Influence of Nitrogen and Sulphur on Seed Production of Oat (*Avena Sativa L.*) under Temperate Condition

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Thesis

Submitted to

The Faculty of Agriculture

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Master of Science in Agriculture

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2023

Dedicated

To my

Beloved parents and Nitika jojra

for their love, cooperation and unending sacrifices

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Agronomy Faculty of Agriculture, Wadura Campus
Sopore-193201

Certificate - I

This is to certify that the thesis entitled, **"Influence of Nitrogen and Sulphur on Seed Production of Oat (Avena Sativa L.) under Temperate Conditions"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)**, to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir is a record of bonafide research work carried out by **Mr. Faisal Hayat (Regd. No. MSA-2019-1261)**, under my supervision and guidance. No part of the thesis 00 has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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We, the members of the Advisory Committee of **Mr. Faisal Hayat (Regd. No. MSA-2019-1261)** candidate for the degree of **Master of Science in Agriculture (Agronomy)** have gone through the manuscript of the thesis entitled, **"Influence of Nitrogen and Sulphur on Seed Production of Oat (*Avena Sativa* L.) under Temperate Conditions"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **"Influence of Nitrogen and Sulphur on Seed Production of Oat (Avena Sativa L.) under Temperate Conditions"** submitted by **Mr. Faisal Hayat (Regd. No. MSA-2019-1261)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner on …………….

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Title of the Thesis	:	**Influence of Nitrogen and Sulphur on Seed Production of Oat (*Avena Sativa* L.) under Temperate Conditions**"

ABSTRACT

An experiment was conducted at Agronomy farm of Sher-e -Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura during *Rabi* 2020 on silt clay loam soil to study effect of combined or sole application of nitrogen with sulphur at variable rates on growth yield and quality of oat seed crop. The soil of experimental plot was medium in nitrogen, phosphorus and potassium but low in sulphur. Application of nitrogen and sulphur combinations *viz.* N_{80} S_{40}, $N_{80}S_{20}$, $N_{80}S_0$, $N_{60}S_{40}$, $N_{60}S_{20}$, N_{60} S_0 and N_0S_0, were randomized in a randomized block design with three replications. Oat crop responded greatly to the combined application of nitrogen and sulphur. The application of F_7:($N_{80}S_{40}$) registered significantly higher values in growth, yield attributes, yield and quality, though remaining at par with N_{80} S_{20}. Maximum plant height (125 cm), LAI (5.17), tillers m^{-2} (371.97), dry matter production q ha^{-1}(65.82), effective tillers m^{-1} (291), spike length (35.24 cm), number of grains spike $^{-1}$ (40.30), test weight (34.76), seed yield (30.43 q ha^{-1}) straw yield (79 q ha^{-1}) were recorded with

F_7:(N_{80} S_{40}). The same treatment also recorded significantly higher values for nutrient content, uptake and quality parameters in terms of plump seeds (92%), crude protein (10.24 %) and hulling percentage (95.85). Maximum B: C ratio of 1.72 was registered with N_{80} S_{40} closely followed by F_6 :(N_{80} S_{20}) (1.62).

Key words: Crude protein Nitrogen, Oat, quality, Sulphur

Signature of Student | Signature of Major Advisor

Dated: ____________ | Dated: ______________

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Faisal Hayat

Place: Wadura, Sopore

Dated:

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Chapter – 1

INTRODUCTION

Livestock is one of the dominant sectors of agriculture in our country supporting about 10.7% of world livestock population (Roy *et al*., 2021), with the share of 5 % in the GDP of the country. Most often, livestock is the only source of cash income for subsistence farms as it serves as an insurance against the crop failure. In Jammu and Kashmir about 20 % of the population is directly dependent on the livestock for their livelihood. With the state livestock population of 8.99 million requiring about 11.19 million tonnes of green fodder, the UT of Jammu & Kashmir is showing the deficit of 53 % in green fodder (Roy *et al*., 2021). Thus, necessitating the demand for increased fodder production. Under this scenario increase in the production and productivity of fodder crops becomes inevitable. In Jammu &Kashmir a number of fodder crops are grown, such as berseem (*Trifoloium alexandrinum*), Lucerne (*Medicago sativa*) and Oats. However, oats being palatable, quick in growth and better tonnage is favoured by the farmers.

