EFFECT OF NITROGEN FERTILIZER RATES ON GROWTH, YIELD AND YIELD COMPONENTS OF OAT (*Avena sativa* L.) VARIETIES AT ROBA EXPERIMENTAL SITE IN WAMANGYE ALKASO KEBELE, KOFELE DISTRICT, OROMIA REGIONAL STATE, SOUTHERN ETHIOPIA

MSc. THESIS

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OCTOBER, 2024

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A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCES COLLEGE OF AGRICULTURE HAWASSA UNIVERSITY HAWASSA, ETHIOPIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PLANT SCIENCE (SPECILIZATION: AGRONOMY)

OCTOBER, 2024

APPROVAL SHEET-1

This is to certify that the thesis entitled "EFFECT OF NITROGEN FERTILIZER RATES ON GROWTH, YIELD AND YIELD COMPONENTS OF OAT (*Avena sativa* L.) VARIETIES AT ROBA EXPERIMEANTL SITE IN WAMANGYE ALKASOKE BELE, KOFELE DISTRICT, OROMIA REGIONAL STATE, SOUTHERN ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of Master of Science in Plant Sciences with specialization in AGRONOMY, the Graduate Program of the Department of Plant and Horticultural Sciences, Hawassa University, College of Agriculture, is a record of original research carried out by HUSSEIN WATTA KALIYO ID. No. GPAgroR/0007/14 under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it be accepted as fulfilling the thesis requirements.

Hussein Mohammed (PhD	______________________	______________________
Name of major advisor	Signature	Date

Demelash Kefalew (PhD	______________________	______________________
Name of co-advisor	Signature	Date

APPROVAL SHEET-II

We, the undersigned, members of the Board of Examiners of the final open defense by HUSSEIN WATTA KALIYO have read and evaluated his thesis entitled "EFFECT OF NITROGEN FERTILIZER RATES ON GROWTH, YIELD AND YIELD COMPONENTS OF OAT (*Avena sativa* L.) VARIETITES AT ROBA EXPERIMENTAL SITE IN WAMANGYE ALKASO KEBELE, KOFELE DISTRICT, OROMIA REGIONAL STATE, SOUTHERN ETHIOPIA", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Plant Science.

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Hussein Mohammed (PhD)		
Name of Major Advisor	Signature	Date
Name of Internal Examiner	Signature	Date
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DEDICATION

I dedicate this thesis manuscript to my beloved parents, Watta Kaliyo Habe and my mother, Shukati Fino Balicha, who educated me without having an education for themselves and died without seeing my success. This work is dedicated to you.

STATEMENT OF THE AUTHOUR

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

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Date of submission ______________________________

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LISTS OF ACRONYMS

ANOVA	Analysis of Variance
CIAT	The International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
CV	Coefficient of Variation
DAP	Di Ammonium Phosphate
EIAR	Ethiopian Institute of Agricultural Research
FAOSTAT	Food and Agriculture Organization Statistics
GLM	General Linear Model
HARC	Holeta Agricultural Research Center
KPU	Kwantlen Polytechnic University
LSD	Least Significant Difference
MARC	Melkassa Agriculture Research Center
MOANR	Ministry of Agriculture and Natural Resource
MOARD	Ministry of Agriculture and Rural Development
NPS	Blended Nitrogen, Phosphorus and Sulphur
NPSB	Blended Nitrogen, Phosphorus, Sulphur and Boron
RCBD	Randomized Complete Block Design

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ABSTRACT

Effect of Nitrogen Fertilizer Rates on Growth, Yield and Yield Components of Oat (Avena sativa L.) Varieties in Wamangye Alkaso Kebele, Kofele District, Oromia Regional State, Southern Ethiopia Hussein Watta Kaliyo (BSc) Hussein Mohammed ((PhD) Demalesh Kefale (PhD)

Absence of nitrogen rate studies and lack of well adapted varieties are the major yield limiting factors for Oat growth and production in the study area. Thus, the experiment was conducted at Kofele District in the 2023 growing season (July - December) to evaluate the effect of nitrogen fertilizer rates on the growth, yield and yield components of oat varieties; and to identify economically appropriate combination of variety and nitrogen level that gives maximum forage and seed yield. Factorial combination of three oat varieties (WALQAA, WAS, SRCP) and five levels of nitrogen (0, 25, 50, 75, 100 kg ha^{-1}) were studied in three replications of the Randomized Complete Block Design (RCBD). Data were collected and analyzed by using SAS statistical software. Results showed that the variety and Nitrogen main effects were significant for days to heading, days to physiological maturity, total tillers, effective tillers, spikes plant^{-1}, plant height, seeds plant^{-1}, forage yield, above ground biomass, thousand seeds weight, straw yield, grain yield and harvest index. The variety main effect was also significant for plant height at 30 day and 60 days after planting. The Variety x N interaction was significant for days to heading, total tillers, effective tillers, plant height at 90 days, days to physiological maturity, number of seeds per plant, forage yield, above-ground biomass, thousand seeds weight, grain yield, straw yield, and harvest index. The highest forage yield (24.46 t ha^{-1}), above-ground biomass (22.5 t ha^{-1}) and straw yield (20. 03 t ha^{-1}) were obtained from variety WLAQAA at nitrogen rate of 75 and 100 kg ha^{-1}, respectively. The highest thousand seeds weight (39.30 gm) was obtained from variety SRCP at 100 kg of nitrogen ha^{-1} while the highest grain yield (6.39 t ha^{-1}) was obtained from variety WAS at 75 kg of nitrogen ha^{-1}. The results of the research indicated that the best variety for forage yield was WALQAA while the best variety for grain yield was WAS. The economic analysis for forage yield revealed that the highest net benefit of 146,737.5 ETB ha $^{-1}$ was obtained from variety WALQAA with 75 kg of nitrogen ha $^{-1}$ which gave marginal rate of return (MRR) of 1,110.2%. However, the result of the present study needs to be evaluated and reconfirmed under different agro- ecologies in order to reach a conclusive recommendation.

Keywords: Nitrogen fertilizer, Oats, Variety

1. Introduction

1.1 Background

Oat (*Avena sativa* L.) is an important cereal grown for both food and feed. It was domesticated around 2000 BC. Hexaploid oats originated from the Hindu Kush region (Malzew, 1930). However, Loskutov (2005) considers the western part of the Mediterranean region, Morocco and Spain to be the primary center of origin.

Oat provides a very nutritious fodder (protein 13- 15%). It is a useful annual forage crop at higher altitudes in the tropics and grown throughout the cooler and wetter parts of the temperate region, chiefly as feed for livestock. Oat straw is used for animal feed and bedding. Oat is widely used as forage crop because of its superior recovery after grazing, and is highly useful for overcoming critical periods of feed shortage (Lovett and Scotts, 1997).

Among cereal grains, oats are used as the main ingredient of rations for all livestock, particularly for pigs, poultry, horses and breeding stock (Tremere, 1982). It also provides the major source of energy in feeds for ruminant livestock in North America (Morrison, 1959) and part of Europe. Up to 30% ground oats of good quality has been used in rations for growing chicken and up to 50% in rations for laying hens (Kellems and Church, 1998). The rich magnesium content in oats helps prevent pyrosis in chickens. Finely grounded oat with skilled milk make a satisfactory ration for boilers during the last three to four weeks (Kerutz, 2002). Oats have also been used by breeders to increase male fertility and are one of the best

remedies for a stressed nervous system (Kreutz, 2002), help to calm performance anxiety. Oats are rich in minerals and vitamins including silicon, manganese, zinc, calcium, phosphorus and vitamins A, B1, B2 and E.

The nutritional value of oat grains differs from other cereals. The oil content, which ranges from 4% to 16% (Frey and Hammond, 1975; Schipper and Frey, 1991), in semolina (unprocessed grain), is the highest among cereal grains. High oil content is desirable for animal nutrition, but less beneficial for human food use because high oil content leads to processing and rancidity problems. The protein content of cultured oats ranges from 13% to 22%, and oat protein has a well-balanced amino acid content that varies little with changes in protein content (Robbins *et al.,* 1971). The amino acid distribution of oats is the most favorable of all cereal grains, with the order generally being oat, barley, wheat, maize, rice, rye, sorghum and millet (Kellems and Church, 1998).

The diversity of varietal types allows oats to be successfully grown in a wider range of climatic conditions than is possible with any other cereal. Oats are best adapted to cool humid climates and grow satisfactorily from 1750 to 3000 meters above sea level (Kipps, 1970; Lulseged, 1981). It can tolerate a very wide pH range and soils with poor fertility and drainage (Boonman, 1993). Oat grows best on red clay and black clay soils, but can also be grown on light sandy soils in areas with good rainfall. It requires more moisture (Kipps, 1970) to produce a given amount of dry matter than any other cereal except rice and needs about 800 - 1000 millimeters of rainfall for Oat production in Ethiopia is limited an average area coverage of 15,502.18 ha and with total production estimate of 30,540.34 tons and productivity of 2.18 tons ha^{-1} which is below its potential due to the influence of biotic and abiotic factors. In Oromia region it covered an area of 10,582.30 ha and production of 23,103.28 tons with an average productivity of 2.18 tons ha^{-1} (CSA, 2022). Bale and Horo Guduru Wollega are the major producing zones while both West

Arsi zones have great potential area also but cultivation area is limited. (CSA, 2022).

Oat production is traditionally considered a low-input crop and can be grown on land with lower fertility. For higher yield, nutrient management is now considered a big factor in growing oats. The unsatisfactory yield of oats is mainly attributed to low soil fertility, insufficient fertilization and cultural practices. Ethiopia's agricultural soils are characterized by low organic matter with poor nutrient retention capacity. The constant loss of nutrients from the soil without replacement causes the soil to become nutrient deficient. Continued depletion of nutrients, especially nitrogen, from the soil will eventually reduce the soil nitrogen supply and reduce productivity and quality of produce. Numerous experiments have shown that oats respond to fertilizer when soil fertility is limiting (Jackson et al., 1994; Koul, 1997; Oumer, 1998 and Gasim, 2001). Nitrogen fertilizer is an important factor in determining the potential yield of a crop and the recommended rate must be determined for the specific soil type. Nitrogen fertilization is thus complex and is worth researching, as its effects are highly variable due to environmental factors. Various reviews have shown that higher doses of nitrogen cause lodging in crops and nitrate toxicity in animals. In addition, oat response to fertilizer application varies depending on soil moisture, soil type, agronomic practices and pre-crops.

1.2 Statement of the Problem

Oats are a newly introduced fodder crop in Kofele district. The adoption rate by the farmers is high due to critical shortage of pastures and adoption of cut and carry system. However, yields are low due to depletion of soil fertility and increased soil acidity. Correct rate of fertilizer application and adapted varieties with economically feasible biomass and grain yield have not been studied. Therefore, the purpose of this study is to determine ecologically and economically suitable varieties and level of nitrogen fertilizer since nitrogen is the main nutrient for vegetative growth.

1.2 Objectives

1.2.1 General objective

To evaluate the effects of different levels of nitrogen (N) fertilizers on growth, yield and yield components of oat varieties.

1.3.2. Specific objectives

- ✓ To identify the high yielding (seed and forage) oat variety for Kofale area.
- ✓ To determine the N-fertilizer rate that gives the highest forage and seed yield.
- ✓ To assess interaction between varieties and nitrogen levels for growth, yield and yield component.
- ✓ To determine the economically feasible combination of variety and N-fertilizer rate that maximizes economic benefit

2. LITERATURE REVIEW

2.1 Origin and distribution of oats

Oats (Avena sativa L.) were domesticated around 2000 BC. Hexaploid oats originated from the Hindu Kush region (Malzew, 1930). However, Loskutov (2005) considers the western part of the Mediterranean region, Morocco and Spain to be the primary center of origin. Oats expanded from Asia Minor north into Europe as an admixture of cultivated emmer wheat. Oats were first planted in the United States in 1602 by Scottish settlers on an island off the coast of Massachusetts. Today, oats are grown mainly in northwestern and eastern Europe, North America, Canada and China. High quality oats are produced in Australia and New Zealand.

2.2 Ecological Adaptation and Oat Requirement

Oats are best adapted to cool moist climates and grow satisfactorily from 1750 to 3000 meters above sea level (Kipps, 1970; Lulseged, 1981). In lower altitude, Oat is less suitable because the branching is limited and a dense canopy can’t form. It can tolerate a very wide pH range and soils with poor fertility and drainage (Boonman, 1993). It grows best on red and black clay soils, but can also be grown on light sandy soils in areas with good rainfall. Oats require more moisture (Kipps, 1970) to produce a given amount of dry matter than any other cereal except rice and need about 800 - 1000 mm of rainfall for good production (Alemayehu, 1973). Oat species requires a temperature of about 20 – 25^0 Celsius for germination and a lower temperature for better growth and development. Frost can cause damage to oat.

2.2 Economic Importance of Oats

2.2.1 Oats as livestock feed

Oat is widely used for grazing because it is easy to cultivate, develops quickly and yields a high amount of dry matter when properly managed. Two cuttings are possible from a well- grown oat field, the first cutting is often used as fodder and the crop is then left for seed, resulting in delayed maturity and lower grain yield. It is widely used as a forage because it has excellent regeneration after grazing, and is very useful to overcome critical periods of forage shortage or to supplement market animals when permanent pastures are of poor quality (Lovett and Scott, 1997). Strong stemmed and heavy seed-bearing varieties such as Jasari and CI- 8251 are more suitable for silage, while fine stemmed varieties such as Lampton and CI- 8257 are preferred for hay production (Lulseged, 1981).

Among cereal grains, oats are used as the main component of ration for livestock, especially pigs, poultry, horses and breeding cattle (Tremere, 1982). It provides a major source of energy in ruminant diets in North America (Morrison, 1959) and parts of Europe. It is used as fodder for dairy cattle, young cattle and sheep, and dehulled as fodder for poultry. Up to 30% of good quality ground oats have been used in chicken rations and up to 50% in layer rations (Kellems and Church, 1998). The rich magnesium content in oats helps prevent pyrosis in chickens. Finely grounded oats with skimmed milk make a satisfactory ration for broilers during the last three to four weeks (Kerutz, 2002). Oats have also been used by breeders to increase male fertility and are one of the best remedies for a stressed nervous system (Kreutz, 2002) and works to calm performance anxiety. Oats are rich in minerals and vitamins including silicon, manganese, zinc, calcium, phosphorus and vitamins A, B1, B2 and E.

