.612^{ns}
Error	24	0.148	0.191	2.464	4.102	3.409	0.529	1.166	2.284
LSD(0.05)		*0.68*	*0.76*	*Ns*	*ns*	*ns*	*ns*	*ns*	*ns*

DF= degree of freedom; *CP=Crude protein; DM=Dry matter; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; ADL=Acid detergent lignin; HC= Hemicellulose; CELU= Cellulose*, RA= Row Arrangement; NL= Nitrogen application; *LSD*= least significant difference

Appendix 4 Layout of experimental design



Appendix 5 Image of Experimental Activities