Oats (*Avena sativa* L) has gained importance world over independent of the end product. It is an important multipurpose cereal crop, cultivated for food, feed and fodder. It is sixth major cereal following wheat, maize, rice, barley and sorghum (Ivanov 2006) and seventh (7th) in the terms of area covered among world cereals (FAO 2013). It contributes 0.86 per cent to the global cereal production. During the period 2009-2013, the average area under oat crop globally was about 9.6 mha in comparison with major cereal crops wheat (220 mha) and barley (50 mha) (FAO 2015). Being highly sensitive to hot and dry climates, it is mostly suited to temperate regions of the world.

In Kashmir valley oats crop assumes importance as major fodder crop which fits well in the rice-based cropping system. Due to its wide range of soil adaptability coupled with suitable climate, acreage under oat crop is increasing day by day. However, one of the major constraints for horizontal expansion of oat cultivation as a fodder in the valley both in irrigated and *rainfed* areas is the inadequate supply of seed. No doubt, currently the requirement of seed is met mostly from the supplies being made by other states through National Seeds Corporation but the cost of such imported seed is quite exorbitant, thereby adding to the problems of poor peasantry. However, one of the important means to lessen this demand of oat seed from other states is to increase its productivity.

Different agronomic measures are taken to improve the productivity of oat crop and providing proper nutritional environment is one of them. Nitrogen and sulphur are two important nutrients influencing the growth and productivity of the cereal crops. Both nutrients are key components of enzymes and reserve proteins in grain of plants. The use of nitrogen is one of the major factors affecting the production of temperate crops. However, its use to increase the productivity has gone up in the past decade but with variable yield response owing to its propensity to lodge the crop at higher rates. Furthermore, excessive use of high analysis fertilizers in the recent past for improved cultivars has led to nutrient imbalance in soil particularly to the deficiency of secondary nutrients like sulphur. Insufficient supply of sulphur has also been witnessed to hamper the growth, yield and quality of crops. Sulphur fertilization improves the nutrient uptake and fertilizer use efficiency of NPK and Zn because of sulphur synergistic relationship with these nutrients. Fertilizer Sulphur tends to increase the yield in cereals up to certain limit (Ying- xing *et al.,* 2017).

With the aforementioned factors in mind, a study titled **"Influence of nitrogen and sulphur on seed production of Oat (*Avena sativa* L.) under temperate conditions"** was conducted at the Agronomy Farm of Sher-e-Kashmir

University of Agricultural Sciences and Technology of Kashmir, Wadura, during *Rabi* 2020-21 with the following objectives:

- To study the effect of nitrogen and sulphur on growth, yield and quality of oat.
- To work out the relative economics of seed production in oat.

Chapter - 2

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work done in India and abroad on oats and other related crops as influenced by nitrogen and sulphur.

2.1 Effects of nitrogen and sulphur

2.1.1 Growth characters

Sadhu *et al.* (1990) recorded an increase in the plant height of oats with the application of nitrogen up to 120 kg ha^{-1}but the increase in the number of tillers was registered only up to 80 kg ha^{-1}.

In a study conducted under temperate Kashmir conditions Bali *et al.* (1998) observed that plant height, tiller count (m^{-2}) and leaf area index increased significantly with the increase in nitrogen from 50-150 kg ha^{-1}. An increase in the nitrogen level up to 120 kg ha^{-1} lead to higher plant height, number of shoot $plant^{-1}$ and the leaf stem ratio as reported by Singh *et al.* (1999).

The maximum height of plants, number of shoot $plant^{-1}$ and the leaf stem ratio, with increasing nitrogen levels of up to 120 kg N ha^{-1}, was reported by Singh *et al.* (1999).