The oil content, which ranges from 4% to 16% (Frey and Hammond, 1975; Schipper and Frey, 1991), is the highest among cereal grains. The protein content of oats ranges from 13% to 22%, and oat protein has a well-balanced amino acid content that varies little with changes in protein content (Robbins et al, 1971). Its amino acid distribution is the most favorable of all cereal grains, with the order generally being oat, barley, wheat, maize, rice, rye, sorghum and millet (Kellems and Church, 1998).

Although much documented information on the feed value of oats is not available for varieties in Ethiopia, Astatke Haile (1976) reported the crude protein content of seven oat varieties at different locations. Reported the crude protein content, 4.19 to 6.13% for Holatta,3.79 to 7.10% for Debre-berhan, and 3.67 to 5.94% for Ginchi.

The thick stemmed and heavy seed-bearing varieties like Jasari and CI-8251 are more suitable for silage while the fine stemmed varieties like Lampton and CI-8257 are preferred for hay making (Lulseged, 1981). Oats has also been used by breeders to boost the fertility of male animals and is one of the best remedies for the stressed nervous system (Kreutz, 2002). It works to calm down performance anxiety. Oats is rich in minerals and vitamins including silicon, manganese, zinc, calcium, phosphorus and Vitamins A, B1, B2 and E.

2.2.2 Oats as a food grain

Although oats are mainly used as livestock feed, the grain can also be processed into human food. Oats are used for human consumption in the form of porridge, oat cakes and oat bran, because it is nutritionally superior to other cereals such as barley, wheat, maize and rice (Purseglove, 1972). Oatmeal is rich in carbohydrates and is a good source of minerals (Ca, P, Fe) and vitamins (thiamin, riboflavin, vitamin E). Oats can be used in baking, as a hot cereal and as a soup thickener. Oat bran can be sprinkled into salads, soups and other foods.

Oats as a food grain have rapidly gained popularity in recent years due to their cholesterol-lowering properties, thus preventing heart problems (Price *et al.,* 1987; Anderson *et al.,* 1990). These are mainly attributed to the water-soluble fiber (β- glucan) content of the grain (Anderson *et. al.,* 1990), but may be partly due to other components including saponins (Price *et. al.,* 1987). Breeders around the world are working to manipulate the levels of β- glucan in oats to create special cultivars. An industrial product, furfural, made from oat hulls, is a valuable solvent and chemical intermediate for the refining of mineral and vegetable oils (Kellems and church, 1998). The protein content of oats ranges from 13% to 22%, and oat protein has a well- balanced amino acid content that varies little with changes in protein content (Robbins et al, 1971). Its amino acid distribution is the most favorable of all cereal grains, with the order generally being oat, barley, wheat, maize, rice, rye, sorghum and millet (Kellems and Church, 1998).

2.3 Oat production in Ethiopia

Oats are grown for human and animal consumption mainly in Northern part of Ethiopia. Oat production in Ethiopia is still insignificant in terms of total area coverage and use.

Total crop area, 81.19% (10,538,341.91 hectares) was covered by cereals (ČSA, 2022), including oat. Only 15,502.18 ha of land was covered by oats and total of 30,540.34 tons were produced with an average yield of 2.18 t ha^{-1} which is far below its potential due to the influence of biotic and abiotic factors. In Oromia region 10,582.30 ha of land cultivated and 23,103.28 tons were produced with an average productivity of 2.18 t ha^{-1} (CSA,2022). Bale and Horo Guduru in Wollega are the main oat producing areas (CSA 2022); The Arsi zones are agroecologically suitable, but its production and use is limited.

2.4 Effect of Nitrogen on Growth and Yield Related Traits of Oat

2.4.1 Effects of nitrogen on oat growth

An increasing rate of N results in a significant increase in plant height. During the growing season, the minimum plant height was recorded in plants that did not receive any additional nitrogen (Islam *et al.,* 2020). They found that statistically significant variation in plant density in oats indicated that nitrogen addition resulted in measurable seedling growth. These findings are consistent with Godara *et al.,* (2016) who reported that all growth parameters were significantly affected by increasing nitrogen levels from 40 to 120 kg ha^{-1}. Sheoran *et al.,* (2017) found that the number of tillers m^{-1} row length was significantly affected with increasing nitrogen levels from 40 to 120 kg ha^{-1}. Anay *et al.,* (2012) revealed that leaf $plant^{-1}$ and shoot number $plant^{-}$ in oat increased significantly with each increment of 40 kg Nitrogen from 0-100 kg $_{ha}$-1.

2.4.3 Effect of nitrogen on yield-related traits

Rao and Patil (1979) found that oat spikelet number increased with increasing nitrogen levels. Ghosh (1985) observed that application of nitrogen 80 kg ha^{-1} improved panicles/m^2 and grain/panicle. Similarly, application of 80 kg ha^{-1} gave the highest grain and straw yield as reported by Sencar (1987). Salmina and Makarova (1998) revealed that grain yield was significantly affected by nitrogen application and achieved the highest yield with 60 kg ha^{-1}. Islam *et al.,* (2020) found that yield and all yield-contributing traits except oat harvest index were significantly affected by different nitrogen levels. Oat ear length was significantly affected by N ratio, with a linear increase in ear length found with progressively higher N values. The shortest ear (13.67 cm) was found in control plants. Mantai *et al.,* (2016) reported that different nitrogen levels could significantly increase panicle length and panicle weight in oat. Filled $spike^{-1}$ grains also increased with higher N levels, but nitrogen rate had the opposite effect on unfilled $spike^{-1}$ grains. There was a significant increase in 1000- grain weight due to nitrogen levels, with the application of 105 kg N ha^{-1} giving the highest (73 g) while the control gave the lowest mean (54.13 g) seed weight.

Mohr *et al.,* (2007) recorded higher weights of 1000 grains at a dose of 80 kg ha^{-1} of nitrogen. Gradual increases in nitrogen application lead to small; but it was a statistically significant increase in grain yield, summarizing all oat yield components. The highest average grain yield (1.76 t $^{ha-1)}$ was achieved with 90 kg N ha^{-1}, the lowest grain yield (0.73 t ha^{-1}) was control. However, mean grain yield was offset by the higher N rate (105 kg ha^{-1}), although the decrease was very slight. An increase in nitrogen level resulted in an increase in plant height, plant $leaves^{-1}$, tiller $palnt^{-1}$, plant density, ear length, full ear 1 and 1000 grain weight, which resulted in an increase in grain yield in oat. Nitrogen also plays an important role in increasing the fertility of most florets compared to low levels (Hanif and Langer, 1972). These findings were consistent with the results reported by Mantai *et al.,* (2016). Joon *et al.,* (1993)

Observed that oat grain yield increased only up to 80 kg N ha^{-1} and then decreased with increasing N. Mohr *et al.,* (2007) showed that low to moderate N rates significantly increased yield with optimum relative yield achieved at plant available N stock of approximately 100 kg ha^{-1} Oat yield was significantly affected by nitrogen application. The application of 105 kg N ha^{-1} showed a significant advantage over the control. The next best result was found for 90 kg $ha^{-1.}$ Such a positive yield response may be due to an increase in vegetative production and dry matter accumulation with successive levels of N application. Increased nitrogen application therefore provides better oat nutrition, resulting in maximum straw yield. Midha *et al.,* (2015) found that increasing nitrogen rates up to 120 kg ha-^{1} significantly increased forage yield compared to lower nitrogen rates. The effect of nitrogen rates on oat harvest index was not significant. The lowest harvest index (25.42%) was calculated for nitrogen application of 105 kg ha^{-1}, but interestingly, the highest value (30.51%) was at the rate of 30 kg N ha^{-1} (Islam *et al.;* 2020). Sharma *et al.,* (2001) found that application of 100 kg N ha^{-1} significantly increased grain and straw yields and harvest index was significantly reduced by N fertilization. Although yield varied greatly with variation in N, reasonably close and positive linear relationships were evident between relative grain yield and panicle length, indicating that higher N was required to optimize oat yield. Regression analysis revealed that more than 90% of the variation in both grain yield and straw yield could be explained by variation in the amount of nitrogen (Islam *et al;* 2020).

2.4.3 Effect of nitrogen on forage yield

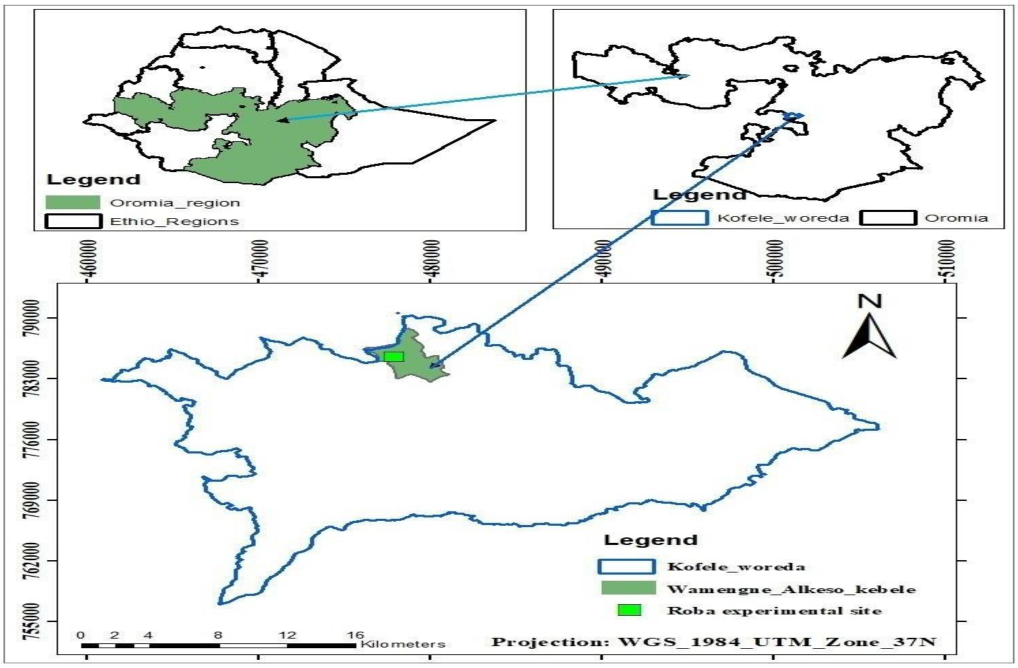
Ohm (1976) observed that application of nitrogen resulted in significant increase in forage yield. Gill *et. al.,* (1976) reported that as the dose of nitrogen increases, there is increase in green and dry matter yield up to 80 Kg ha^{-1}N. Similar results were obtained by Borgohain (1978), Rao and Patil (1979), Ghosh (1985), Thakuria and Rafique (1993), Darwinkel *et. al.,* (1995), Singh *et.al.,* (1998) and Sharma and Bhunia (2001). Joon *et. al.,* (1988) observed increased dry matter accumulation with successive level of nitrogen up to 160kg ha^{-1}. Boruah and Mathur (1979) observed that green and dry matter yield increased significantly with increasing levels of nitrogen from 0-120 Kg N ha^{-1}. Management practices such as sowing date, rate of N fertilization and seeding rate can significantly affect oats grain quality (Boonman, 1993).

3.MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location of the experimental site

The experiment was conducted in Wamangye Alkaso Kebele, Kofele Woreda, West Arsi zone of Oromia National Regional State, Ethiopia, during 2023 main cropping season under rain fed condition. Wamangye Alkaso Kebele is found 3 km north of Kofele town along Kore road (Figure 1.). The research was conducted on a private farm land. The site is found at 07^{o} 09'



06.00''N and 38^{o} 49' 59.99''E.

Figure 1 Administrative map of Ethiopia, Oromia Regional State, Kofale District Wamangye Alkaso Kebele, ROBA experiment site,2023, Source: self

According to Ethiopian agro-ecological classification the experimental site is grouped under Dega. The area has bimodal rainfall with the short rainy season (belg) from February to April while the main rainy season which accounts to 70% of the annual rainfall is from June to September, with the highest rainfall concentrations in June, July and August. The altitude of the study site is 2,679 meter above sea level. Mean annual rainfall of the district is 1170 mm. The mean minimum and maximum annual temperature of the experimental site is 8.5° C and 19.6°C (Fasil *et. al.*, 2024). The dominant crops grown in the Woreda are *Horedum vulgare, Solanum tuberosum, Triticum aestivum* L., *Vicia faba, Pisum sativum, Zea mays, Ensete verntricosum* according to the area they occupy. Soil texture of experimental site is sandy clay loam.

3.1.2 Experimental Materials

3.1.2.1 Oat varieties

Three newly released varieties by Holeta Agricultural Research Center were used for the study. The selection of these varieties was based on their performance in dry matter production and adaptability to the high land area as described in Table 1.

Table 1 Description of the varieties used for the study at ROBA experimental site, during 2023 main cropping season

Variety	Altitude range(mabsl)	Soil Type	Year release	Potential yield of DM Mt ha^{-1}	Breeder/Maintainer
WALQAA (SRCPX80Ab2596)	1,500 –3,00	Nitosol	2019	100	HARC/EIAR
WAS (CI-1506)	1,500–3,000	Nitosol	2019	195	HARC/EIAR
SRCP (SRCPX80Ab2291)	1,500 –3,000		2015	157	HARC/EIAR

Source: MoA (2019).

3.1.2.2. Nitrogen Fertilizer

Five levels of urea i.e., 0 kg/ha, 25 kg/ha, 50 kg/ha 75 kg/ha and 100 kg/ha were used as a source of nitrogen fertilizer.

3.1.3 Treatments and Experimental Design

The 15 treatments used were combinations of three oats varieties; WALQAA (SRCPX80Ab2596), WAS (CI-1506), and SRCP (SRCPX80Ab2291), and five levels of urea fertilizer (0, 25, 50, 75 and 100 kg ha^{-1}) (Table 2).

Table 2 Treatment combinations and codes for the study at ROBA experimental site, during 2023 main cropping season**.**

Treatment Code	Nitrogen Rate	Variety	Treatment Code	Nitrogen Rate	Variety	Treatment code	Nitrogen rate	Variety
T1	0	WALQAA	T6	00	WAS	T11	0	SRCP
T2	25	WALQAA	T7	25	WAS	T12	25	SRCP
T3	50	WALQAA	T8	50	WAS	T13	50	SRCP
T4	75	WALQAA	T9	75	WAS	T14	75	SRCP
T5	100	WALQQA	T10	100	WAS	T15	100	SRCP

Randomized Complete Block Design (RCBD) with factorial arrangement of three replications was used. The size of each plot was 2.8 m^2 (1.4 m width x 2 m length). The spacing between plots was 0.5 meter while between blocks were 1 meter. The spacing between rows of oat plant was 0.20 meter. Each plot divided into 7 rows. Plants from the outer side of two rows were considered as border and not considered for data collection. The two rows next to border rows were used for destructive harvest to measure dry matter. From the three central rows 0.40 meter by 0.50 meter were marked to collect data for number of total and effective tillers.

3.1.3 Experimental Procedures and Management

The experimental land was ploughed two times by oxen. Fine seedbeds were prepared and leveled manually and plots were layout. Seeds of the three varieties were planted by drilling using uniform seeding rate of 100 kg/ha as per the recommendation for pure stand of oats in the highlands of Ethiopia (Astatke Haile, 1979). At the planting time recommended fertilizer rate of 121 kg/ha of NPSB was applied as basal application uniformly to all the plots. After tillering, urea was applied at the rate of 0, 25, 50, 75, 100 kg/ha to each three varieties of oat following the randomization at planting time.

3.1.4 Soil sampling and Analysis

Composite soil sample was taken from the experimental site before planting to determine available plant nutrients in the soil. Soil sample was randomly collected in a zigzag pattern before sowing from a depth of 0 - 20cm using soil auger. The soil sample was taken to Hawassa College of Agriculture soil laboratory for analysis. In the lab the soil sample was air dried, grounded using a pestle and mortar, and allowed to pass through a 2 mm sieve. Selected physico-chemical properties mainly texture (particle size), soil pH, cation exchange capacity (CEC), organic carbon, total soil available N and P were analyzed. Particle size distribution was determined using the Bouyoucos hydrometer method (Dewis and Freita, 1984). Organic carbon was determined by Potassium dichromate method (Jackson, 1970). Total nitrogen was analyzed by Micro-kjeldahal method (Jackson, 1970). The pH of the soil was determined at 1:2.5 (weight/volume) soils to water dilution ratio usinga glass electrode attached to digital pH meter (USDA, 1984). Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4OAC) and displacing it with 1N NaOAC (USDA, 1989). Available phosphorus was determined using the Bray method (Bray and Kurtz, 1945).

3.1.5 Data Collected

3.1.5.1 Phenological parameters

Days to heading: - this is the number of days from planting to 50% heading determined in each plot based on visual observation. Days to physiological maturity: - this is the number of days from planting date to the time when the plants reached 90% maturity based on visual observation. It was determined by leaves senescence as well as threshing of grain from the glumes when pressed between the forefinger and thumb.

3.1.6.2 Growth Parameters

Plant height (cm): The plant height was measured on 30^{th}, 60^{th}, and 90^{th} day after planting from the soil surface up to top of the shoot and at 90% physiological maturity from the soil surface to the top of the longest panicle excluding awns on ten randomly pre-tagged selected plants from the net plot area of 2.8 m^2. The total measured plant height was summed together and divided by the number of plants measured to get average height per plant.

Total number of tillers: - A plant area of 0.40 meters by 0.50 meters was marked after complete germination of plants and counted as planted seeds seedlings.

After formation of tillers all the plants in the marked area were counted again and the total number of tillers were determined by subtracting total number of plants from the planted seedlings to determine the total number of tillers. Total number of tillers produced per plant was determined by dividing the total number of tillers counted total number of emerged seedlings.

Effective tiller: - are plant shoots which bears seed. It was calculated by counting the number of plants that set seeds in 0.4 * 0.5 m^2 subtracting the total number of panicles from the planted net plot area. The mean number of effective tillers per plant was calculated from the same area by dividing total number of tillers to seed sets tillers.

Number of spikes plant $^{-1}$: - spikes are the branch of floret bearing seed formed on the panicle. The number of spikes per plant or panicle calculated from ten pre-tagged plants and converted to plant base.

Spikelet per spike: - spikelet are florets or seed-bearing branch formed on each spike. The mean number of spikelets per spike was determined from ten randomly pre-tagged and selected plants and converted into plant base.

Panicle length (cm): - Panicle mean branched indeterminate inflorescence in which the branches are racemes, so that each flower has its own stalk (called a pedicel) seed bearing part of the plant. The panicle length was measured from ten randomly selected pre- tagged plants and means them taken as average panicle length.

Forage Biomass yield: - the two rows next to the border row from both sides of the plots were harvested as each Varity reached on average recommended harvesting stage for green feed (i.e. soft dough stage) in order to estimate the green herbage biomass. The total fresh biomass weight was recorded in the field and 500 g sample of each plot were collected using a paper bag and incubated at 65 °C in a forced draft oven for 72 hours at Hawassa College of Agriculture crop physiology laboratory. The dry matter was used to determine forage biomass expressed in tones per hector.

Above ground biomass (t ha^{-1}): - At a physiological maturity, the whole plant parts, including leaves, stems and seeds from the central three rows in each plot were harvested and sun dried separately for over two weeks until constant weight was obtained. The weighted biomass was then expressed in tons per hector.

Number of seeds per plant: - seeds were collected from ten pre-tagged plants, separately threshed, dried, cleaned and counted and their average number per plant was determined.

Straw yield (t ha^{-1}): - after threshing each variety separately, seeds were separated from the straw and average straw weight were taken and converted into hectare base.

Grain yield (t ha^{-1}): - grain yield was measured from the three harvested central rows (1.6 m^2) and converted to tons per hectare. Grains were threshed, cleaned and sun dried until it was believed completely dry when crashed by teeth as there was not moisture measurement and then weighed using electronic balance and converted to hectare.

3.1.7 Statistical Data Analysis

Data collected was subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) procedure of SAS version 9.0 and interpretations were made following the procedure described (Gomez andGomez,1984). When the effects of the treatments were found significant from the ANOVA test, the means were compared using least significance difference (LSD) test at 5% level of significance.

3.1.8 Economic Analysis

The partial budget analysis was done for economic analysis as described by CIMMYT (1988). The economic advantages of applied nitrogen rate and varieties were carried out using partial budget analysis. In this experiment, the costs that vary were calculated by adding costs of fertilizer and labor for fertilizer application. However, other management and fixed costs were assumed to be equal for all and not included in the calculation. The average grain and straw yield were adjusted by 10% down wards to reflect the difference between the experimental yield and the farmers yield would expect from the same treatment. Following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. To identify treatments with maximum return to the farmers' investment, marginal analysis was performed on non- dominated treatments. For a treatment to be considered as a worthwhile option to farmers, the marginal rate of return (MRR) needs to be at least between 50% and 100% (CIMMYT, 1988). However, other researchers suggested a MRR of 100% as realistic (Amanuel *et al.,* 1991; Getachew and Rezene, 2006). Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) as MRR (%) = ΔNB/ΔTVC*100.

4.RESULT AND DISCUSSION

4.1 Soil Physico-chemical Properties of the Experimental Site

Selected physico-chemical properties of the experimental site soil were analyzed using standard soil analysis procedure. Based on the soil analysis made, the soil texture of the study area was sandy clay loam (Table 1.), which was ideal for the growth of Oat forage (Onwueme and Sinha, 1991). The soil pH of the experimental site was 5.1. Thus, according to Tekalign (1991), the pH of the soil is strongly acidic (Table 1).

According to analysis, the available P level (25 mg/kg) at the experimental site was medium. (Olsen *et al.,* (1954) identified indicative phosphorus ranges, encompassing 5 mg/kg (very low), 5-15 mg/kg (low), 15-25 mg/kg (medium), and > 25 mg/kg of soil (high)). Based on this criterion, the available phosphorus content was medium.

The soil organic carbon (OC) was 3.2%, which is within the range of high organic carbon content (Landon 1991). Tekalign (1991) classified soil total N availability of <0.05% as very low, 0.05- 0.12% as poor, 0.12-0.25% as moderate, and >0.25% as high. According to this classification, analysis of soil sample indicated a moderate level of total N 0.161% (Table 1.). Cation exchange capacity (CEC) is an important parameter of soil because it indicates the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. In accordance with Landon (1991), soils with CEC values of 40 or more cmol (+)/kg are classed as very high, 25 to 40 cmol (+)/kg as high, 15 to 25, 5 to 15, and 5 cmol (+)/kg as medium, low, and very low, respectively. According to this classification, the soil of experimental site has a medium CEC of 23 cmol (+)/kg (Table 2) indicating that it has a moderate capacity to retain the cation. In general, the soil of the study area was suitable for oat production.

Table 3 Selected physico-chemical soil properties at ROBA experimental site before planting during 2023 cropping season

Soil characters analysis result	Value	Rating	References
Particle size distribution			
Sand (%)	55		
Silt (%)	21		
Clay (%)	24		
Texture class	Sandy-clay-loam		Dewis and Freita, 1984.
Soil pH	5.1	Strongly acid	USDA, 1984.
Organic carbon	3.2	High	Jackson, 1970.
Total available soil nitrogen	0.161	Low	Jackson, 1970.
Total available soil phosphorus (mg/kg)	25	High (12-25)	Jackson, 1970.
CEC (cmol (+)/kg	23	Medium	USDA, 1989.

4.2 Days to Physiological Maturity

SRCP (127 days) was the earliest maturing variety while WALQAA (141 days) was the latest maturing variety. WAS (129 days) was intermediate in maturity (Table 1). There was statistically significant difference between each of the varieties. (Appendix Table 1).

Delays days to physiological maturity (135) was recorded from nitrogen level of 100 kg ha^{-1} which was significantly later than days to maturity at lower levels of N. The earliest days to maturity of 129.8 days was recorded in the control plot, which was significantly earlier than that under higher N levels, 25, 50, 75 and 100 kg per hectare. The days to maturity was shortened by 5.2 days without nitrogen application compared to 100 kg ha^{-1}. This may be due to suitability of nitrogen for the growth and development. The days to maturity increased with early seeding and with higher rates of N fertilizer (William *et al.,* 2004). With increased nitrogen rate, there was a linear delay in maturity from 1 to 4 days (Mahmood *et al.,* 2017).

4.3 Plant height at 30 days after plating

At 30 days after planting WALQAA was significantly taller than both WAS and SRCP (23.9 vs 13.9 and 13.5 cm, respectively) (Table 2). WAS and SRCP were at par in plant height after 30 days. The difference in plant height at 30 days after planting may be due to genetic variation between the cultivars in early growth. Only relatively small amounts of fertilizer are required during the very early stages of plant growth (Hanway, 1966). Consistent with this result Islám (2020) also found no significant difference between oat varieties in plant height at 30 days after planting. In contrast, application of 110 kg nitrogen ha $^{-1}$ showed significant effect when compared with 70 and 90 kg N ha $^{-1}$ on plant height of oat at 30 days (Gangaiah, 2005).

4.4 Plant height at 60 days after planting

At 60 days after planting the tallest plants (85.5 cm) were obtained from variety WALQAA while the shortest plants (46.5 cm) were from variety SRCP. The difference in plant height after 60 days between each of the varieties was statistically significant (Table 4). The difference in plant height at 60 days after planting could be due to genetic difference between the cultivars in early growth rate.

Nitrogen application did not have significant effect on plant height at 60 days after planting (Table 4). Plant height after 60 days planting under N0 (61.9) was almost the same as plant height after 60 days after planting under N100 (61.6 cm). At early growth plants depends on the food reserve in the endosperm of the germinating seed.

Table 4 Days to physiological maturity, plant height at 30, 60 days after planting and number of spikes per plant as affected by main effects of variety and nitrogen rate at ROBA experimental site during 2023 main cropping season.

Variety	Days to physiological maturity	Plant height at 30 days (cm)	Plant height at 60 days (cm)	Number of spike plant^{-1}
WALKA	141a	23.9a	85.53a	7.04a
WAS	129.3b	13.27b	55.26b	6.53b
SCRP	127c	13.53b	46.49c	6.49b
LSD (0.05)	1.02	1.11	3.43	0.21
Nitrogen				
0	129.8d	16.48	61.86	6.6ab
25	131.4c	16.69	60.68	6.87a
50	132.2bc	16.9	62.13	6.44b
75	133.3b	17.41	65.91	6.73a
100	135.6a	17.09	61.56	6.8a
LSD (0.05)	1.31	NS	NS	0.27
CV (%)	1.03	4.2	8.8	7.4

Means in the same column followed by the same letter/s are not significantly different from each other at a 5% level of significance; LSD (0.05) =Least significant difference at 5%; and CV (%) =Coefficient of variation in percent; NS= non-significant.

Nitrogen uptake by oat plants is low during early development and increases as the crop grows. Only relatively small amounts of fertilizer are required during the very early stages of plant growth (Hanway, 1966). Contrary to our findings Islam *et al.* (2020) reported that different levels of nitrogen fertilizer had significant effect on oat plant height at 60 days after planting. In general, the effect of nitrogen was observed after 60 days of planting which indicated that oat for forage must be harvested only after 60 days of planting to obtain the benefit of nitrogen application.

4.5 Number of spikes per plant

The highest number of spikes was recorded (7.04) from variety WALQAA and the lowest number of spikes (6.49) was obtained from variety SCRP, which was statistically at par with that of variety WAS (6.53) (Table 4). This is due to the genetic difference of varieties to produce spike number in oats. The minimum numbers of spikes 6.44 was recorded from nitrogen rate of 75 kg ha^{-1}. This was significantly lower than number of spikes plant^{-1} under all other N levels (6.6 to 6.9) which were not significantly different from each other. (Islam *et al.,* (2020) reported maximum number of filled grains spike^{-1} (37.80) at 90 kg N ha^{-1} and number of filled grains spike^{-1} (18.07) under the control (N0).

4.6 Days to heading

Under all N levels WAS (VII) was the earliest heading (76 to 84 days) variety. SRCP (VIII) was intermediate in heading (81 to 85 days) while WLAQAA (VI) was the latest heading variety (87 to 96 days). Under all nitrogen levels, except under nitrogen 100, the difference between any two varieties was statistically significant. Under N100, SRCP (VIII) and WAS (VII) were at par (85 and 84 days). The difference between SRCP (VIII) and WAS (VII) narrowed down as N level increased (9.3, 4, 3, 2 and 1 days under N0, N25, N50, N75 and N100, respectively), interaction due to heterogeneity of variances. SCRP

(VIII) was not responsive to nitrogen application, while WALQAA was the most responsive. The difference between N0 and N100 was 9, 7.3 and 4 days in WALQAA, WAS and SRCP, respectively. If there was no interaction between the varieties and N levels, the three lines would have been parallel; no rank change of the varieties over the five N levels and the difference between any two varieties would have been constant over all five N levels.

The difference between any two N levels is also not consistent when applied on each of the three varieties (Figure, 2. 1B). This also contributed to the significant VAR x N interaction for days to heading (DH). When applied to WAS and SRCP, mean DH were arranged as N0 < N25< N50< N75< N100. For WALQAA mean DH of N25 (89.3 days) is higher than that of N50 (88.7 days). Figure, 2). The difference between any two N levels was also not consistent over the three varieties. This has also contributed to the significant VAR x N interaction for this trait. Increasing the level of nitrogen from 0 to 46 kg ha^{-1} prolonged days to heading by 12.89%; while, increasing the level of nitrogen further from 0 to 69, 92, 115 and 138 kg ha^{-1} prolonged the days to maturity by 12.89%, 14%, 21.85% and 24.68%, respectively on wheat varieties (Yohannes and Nigussie, 2019)

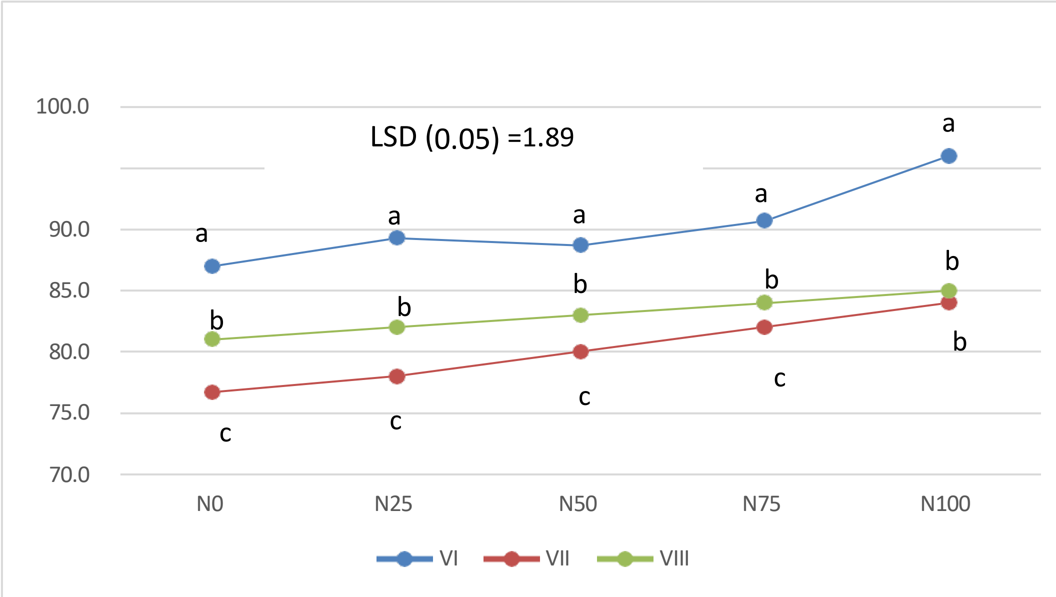


Figure 2 Response of varieties to nitrogen levels on days to heading at ROBA experimental site during 2023 main cropping seasons

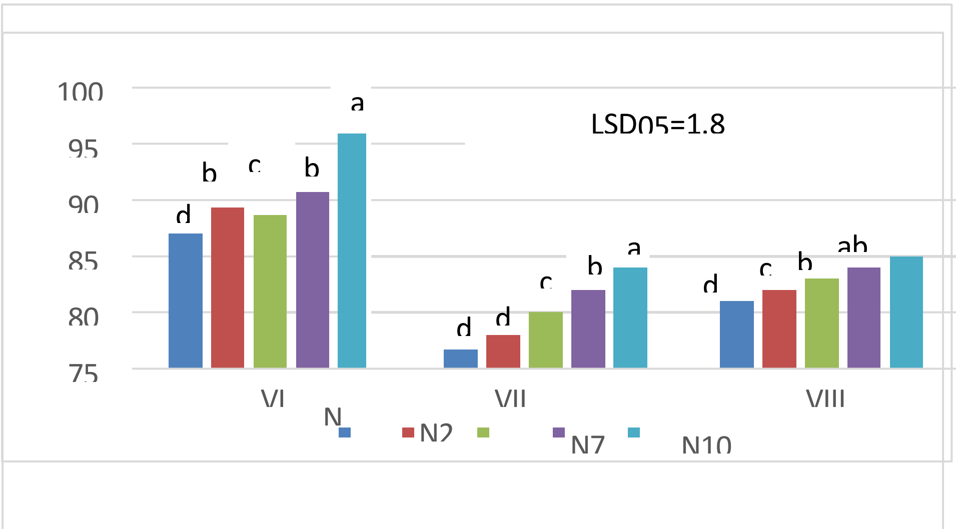


Figure 3 Variety x N Interaction for number of days to heading at ROBA experimental site during 2023 main cropping season

4.7 Plant height at 90 days

WALQAA had the tallest plants under all N levels at 90 days after planting. The lines of WAS and SRCP are intermingled, the two varieties do not differ in PH90 at most levels of nitrogen. However, WALQAA was significantly taller than both varieties under all levels of nitrogen.

Allied to each of the varieties as N increases from 0 to 100 kg ha^{-1}, there is a tendency for PH90 to increase and then decline. WALQAA attains the highest PH90 at N50 while WAS and SCRP attain the highest PH90 at N75 (Figure, 4).

The tallest plant (150 cm) was recorded from WALQAA variety with nitrogen level of 50 kg ha^{-1}. The same WALQAA variety was statistically comparable with the amount of nitrogen 75 and 100 kg ha $^{-1}$.

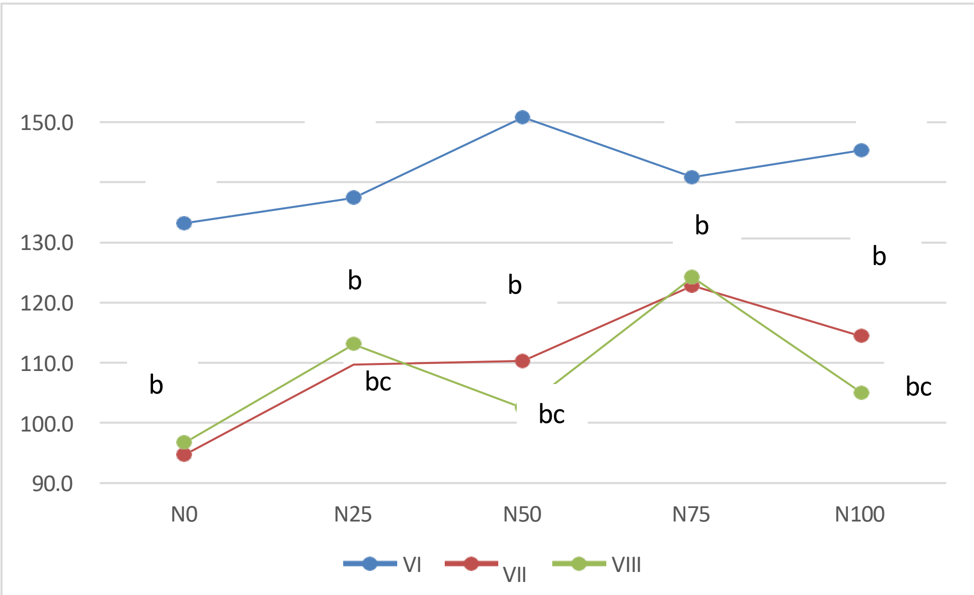


Figure 4 Response of each variety to nitrogen levels on plant height at 90 days after planting at ROBA experimental site during 2023 main planting season.

However, the shortest (94 cm) was recorded from WAS variety without fertilizer. It was statistically similar with nitrogen rate of control, 50 and 100 kg ha $^{-1}$ for variety SRCP (Figure 5). Difference in plant height of (56 cm) between 0 and 75 kg ha^{-1} of nitrogen and in the varieties WAS and WALQAA was observed.

The difference in plant height at 90 days may be due to the genetic potential of the cultivars and the difference in effective nitrogen utilization at the optimal level between cultivars.

These findings are consistent with (Godara *et al.,* 2016) who reported that all growth parameters were significantly affected by increasing nitrogen levels from 40 to 120 kg ha^{-1}. Also, the growth characteristics of oats were significantly affected by different nitrogen levels (Islam *et al.,* 2020).

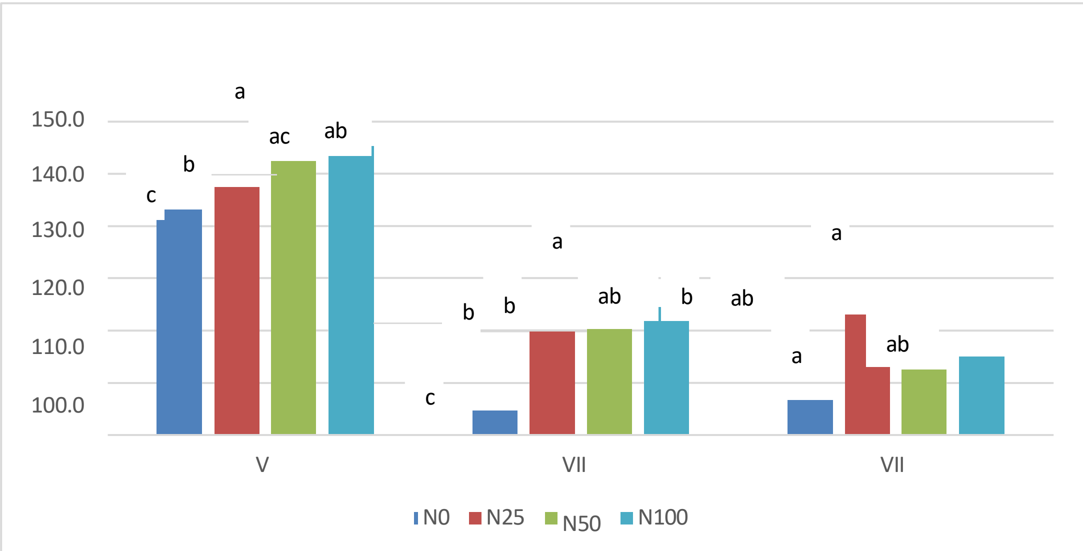
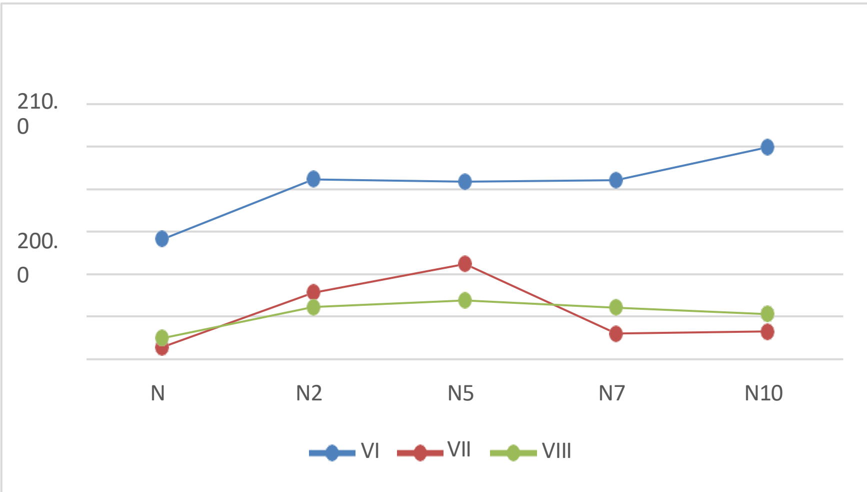


Figure 5 Variety X N interaction effect on plant height at 90 days after planting at ROBA experimental site during 2023 main cropping season.

4.8 Plant height (cm) at physiological maturity

Lines of WALQAA (VI) and SRCP (VIII) can be assumed parallel, the parallelisms were lost due to the irregular response of WAS (VII) to increasing N levels. If only WALQAA and SRCP were in the experiment the VAR x N interaction for PH would have been non - significant. WAS was taller than SRCP under N25 and N50, but it was shorter than SRCP under N0, N75 and N100. WALQAA was significantly taller than the other two varieties under all levels of N (Figure 6). The difference between WAS and SRCP in PH was statistically significant only under N50, N75 and N100. This is how the three varieties contributed to the significant VAR x N interaction. Only for WALQAA, PH under N100 was significantly taller than PH under all remaining N levels. For WALQAA and SRCP, PH under N25, N50 and N75 were statistically at par, while for WAS they are



statistically different.PH under N0 was significantly shorter than that under other N levels in all three varieties. The tallest plants were observed under N100 for WALQAA but under N75 for WAS and SRCP. This is how the five N levels contributed to the significant VAR x N interaction for PH (Figure 6)

Figure 6 Response of each variety to nitrogen levels on plant height at physiological maturity at ROBA experimental site during 2023 main cropping season.

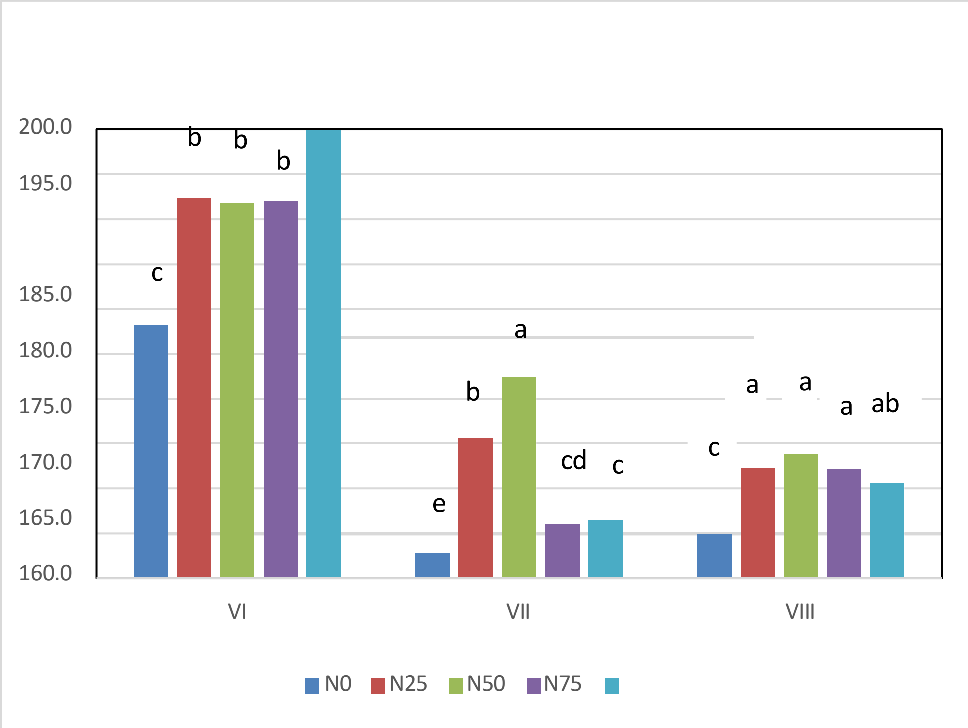


Figure 7 Variety X N interaction effect on plant height at physiological maturity at ROBA experimental site during 2023 main cropping season.

The difference in plant height may be due to the genetic potential of the variety and its response to an optimal application of nitrogen rate and the subsequent increase in all growth stages of the crop. The maximum plant height (151.96 cm) was recorded in cultivar Scott at 80 kg ha $^{-1}$ nitrogen application and the lowest plant height (122.96 cm) were recorded in cultivar S-2000 without nitrogen application (Ali *et al.,* 2017).

4.9 Total number of tillers (m^2)

Under all N levels WAS VII had the highest total tillers and WALQAA VI had the lowest total tillers except at N0 where SRCP VIII had the lowest total tillers. (Table 5). WALQAA and WAS had the highest total tillers under N0 while SRCP had the highest total tillers under N75. There was significant difference between the three varieties in total tillers at all N levels except at N25 where the difference between WALQAA VI and SRCP VIII was non-significant. (Table 5). For WALQAA and WAS, total tillers decreased from N0 to N50 while for SRCP total tilles increased from N0 to N75. Parallelism was disturbed due to SRCP. When applied to WALQAA, total tillers under N0 was significantly higher than total tillers under the remaining N levels which were at par with each other. Under WAS the difference between total tillers of N25, N50 and N100 are not significantly different from each other. The same is true for total tillers under N0 and N75. Under SRCP the difference between total tillers of N50, N75 and N100 are not significantly different from each other. This differential response was the source of the significant VAR x N interaction for total tillers. The highest total number of tillers (871.7 cm) was obtained from WAS variety in the control which was statistically similar with nitrogen rates of 25 and 75 kg ha^{-1} for the same WAS variety. However, the lowest number of tillers (162.3) was recorded in the SRCP variety in the control plots (Table 5). This may be due to the difference in genetic potential in shoot production and nitrogen availability for tiller initiation since Nitrogen use efficiency varies with the variety. This is consistent with Sheoran *et al.,* (2017) who found that the number of tillers per m^2 in oat was significantly affected with increasing nitrogen levels from 40 to 120 kg ha^{-1}. Also, the maximum number of tillers $plant^{-1}$ (9.93) was observed when 105 kg ha^{-1} N was applied to oat followed by 90 kg N ha^{-1} (Islam *et al.,* 2020).

Table 5 Interaction effect of nitrogen and varieties on total tillers and effective tillers per m^2 at ROBA experimental site during 2023 main cropping season.

N	Total tillers per m^2			Effective tillers per m^2		
Kg ha^{-1}	Variety			Variety		
	WALQAA	WAS	SRCP	WALQAA	WAS	SRCP
0	458.3^{d}	871.7^{a}	162.3^{f}	393.3^{e}	796.7^{a}	133.3^{f}
25	370^{e}	801.7^{ab}	408.3^{de}	326.7e	653.3^{b}	366.7^{e}
50	358^{e}	778.3^{b}	565c	313.3e	685^{b}	511.7^{d}
75	385^{de}	868.3^{a}	620c	311.7e	795^{a}	531.7^{cd}
100	380^{e}	733.3^{b}	565c	355e	611.7^{c}	496.7^{d}
LSD		77			85.87	
CV		8.3			10.6	

Means in columns and row followed by the same letter/s are not significantly different from each other at a 5% level of significance; LSD (0.05) = Least significant difference at 5%; and CV (%) = Coefficient of variation; NS= Non-significant; m^2 = meter square

4.10 Number of effective tillers (m2)

Analysis of variance shows the main effect of variety, nitrogen and interaction effect had significant (P<0.001) effect on the total number of effective tillers (Appendix Table 1). The highest total number of effective tillers (796.7) per m^2 was obtained from WAS variety the control (Table 5). It was also statistically similar with nitrogen rate of 75 kg ha^{-1} for the same variety. However, the lowest number of effective tillers (133.3) m^2 was recorded in the SRCP variety on the control plots (Table 5).

This may be a consequence of the difference in the genetic potential for shoot production among oat varieties and the role of nitrogen in the rapid response to the vegetative growth of the plant. This is in consistent with Anay *et al.,* (2012) who reported that the number of tillers plant^{-1} in oats increased significantly with each increment of 40 kg nitrogen from 0-100 kg ha^{-1}. The maximum number of effective tillers (810.33 m^{-2}) was observed when oat cultivar scott was treated with 80 kg of nitrogen per hectare, while the minimum number of effective tillers (683.22 m^{-2}) was recorded in oat cultivar scott without nitrogen application Ali *et al.,* (2017).

4.11 Panicle length (cm)

Analysis of variance shows the main effect of variety significantly (P<0.001), main effect of nitrogen significant (P<0.05) and interaction significant (P<0.01) affected panicle length of oat. (Appendix Table 1)

The highest panicle length (38.3 cm) was found on variety WALQAA with application of nitrogen 50 kg ha^{-1} (Table 6). Its statistically par with 100 kg ha^{-1} and control with the same variety. The lowest panicle length (24.5 cm) was found on variety SRCP at control plots. This was statistically par with varieties WAS and SRCP at all nitrogen levels and control plots (Table 6). This may be due to genetic variation among varieties and availability of nitrogen at optimum level boost the panicle length. In line with, William *et al,* (2004) who reported panicles length plant $^{-1}$ were affected by N fertilizer rate and oat cultivar. The oat variety AC Assiniboia had a greater number of panicles length plant $^{-1}$ than oat CDC Pacer, and progressively greater N fertilizer rates linearly increased panicle length plant $^{-1}$. William *et al,* (2004).

Table 6 Interaction effect of variety and nitrogen on panicle length (cm) and number spikelets per plant of oat at ROBA experimental site during 2023 main cropping season.

Nitrogen	Panicle length (cm)			Number of Spikelet per plant		
	Variety			Variety		
	WALQA	WAS	SRCP	WALQA	WAS	SRCP
0kg	32.1abc	29.8bcde	24.5e	24.5e	28.1ab	26.2ab
25kg	29.7bcde	30.7bcde	25.2de	25.2de	22.3b	25.7ab
50kg	38.3a	30.2bcde	26.4cde	26.4cde	24.1ab	24.9ab
75kg	31.3bcd	30.1bcde	26.3cde	26.3cde	30.7a	25ab
100kg	33.5ab	26.6cde	26.7cde	26.7cde	27.8ab	23.4b
LSD(0.05)	6.4			7.25		
CV (%)	9.2			7.2		

Means in columns followed by the same letter/s are not significantly different from each other at a 5% level of significance; LSD (0.05) = Least significant difference at 5%; and CV (%) = Coefficient of variation; NS = Non-significant

4. 12 Spikelet per plant

Analysis of variance shows the main effect nitrogen and the interaction effect has significant($P<0.05$) effect on spikelet's per plant of oat (Appendix Table 1.)

The highest number of spikelet's per plant (30.7) was found from variety WAS with application of nitrogen rate 75kg ha^{-1} while the lowest (24.5) from variety WALQA at the control plot (Table 6). All applied nitrogen rates showed lowest number of spikelet's on variety WALQA compared to SRCP and WAS varieties with the same treatment. This may be due to genetic variation among varieties although availability of nitrogen at optimum level increases cell division and elongation. In line with this variety AC Assiniboia had a greater number of spikelet's plant $^{-1}$ than CDC Pacer, and progressively higher N fertilizer rates linearly increased spikelet's plant $^{-1}$ (William *et al.,* 2004).

4.13 Number of seeds per plant

Results of the current study shows that; the effects of variety and nitrogen rate were significant (P<0.001) on number of seeds per plant of oat and the interaction effect was also significant (p<0.01) effect (Appendix Table 2.)

The highest number of seeds per plant was obtained from variety WALQAA with nitrogen rate of 25 kg/ha. However, the lowest number of seeds were obtained (85.01) from variety WAS at control plots which is statistically similar with variety WAS with nitrogen 25, and 75 as well as variety SCRP at nitrogen rate of 75, and 100kg ha^{-1}.

This is due to the genetic variation of the variety to respond and utilize different nitrogen rate.

4.14 Forage yield (t ha^{-1})

The result of this study showed that, the effect of variety and nitrogen rate were significant (P<0.001) on forage yield of oat and the interaction effect was also significant (P<0.01) (Appendix Table 2). There was no rank change between the three varieties of oats. WALQAA was the highest yielding variety, WAS was the second while SCRP was the third, except under N75 where WAS and SCRP gave almost equal forage yield (Figure,9). At each level of N there was significant difference between forage yield of WALQAA and SCRP. Due to the inconsistent performance of WAS, its difference from both WALQAA and SCRP was sometimes significant. The magnitude of the difference between varieties increased as N increased from 0 to 100 kg ha^{-1}, interaction due to heterogeneity of variance.

Applied to any variety forage yield increased as N applied increased, reached a maximum and then declined (Figure 9). The lowest forage yield was obtained from the control (N0) in all three varieties. The maximum forage yield was attained at N75 in WALQAA (24.28 t ha $^{-1}$) and SCRP (20.52 t ha $^{-1}$) and at N50 in WAS. The highest range (6.24 t ha^{-1}) was in WALQAA while the lowest range (2.91 t ha^{-1}) was in SRCP. There was interaction due to rank change and due to heterogeneity of errors (Figure 8).

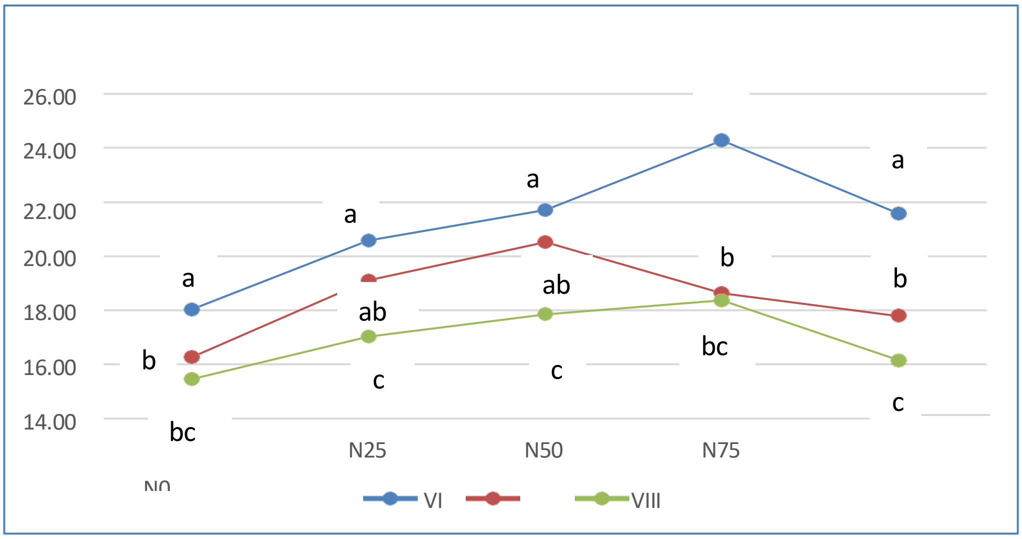


Figure 8 Response of each variety to nitrogen levels on forage yield of oat varieties at ROBA experimental site during 2023 main cropping season.

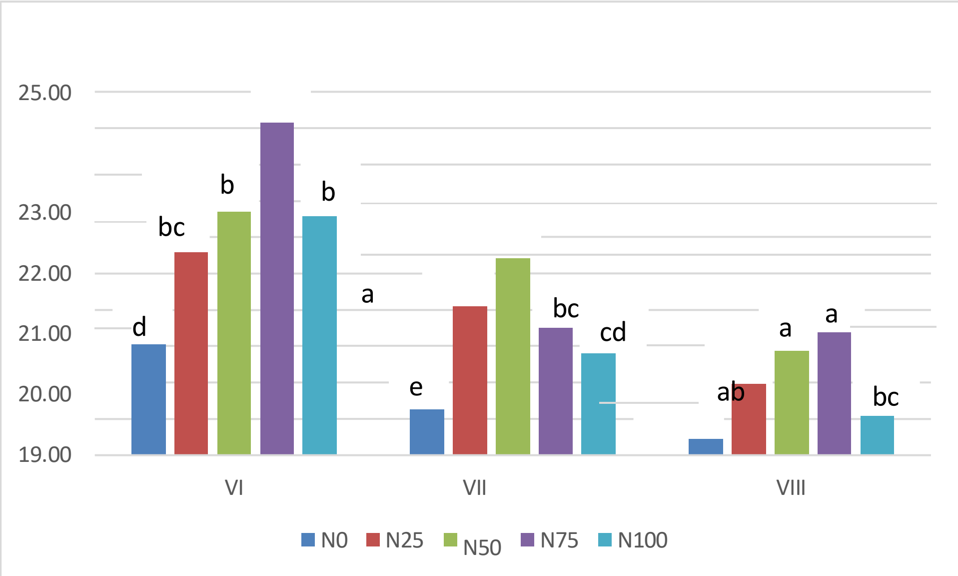


Figure 9 The interaction effect of variety and nitrogen levels on oat forage yield at ROBA experimental site during 2023 main cropping season.

Varieties react differently to nitrogen levels. This is because an optimum nitrogen rates promoted vegetative growth as it is an essential for food synthesis and stimulates cell division and cell elongation.

Genetic variation also exists between varieties that respond differently to nitrogen levels. The result is also quite consistent with Haider (2008) who reported that the difference in forage yield among oat cultivars is due to different nutrient management practices. Similarly, to Ali *et al.,* (2017) found that in the interaction of oat cultivars and nitrogen levels, the highest green forage yield (84.90 t ha^{-1}) was achieved in the treatment at 80 kg ha^{-1} with variety Scott. Applying nitrogen at the ideal level increases fodder production. However, due to lodging, further increases in nitrogen above 75 kg ha^{-1} reduced forage yield. These results were consistent with those of Ali *et al.,* (2017), who found that increasing the nitrogen application rate progressively increased the dry matter yield up to 80 kg N ha^{-1}, after which increasing the application rate further reduced the dry matter yield. In a similar way, Iqbal *et al.,* (2009) found that increased nitrogen application rate improved all growth and yield parameters, but that higher N rates had a negative impact on forage yield.

4.15 Above ground biomass (t ha^{-1})

The current study shows, the main effect variety and nitrogen rate were significant ($P<0.001$) and the interaction effect was also significant ($P<0.01$) affected. (Appendix Table 2.).

There is rank change of the varieties in aboveground biomass. WALQAA gave the highest above ground biomass under N0, N75 and N100 (22.5 t ha^{-1}) (Figure 10). At N25 WAS gave the highest above ground biomass.

At N50, WALQAA and WAS gave similar above ground biomass. SRCP gave the lowest above ground biomass under all N levels except under N75 where it ranked second. The difference between the varieties was also not consistent over the N levels; interaction due to heterogeneity of variances.

Increasing the N rates increased aboveground biomass yield in all varieties except that above ground biomass decreased as N rate increased from 0 to 25 in WALQAA and as N was increased from 50 to 75 under WAS (Figure 10). There was some rank change of the N levels under the different varieties. The difference between aboveground biomass yields of the N levels was also not consistent, it was high under WALQAA but lower under WAS. (Figure 10). It was statistically similar to the control plot and 100 kg nitrogen rate for the WAS and SRCP varieties, respectively. As nitrogen fertilizer rate increases, there was a proportional increase in above ground biomass except for the WAS variety at a nitrogen rate of 75 kg nitrogen which didn't show increment. This is because nitrogen is an essential nutrient for food synthesis, promotes cell division and cell elongation. Genetic variation occurs among varieties that respond significantly to nitrogen levels. This finding is in line with, *Mahmood et al.,* (2021) who reported that application of nitrogen at 240 kg/ha enhanced the growth and yield attributes of oats.

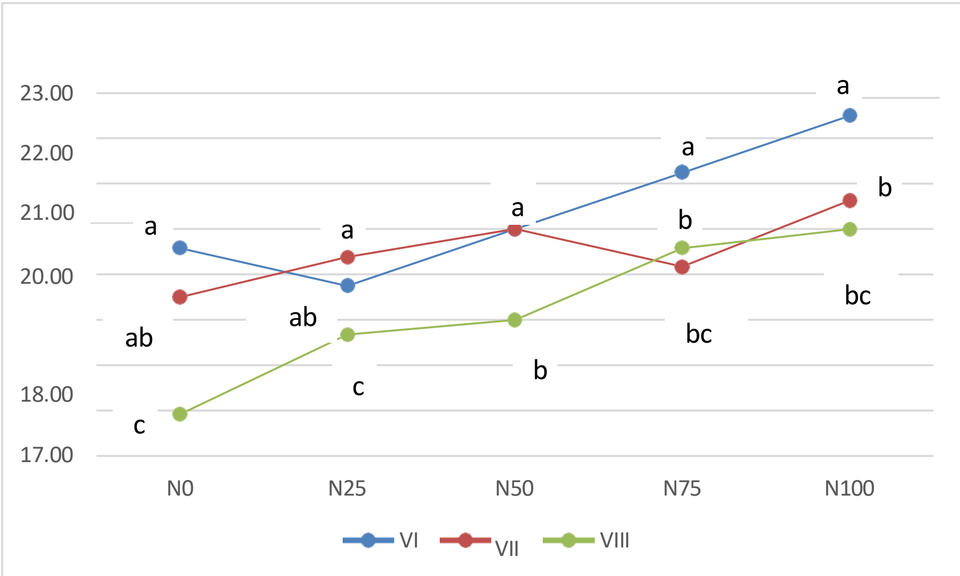


Figure 10 Response of each oat variety to nitrogen levels on above ground biomass yield at ROBA experimental site during 2023 main cropping season.

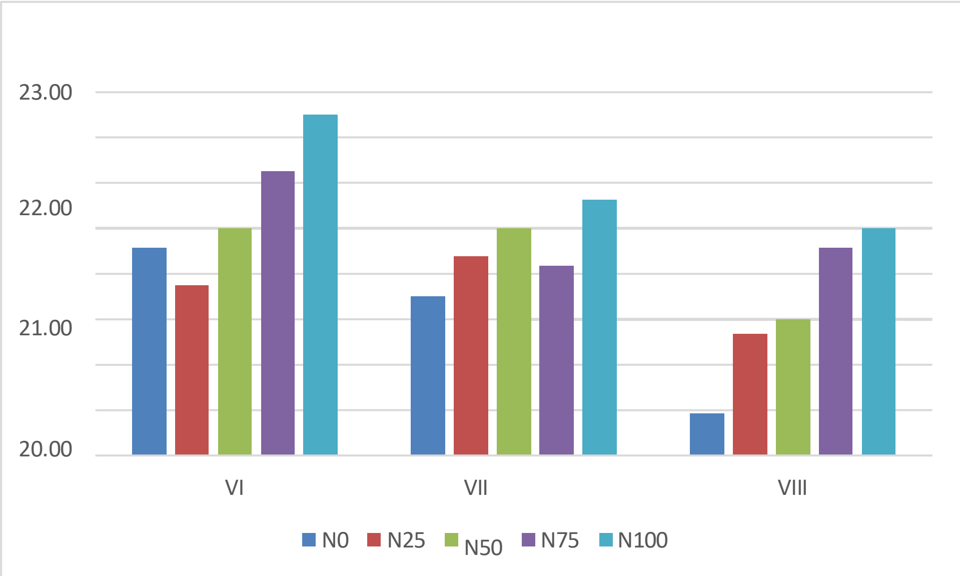


Figure 11 Interaction effect of variety and nitrogen on aboveground biomass yield of oat at ROBA experimental site during 2023 main cropping season.

4.16 Thousand seeds weight (gm)

In this study, thousand seeds weight was significantly ($P<0.001$) affected by the main effect variety; nitrogen rate and the interaction effect (Appendix Table 2).

The highest thousand seeds weight (39.33gm) was obtained from variety SCRP with nitrogen rate 100 kg ha^{-1} and the lowest (33.33 g) from variety WAS with nitrogen rate of 25 kg ha^{-1} (Table 11). This is statistically similar for the same variety at control and 50 kg nitrogen and for WALQAA variety with nitrogen rate of 50 kg ha^{-1}. Increasing the rate of nitrogen application may lead to an improvement in production of photosynthates at source and their transportation to sink efficiency. Consistent with this, Mohr *et al.,* (2007) noted that the weight of 1000-grains seeds were higher at the nitrogen rate of 80 kg ha^{-1}. Also, similar with Islam, et al (2020) who reported that application of 105 kg N ha^{-1} gave the highest (73.00 gm) while the control gave the lowest mean (54.13gm) 1000- seed weight.

4.17 Grain yield (ton ha-^{1})

Results of the current study showed that, grain yield was significantly (P<0.001) affected by the main effect of variety, nitrogen rate and the interaction. Appendix Table 2.

Below N75, SRCP was the highest yielding variety (5.03 to 5.21 t ha^{-1}), while above N50,WAS was the highest yielding variety (5.28 to 6.39 t ha^{-1}). WALQAA was the lowest yielding variety under all N levels (2.34 to 3.47 t ha^{-1}). There was some rank change between WAS and SRCP. The difference in grain yield that existed between any two varieties was also not constant over the five N levels. The difference between any two varieties were statistically significant at any N level.

Grain yield under N100 was lower than that under N75 for all three varieties. Applied to any variety grain yield tended to increase as N applied increased, then grain yield reached a maximum and then declined. The lowest grain yield was obtained from the control (N0) in WALQAA, from N25 in WAS and from N50 in SRCP.

The highest grain yield was obtained from variety WAS with nitrogen rate of 75 kg ha^{-1} while the lowest (2.34 t) from WALQAA variety at the control plot. (Figure 12). This is because of the lodging observed in WALQAA variety before harvest. Grain yield increased from 2.34 to 6.39 t/ha^{-1} with increasing nitrogen application rate only from 0 to 75 kg ha^{-1}.

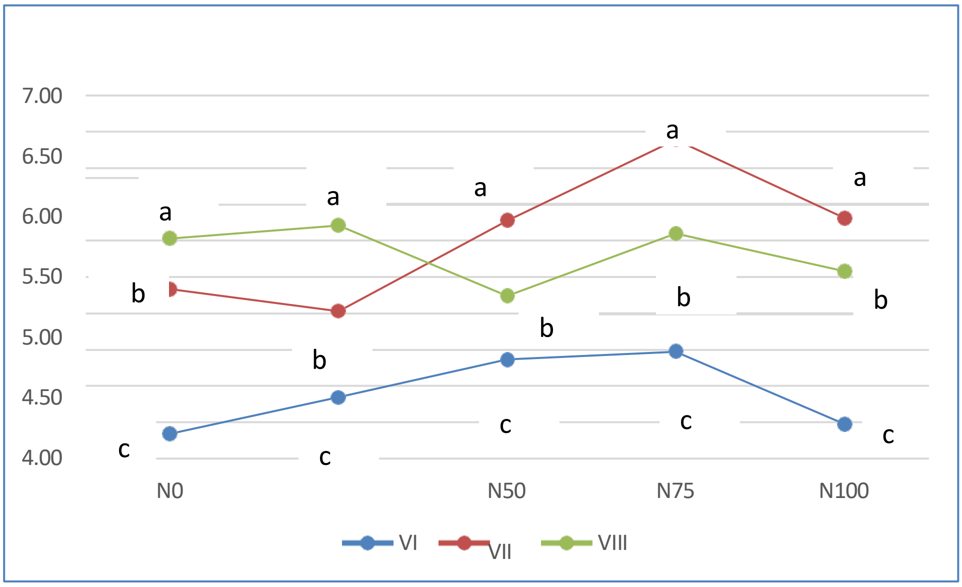


Figure 12 Response of each variety to N level on grain yield of oat at ROBA experimental site during 2023 main cropping season

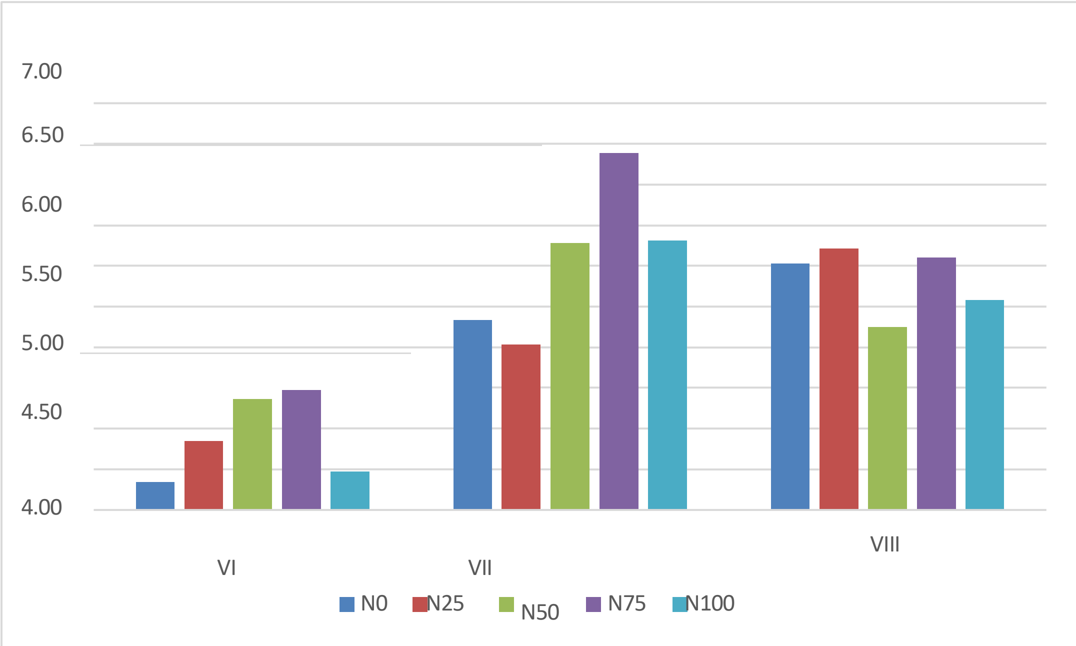


Figure 13 Effect of Variety and Nitrogen interaction on grain yield of oat at ROBA experimental site during 2023 main cropping season. The yield of all varieties in the treatment was increased as the nitrogen fertilizer rate increased up to 75 kg/ha. However, the increase was not uniform among the three varieties. This may be due to higher performance of growth parameters (plant height, dry matter accumulation and crop growth rate or relative growth rate) and variation in genetic potential between varieties that respond to nitrogen rate. Additionally, increased nitrogen levels resulted in increased plant height, number of tillers, number of spikes, and 1000 grain weight, resulting in increased grain yield. Nitrogen plays an important role in increasing the fertility of most florets compared to low levels (Hanif and Langer, 1972). These findings correspond with the results reported by Mantai *et al*., (2016). Similarly, Joon *et al*., (1993) observed that oat grain yield increased only up to 80 kg N ha^{-1} and then decreased with increasing nitrogen. (Mohr *et al*., (2007) showed that low to moderate nitrogen rates significantly increased oat grain yield.

The highest performance of growth parameters (plant height, dry matter accumulation and crop growth rate or relative growth rate) increased due to higher availability of metabolites. Increasing N also increased lodging and decreased grain weight, and grain plumpness, suggesting that optimal N management must balance yield improvement and grain quality. Oats were highly responsive to increasing nitrogen fertilizer at low rate but less responsive to higher rates. Oat grain yield continued to increase to the highest nitrogen rate (140 kg ha^{-1}) but, leveled off at 100 kg ha^{-1} increasing from 6.63 to 6.74 t ha^{-1} at 140 kg ha^{-1} William *et al.,* (2020).

It was recorded that the lodging of 22.50 and 45.00 degree was observed in WAS and WALQAA varieties during the growing period. The lodging can be due to the cultivars genetic difference and nutrient management. It suggests that while the N rate increases, lodging increased across the varieties at a far higher percentage. However, compared to other varieties, WALQAA variety found to be more susceptible to lodging compared to other two varieties, which may then have an impact on growth, forage yield, seed yield, and quality.

4.18 Straw yield (t ha^{-1})

Analysis of variance shows the straw yield was affected by the main effect of variety; nitrogen rate and their interaction effect significantly (P<0.001) (Appendix Table 2).

The highest straw yield (20 t ha^{-1}) was recorded from nitrogen application of 100 kg ha^{-1} from variety WALQAA and the lowest from variety SRCP in the control plots.

For the same variety, it was statistically similar at nitrogen rate of 75 and 100 kg ha^{-1}. When the amount of nitrogen fertilizer increased, there was a proportional increase in straw yield for WALQAA variety except control plots, which was high. For WAS and SRCP varieties, straw yield increased as nitrogen rate increased from 0 to 25 kg ha^{-1}, then an increased nitrogen rate from25 to 75 kg ha^{-1} decreased the straw yield.

This is due to the optimal rate of nitrogen, which increases the vegetative growth of oats as the result of increase photosynthesis, cell division and cell elongation contributed by nitrogen. There is also genetic potential variation among varietal responses to nitrogen levels. Increased nitrogen application provided better oat nutrition, resulting in maximum straw yield. This result is in consistent with Patel and Rajgopal (2002), they reported a linear response for nutrient uptake up to 75 kg of nitrogen ha $^{-1}$ and 60 kg P_2O_5 ha^{-1}. Tiwana *et al.,* (2004) reported that application of 60 kg N ha^{-1} significantly increased seed and straw yield of oats. Also, Devi *et al.,* (2010) reported that nitrogen content in forage, grain and straw as well as soil after oat harvest was significantly affected by applied nitrogen levels. The application of 105 kg N ha^{-1} on oat varieties showed a significant superiority over the control (Islam *et al.,* 2020).

Table 7 Interaction effect of variety with nitrogen on Thousand Seeds Weight (gm) and Straw yield (t ha^{-1}) of oat at ROBA experimental site during 2023 main cropping season.

Nitrogen	TSW (gm)			Straw Yield (t ha^{-1})		
	Variety			Variety		
	WALQAA	WAS	SRCP	WALQAA	WAS	SRCP
0kg	35.33d	34efg	34.33ef	17.25bc	14.17fgh	14.17j
25kg	34.67^{de}	33.3^{g}	34.67^{de}	15.91^{cde}	15.35^{def}	15.35^{i}
50kg	34^{efg}	33.67^{fg}	38.33^{b}	16.64^{bcd}	14.72^{efg}	14.72^{gmi}
75kg	37.67^{bc}	37.67^{bc}	38.33^{b}	17.78^{b}	12.78^{hi}	12.78^{fg}
100kg	37.67^{bc}	37.33^{c}	39.33^{a}	20.03^{a}	15.32^{def}	15.32^{def}
LSD		0.92			1.41	
CV		1.53			5.58	

Means in columns followed by the same letter/s are not significantly different from each other at a 5% level of significance; LSD (0.05) = Least significant difference at 5%; and CV (%) = Coefficient of variation; NS = Non-significant

4.19 Harvest index (%)

Results of this study showed that the main effect of variety; nitrogen and the interaction effect were significant (P<0.001) on harvest index of oat. (Appendix Table 2). The lowest harvest index (20.74%) was calculated for variety WALQAA at nitrogen rate of 25 kg ha^{-1} while the maximum harvest index (33.36%) was calculated for variety WAS at nitrogen rate of 75 kg ha^{-1}. It was statistically at par with nitrogen rate of 25 kg ha^{-1} for variety SRCP (Figure 14). In line with this, Sharma *et al.,* (2001) revealed that application of 100 kg N ha^{-1} significantly increased the grain and straw yields and harvest index was significantly reduced by nitrogen fertilization.

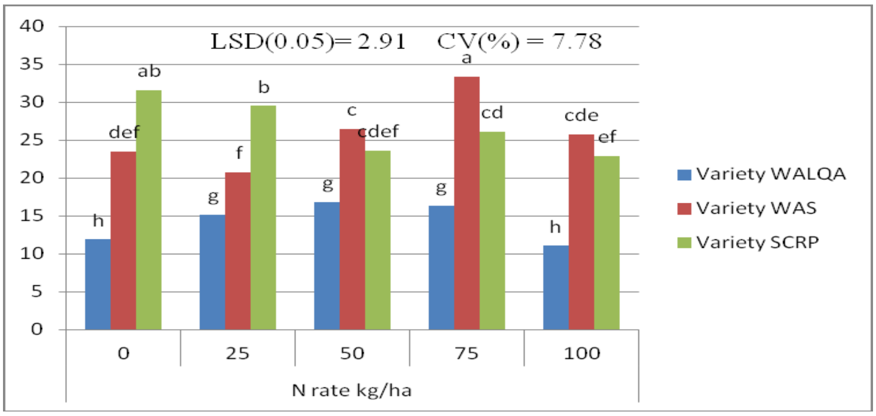


Figure 14 Interaction effect of variety and nitrogen on oat Harvest Index (%) of oat at ROBA experimental site during 2023 main cropping season.

4.3 Partial Budget Analysis

The agronomic data on which the recommendations are based must be relevant to the farmers' own agro-ecological conditions and the evaluation of these data must be consistent with the farmers' objectives and socio-economic circumstances (CIMMMYT, 1988).

Based on the partial budgeting procedure described by CIMMYT (1988), the variable costs included urea fertilizer costs (34.45 ETB kg $^{-1}$) at the time of planting and labor cost at harvest, three persons assumed to harvest one ton in one day (900 birr for three persons ton $^{-1}$) were considered as gross benefit. Average forage yield for oat was adjusted downward by 10% to reflect the farmer's field yield as described by CIMMYT (1988). The net dry forage yield was multiplied by the market price (7.5 ETB kg^{-1}) to obtain the gross field benefit. Costs and benefits were calculated for each treatment. The variable costs were added and subtracted from the gross benefits to obtain the net benefit. The data analysis indicated that the economic analysis of oat varieties is affected by the interaction effects of the variety with the amount of nitrogen fertilizer (Table 8). A partial budget analysis was carried out for the variety with nitrogen as a factor, for which significant effects on forage yield were observed (Table 8). From the budget summary of the economic analysis, it is clear that the highest net yield (146,737.5 ETB/ha) was obtained from the WALQAA variety at 75 kg/ha nitrogen with a marginal yield of 1110.2% (Table 8). In contrast, the lowest net benefits of 95,096.99 ETB/ha were obtained from the SRCP variety at control nitrogen. Similarly, maximum net income (Rs. 107,813.50) was recorded when nitrogen was applied at 80 kg N/ha in oat scott cultivar (Ali *et al.,* 2017). In order to use the marginal rate of return (MRR) as a basis for fertilizer recommendations, the minimum acceptable marginal rate of return must be 100% (CIMMYT, 1988).

Table 8 Summary of partial budget analysis of the effects of nitrogen rate on forage yield of Oat varieties at ROBA experimental site during 2023 main cropping season

Treatment	Forage yield (t)	Adjusted Forage yield (t)	GFB (birr)	TVC (birr)	NB (birr)	MRR (%)
SRCP + 0 kg	15.46	13.92	109013.7	13916.7	95096.99	-
WAS+0 kg	16.27	14.64	114703	14643	100060	683.33
SRCP+ 25 kg	17.03	15.33	120061	16188.25	103872.7	246.74
WALQAA+0 kg	18.04	16.23	127160.3	16233.3	110927	15658.7
SRCP+ 50 kg	17.86	16.1	125891.3	17793.8	108097.5	D
SRCP+ 100 kg	16.15	14.53	113835.9	17977.3	95858.57	D
WAS+25 kg	19.1	17.19	134633.3	18048.55	116584.7	290.9
SRCP+75 kg	18.37	16.54	129529.1	19119.45	110409.6	D
WAS+ 75 kg	18.64	16.78	131432.6	19362.45	112070.1	D
WALQAA+25 kg	20.58	18.52	145088.4	19383.25	125705.1	655.52
WAS+100 kg	17.79	16.01	125397.8	19453.3	105944.5	D
WAS+50 kg	20.52	18.47	144644.2	20187.8	124456.4	D
WALQAA+50 kg	21.7	19.53	152963.2	21249.8	131713.4	683.33
WALQAA+100 kg	21.57	19.41	152046.7	22855.3	129191.4	D
WALQAA+75kg	24.28	21.85	171173.3	24435.75	146737.5	1110.2

Where, GFB = Gross field benefit; TVC = Total variable costs; NB = Net benefit; MRR = marginal rate of return; ETB/ha = Ethiopian Birr per hectare; D = Dominated treatment; t = Ton per hectare

Table 9 Summary of partial budget analysis of the effects of Nitrogen rate on grain yield of Oat varieties at ROBA experimental site during 2023 main cropping season.

Treatment	GY (t)	AGY(t)	GFB (birr)	TVC (birr)	NB (birr)	MRR (%)
WALQAA + 0 Kg	2.34	2.10	105152	0	105152	-
WALQAA + 25 Kg	2.84	2.55	127652	1350	126302	1566.7
WALQAA + 50 Kg	3.36	3.02	151200	2700	148500	1644.3
WALQAA + 75 Kg	3.47	3.13	156299	4050	152249	277.7
WALQAA + 100 Kg	2.47	2.23	111299	5400	105899	D
WAS + 0 Kg	4.33	3.90	194999	0	194999	-
WAS + 25 Kg	4.03	3.63	181350	1350	180000	D
WAS + 50 Kg	5.28	4.75	237749	2700	235049	4077.7
WAS + 75 Kg	6.39	5.75	287550	4050	283500	3589.0
WAS + 100 Kg	5.31	4.78	238950	5400	233550	D
SRCP + 0 Kg	5.03	4.53	226350	0	226350	-
SRCP + 25 Kg	5.21	4.69	234302	1350	232952	489.0
SRCP + 50 Kg	4.24	3.81	190652	2700	187952	D
SRCP + 75 Kg	5.10	4.59	229500	4050	225450	2777.7
SRCP + 100 Kg	4.58	4.12	206249	5400	200849	D

Whereas; GY – Grain yield, AGY – Adjusted grain yield, GFB - Gross field benefit, TVC - Total variable cost, NB – Net benefit, MRR – Marginal rate of return

Budget summary was also performed for grain yield of oat varieties with nitrogen rates. From the budget summary of the economic analysis, the highest net grain yield (283,500 ETB/ha) was obtained from variety WAS at 75 kg/ha nitrogen, while the highest marginal yield of 4,077.7% from 50 kg nitrogen with similar variety. (Table 9). In contrast, the lowest net benefit of 105,152 ETB/ha was obtained from variety WALQA at control nitrogen.

5. SUMMARY AND CONCLUSION

The low state of soil fertility and improved and well adapted Oat varieties are the limiting factors of forage yield and seed production in the study area. Ensuring an optimum supply of nitrogen fertilizers to oat varieties can lead to higher forage and seed yields. However, limited research has been conducted on the effect of nitrogen fertilizer rates on yield and yield components of oat varieties. Therefore, a field experiment was conducted to evaluate the effect of nitrogen rates on yield and yield components of oat varieties and to identify the economically feasible nitrogen level that provides optimum yield for oat varieties. Five levels of nitrogen (0, 25, 50, 75, 100 kg ha^{-1}) and three oat varieties (WALQAA, WAS and SRCP) were tested in factorial combination with three replications in a Randomized Complete Design.

Data were collected on phenology, growth, yield components and yield of oat and analyzed using SAS 9.0 statistical software.

The results showed that the main effect due to nitrogen application and cultivars significantly affected the number of days to heading, days to physiological maturity, total tillers, effective tillers, spike number, plant height at 90 day after planting and physiological maturity, number of seeds per plant, forage yield, above-ground biomass, thousand seed weight, straw yield, grain yield and harvest index. While plant height at 30 and 60 days after planting significantly affected only by variety. SRCP variety was earlier in heading and maturity than other varieties. Early and fast- growing variety was WALQAA compared to SRCP and WAS at 30^{th} and 60^{th} day plant height.

Increasing Nitrogen rate from 0 kg ha^{-1} to 100 kg ha^{-1} increased the number of days required to reach maturity from 129.8 days to 135.6 days. The interaction of nitrogen fertilizer rate with varieties significantly affected total tillers, effective tillers, and plant height at 90 days and maturity, number of seeds per plant, forage yield, aboveground biomass, thousand seeds weight, grain yield, straw yield and oat harvest index. Significantly delayed heading date (96) was recorded for WALQAA at the rate of 100 kg ha^{-1}, highest total number of tillers per m^2 (868.3) and effective tillers per m^2 (795) was obtained from WAS at the rate of 75 kg ha^{-1}. Significantly, the highest plant height (150 and 199.83 cm) was obtained from WALQAA variety with nitrogen rate of 50 and 100 kg ha^{-1} at 90 days after planting and height at physiological maturity, respectively. The highest yield of fodder (24.46 t ha^{-1}), aboveground biomass (22.5 t ha^{-1}), straw yield (20 t ha^{-1}) was found from variety WALQAA with nitrogen rates of 100 and 75 kg ha^{-1}. The highest thousand seeds weight (39.33 gm) and seed yield (6.39 t ha^{-1}) were found from variety SRCP and WAS at nitrogen rates of 100 and 75 kg ha^{-1}, respectively.

The economic analysis also showed the highest net benefit of forage yields (146,737.5 ETB ha^{-1}) from the application of 75 kg nitrogen ha^{-1} from variety WALQAA with a marginal yield of 1,110.2%. Based on this study result, variety WALQAA is recommended for fodder production and WAS for grain production with nitrogen fertilizer rate of 75 kg ha^{-1} which brought maximum fodder, grain yield and economic benefit in the study area. However, the result of this study needs to be evaluated and verified under different agro-ecologies to reach a conclusive recommendation.

REFERANCE

Ali, I., S.I. Zamir, M. Hussain, M. D. Shan and M. Ajmal, 2017. Agro-economic studies of different oat (*Avena sativa L.*) cultivars under varying nitrogen levels. Journal of Environmental and Agricultural

Darwinkel A, Rops AHJ, Wijnholls KH. 1995, Nitrogen, seed rate and growth regulation in oats. Verslag Proefstation Voor de Akkerbouls en de Groenteteelt in de Vollegrond, , 188:52.

Gasim, S.H. 2001. Effect of nitrogen, phosphorus and seed rate on growth, yield andquality of forage maize (*Zea mays* L.). M.Sc. Thesis, Faculty of Agriculture, University of Khartoum.

Gill PS, Singh Kanwar, Tripathi HP. 1976 response of oats varieties to nitrogen and phosphorus application. Forage Res.; 2:159-164.

Godara, A.S., B.S. Satpal and S.K. Duhan. 2016. Effect of different nitrogen levels on forage yield, quality and economics of oat (*Avena sativa* L.) genotypes. ForageRes. 41(4): 233-236.

Haider, G. 2008. Effect of different sowing techniques on growth, forage yield and quality of four oat (Avena sativa L.) cultivars. M.Sc. Agri. Thesis, Deptt. Agron. Uni. Agri. Faisalabad, Pakistan

Hanway, J.J. 1966. How a corn plant develops. Special Report No. 38, Iowa StateUniversityof Science and Technology, Cooperative Extension Service.

https://www.agric.wa.gov.au/. Accessed on: 27.12.2019. Indian J Agron. 1985;30(2):172-176.

Iqbeal, M.F., M.A. Sufyan, M.M. Aziz, I.A. Zahid, Q. Ghani and S. Aslam. 2009. Efficacy of nitrogen on green fodder yield and quality of oat (Avena sativa L.). J. Anim. Plant. Sci.

19(2): 82-84.

Jackson, G.D., R.K. Berg, G.D. Kushnak, T.K. Blake and G.I. Yarrow. 1994. Nitrogeneffects on yield, beta-glucan content, and other quality factors of oat and waxy hulless barley. Commun. Soil Sci. Plant Anal. 25(17-18): 3047–3055.

Loskutov, I. 2005. Classification and Diversity of the Genus Avena L. In: Cereal Genetic Mahmood TA, Basim KH, Razzaq GN. 2021. Effect of different levels of nitrogen fertilization and cultivars on the green fodder yield and the grain yield of oats (*Avena sativa L.*). Annuals of the Romanian Society for Cell Biology;25(2)

Malzew, A. I. 1930. Wild and Cultivated Oats. Bulletin of Appl. Botan. Genet. Plant Breeding, Suppl. 38. [Paper on origin of oats]. McMullen, M. S. (2000). Oats. In: K. Kulp and J. G. Ponte.

Mantai, R.D., J.A. Gonzalez de Siva, E. Gh. Arenhardt, O.B. Scremin, A.T. Woschinski de Mamann, R.Z. Frantz, A.C. Valdiero, R. Pretto and D.K.Krysczun. 2016. Simulation of oat grain (*Avena sativa* L) using its panicle components and nitrogen fertilizer. Afr. J. Agric. Res. 11(40): 3975- 3983. DOI:10.5897/AJAR2016.10943

May, E.W., R.M. Mohr, G.P. Lafond, A.M. Johnston and F.C. Stevenson. 2004. Effect of nitrogen, seeding date and cultivar on oat quality and yield in the Eastern Canadian Prairies. Can. J. Plant Sci. 84(4): 1025-1036.

Mengistu, A. 1997. Conservation-based forage development for Ethiopia. Self Help Development International, Addis Ababa, Ethiopia. p.170.

Midha, L.K., B.S. Duhan and S.K.M. Arya. 2015. Performance of promising entries of oat (*Avena sativa L.*) under different nitrogen levels. Forage Res. 41(2): 122- 125.

MoA. 2019. Ministry of Agriculture, Plant variety release, protection and seed quality control directorate. Crop variety register, Issue No.22, 2019. Addis Ababa, Ethiopia.

Mohr, R.M., C. .A. Grant, W.E. May, and F.C. Stevenson. 2007. The influence of nitrogen, phosphorus and potash fertilizer application on oat yield and quality. Can. J. Soil Sci.87(4): 459-468.

Muurinen, S., J. Kleemola and P. Peltonen-Sainio. 2007. Accumulation and translocation of nitrogen in spring cereal cultivars differing in nitrogen use efficiency. Agron. J. 99(2): 441-449. DOI: 10.2134/agronj2006.0107

Ohm HW. 1976. Response of 21-oats cultivars to nitrogen fertilization. Agron.J.;68:773- 775.

Omer, E.A. 1998. Farm yard manure and urea fertilization on growth and forage yield of two maize (*Zea mays L.)* cultivars. M. Sc. Thesis, Faculty of Agriculture, University of Khartoum.

Patel JR, Rajgopal S. Response of oats (*Avena sativa* L) to nitrogen and phosphorus levels. Indian J Agron. 2002; 47(1):134-137.

Peterson, D.M., D.M. Wesenberg, D.E. Burrup and C.A. Erickson. 2005. Relationships among agronomic traits and grain composition in oat genotypes grown in different environments. Crop Sci. 45(4): 1249-1255. DOI: 10.2135/cropsci2004.0063 Rao CN, Patil BD. Effect of nitrogen levels on yield of oats. Forage Res. 1979; 5:151-153.

Rocquigny, P.J., M.H. Entz, R.M. Gentile and S.C. Duguid. 2004. Yield physiology of a semi dwarf and tall oat cultivar. Crop Sci. 44(6): 2116-2122. DOI: 10.2135/cropsci2004.2116

Salmina IS, Makarova VV. 1988; The content of nitrogen and phosphorus compounds in oats seed depending on level of mineral nutrition. Sibirskii-Vestnik-Sel' skokhozyaistvennoi-Nauki. 3:18-20.

Sencar O. 1987; Effect of sowing date and nitrogen application on grain yield, straw yield andharvest index of four Oats varieties Dogo-Turk-Tarim-Ve-Ormancilik-Dergisi. 1987; 11(2):425- 434.

Sharma MS, Singh BP, Shiva Dhar. Effect of cutting, nitrogen and phosphorus levels on yield and nutrients removal of Oats (Avena sativa). Range-management and Agro forestry. 2002; 23(2):115-118.

Sharma SK, Bhunia SR. Response of oats (*Avena sativa* L) to cutting management, method of sowing and nitrogen. Indian J Agron. 2001; 46(3):563-567.

Sheoran, R.S., U.N. Satpal Joshi, B.S. Duhan, P. Kumari, S. Arya and D.S. Phogat.2017. Agronomic evaluation of oat (*Avena sativa* L.) genotypes for forage yield, quality and economics under varying levels of nitrogen. Forage Res.43(1

Singh R, Sood BR, Sharma VK, Sharma VK, Rana NS, 1998; Effect of cutting management and nitrogen on forage and seed yield on oats. Indian J Agron. 43:362- 366.

Sood BR, Kumar N. 1994; Effect of nitrogen and phosphorus on forage yield and nutritional uptakeof oats-berseem mixture. Crop Res. Hisar. 8(2):139-244.

Thakuria K, Rafique RT. Effect of cutting stage and nitrogen level on fodder production and yield of oats (*Avena sativa* L). Indian J. Agron. 1993; 38(2):308-309. Turkish J. Field Crop. 18(2): 254-259.

William E. M., Ramona M. M., Guy P. L., Adrian M. J. and F. Craig S. 2004. Effect of nitrogen, seeding date and cultivar on oat quality and yield in the eastern Canadian prairies. Canadian Journal of Plant Science. 1025-1036p

William Earl, May Stewart, Brandt Kayleigh, Hutt-Taylor. 2020. Response of oat grain yieldand quality to nitrogen fertilizer and fungicides. 1021-1034p

Yohannes Erkeno and Nigussie Dechassa. 2019. Effect of Rates and Time of Nitrogen Application on Growth, Yield, and Yield Components of Wheat (*Triticum aestivum* L.) in Eastern Hararghe, Ethiopia. Journal of Natural Sciences Research 1-15p

BIOGRAPH OF AUTHOR

Hussein Watta Kaliyo was born to his father “Watta Kaliyo Habe” and his mother “Shukati Fino Balicha” on January 1, 1961 at Wamangye Abossa Kebele, Kofele Woreda, west Arsi zone, Oromia Regional State. He completed his bachelor's degree from Haramaya College of Agriculture in Plant Science in 1984 and worked in various positions for the Government of Ethiopia, The Lutheran World Federation, DanChurchAid, Kwantlen Polytechnic University from 1984 to 2018. In terms of residence, Hussein has lived and worked in Tanzania, Mozambique, South Sudan, Kenya and Canada and is now back in his home village supporting the community.

As a philanthropist, Hussein founded the "Rural Organization for Betterment of Agro-pastoralists" (ROBA) in 1999 and implemented projects in the fields of education, public health, agriculture and natural resource management. He has extensive experience in managing emergency and development projects. Hussein currently lives in Kofele and supports communities in the West Arsi zone through fundraising and implementing community development projects. He pursued his MSc education in 2023 and completed in 2024 specializing in Agronomy.

Hussein loves gardening and animal farming and his future interest is to advocate for the rural poor economic and political empowerment.

APPENDIX TABLES

Appendix Table 1. Mean square values of ANOVA for phenological and growth parameters of oat varieties and nitrogen fertilizer application at ROBA experimental site during 2023 main cropping season

Source	DF	DH	DM	T TILLER	E TILLER	NSPK	NSPKL	PL	PH30	PH60
REP	2	1.422	1.40	9508.02*	9629.49*	0.0995	22.006*	15.47*	1.55	
VAR	2	415.08***	850.20***	755694.49***	576233.89***	1.393***	11.483	190.85***	555***	6295***
N	4	60.25***	41.91***	20484.86***	6442.22***	0.256***	16.676*	14.51*	1.18	36.83
VAR*N	8	4.42*	3.81	49461.66***	45794.30**	0.160	14.139*	14.40**	2.73	19.32
Error	28	1.27936	1.85	2122.40	2635.68	0.079	5.745	4.52	2.21	21.07

NB; DH-date of heading, DM-days to maturity, T TTILLER- total tillers, E TTILLER-effective tillers, NSPK-number of spikes, NSPK- number of spikelets, PL-panicle length, PH30-plant height on 30 day, PH60-plant height on 60 day.

Appendix Table 2. Mean square values of ANOVA for growth and yield components of varieties and nitrogen fertilizer application at ROBA experimental site during 2023 main cropping season

Source	DF	PH90	PH	NSDPP	FORYLD	AGBM	TSW	GYLD	STRY	HI
REP	2	86.46	16*	24	0.74	1.48	1.09*	0.28	68.52***	3.04
VAR	2	5188.3***	4545***	9790***	70***	18.08***	12.42***	21.42***	10.34***	734.17***
N	4	513.26**	257***	966***	20***	12.73***	30.85***	1.65***	10.34***	33.34***
VAR*N	8	139.64*	79***	543**	3.21**	1.88*	3.75***	1.12***	4.89***	47.86***
Error	28	60.12	4.7	107	0.79	0.71	0.30	0.096	0.71	3.02

NB: PH90-plant height on 90-day, PH-plant height at physiological maturity, NSDPP-number of seeds per plant, FORYLD-forage yield, AGBM- aboveground biomass, TSW-thousand seeds weight, GYLD- grain yield, STRY-straw yield, HI-harvest In

APPENDIX PICTURES

Appendix picture 1. Photo of Field observation

P7T13(100+WAS)

When soil sample taken

Field layout

When plant height measured at 60 days

During harvesting

Seeds drying