Sharma and Bhunia (2001) recorded taller plants, greater number of shoots per plant and more leaf stem ratio with the application of 80 kg N ha^{-1} substantially. Patel and Rajagopal (2015) while studying effect of nitrogen and phosphorus on oats observed considerable improvement in growth attributes up to 50 kg N ha^{-1}.

Oat responsiveness to the N requirement reported by Malakar *et al.* (2009) reflected significantly larger plant height (90.45 cm), dry matter accumulation (424.04 g m^{-2}) and leaf area index (4.19) in the treatments receiving 80 kg nitrogen ha-1 compared to 0 and 40 kg N ha-1 while remaining at par with 120 kg nitrogen ha^{-1} at 60 DAS. Significant improvement in the growth parameters of oats up to 80 kg ha^{-1} nitrogen was noted by Devi *et al.* (2010).

Significantly taller plants, a higher leaf area index, more number of tillers, and higher dry matter accumulation in fodder oat crop with the application of 150:70:40 kg ha^{-1} of N: P_2O_5:K_2O compared to lower fertility levels were reported by Jehangir *et al.* (2013) under temperate Kashmir conditions.

Significant response up to 45 kg S ha^{-1} with regard to plant height and LAI in aromatic rice was reported by Shivay *et al.* (2014).

In comparison to lower levels of 50, 75, and 100 kg N ha^{-1}, application of 125 kg N ha^{-1} resulted in considerably higher plant height (96 cm), leaf area index (3.58), and dry matter yield (104 q ha^{-1}) in oats Jah *et al.* (2015).

Application of 150 kg N in combination with 60 kg S secured significantly higher values for plant height, tillers m-2, dry weight (g plant $^{-1}$) over lower levels of nitrogen and sulphur (Singh *et al.,* 2021). Significant response to nitrogen @ 105 kg ha^{-1} with regard to overall growth parameters was reported by Islam et al. (2021).

Application of 120 kg N+ 60 kg S led to significantly taller plants (Dawar *et al*,2022)

2.1.2 Yield attributes and yield

Rana *et al.* (2019) reported that straw as well as seed yield increases with increment of 40 Kg N from 0-120 Kg N ha^{-1}.

Browne *et al*. (2003) noted high yield and hull ability in the Ireland region with the increase in nitrogen levels up to 190 kg ha^{-1} for resistant oat types. Number of panicles m^{-2} an important yield component was found responsive up to 120 kg ha^{-1}, however grain yield was responsive to nitrogen increment between 15 and 80 kg nitrogen ha^{-1} (May *et al.,* (2004). Hamill (2002) recorded an increase the grain yield with the supply of 80 kg nitrogen ha^{-1} on the soils containing 36 kg

NO_3- N ha^{-1} in upper 60 cm soil but with no further increment on the yield in the soils containing 100 kg NO_3- N ha^{-1} in upper 60 cm. Mohr *et al.* (2007) recorded optimum relative seed in oat with the plant available supply of 100 kg nitrogen ha^{-1}.

Luikham *et al*. (2012) found that in oats, applying 80 kg N ha^{-1} at 50 percent flowering stage led to taller plants (60.13 cm), tiller (79.83 m^{-1}), dry matter yield (55.78 q ha^{-1}), crude protein content (5.19 percent) when compared to control, but was comparable to 120 kg N ha^{-1}.

An improvement in the grain yield of wheat crop to the tone of 11% was registered in the with 60 kg S ha^{-1} by Podelesna (2013). In a study conducted at Poland, fertilization with sulphur in wheat lead to an increasing effect of NPK fertilizers to the tone of 3.57%, with no effect on 1000 grain weight (Klikocka *et al.*, 2016).

A two-year study conducted at Poland on sandy loam soil revealed that application of sulphur regardless of source and dose lead to an improvement in the grain yield of 7.8% compared to the sulphur omitted treatments Barczak *et al.* (2017).

In a study conducted at Peshawar in calcareous soils application of 150kg N+ 45 kg S recorded significantly higher test weight (45.6) against control (Shah *et al*. 2018). Islam *et al*. (2021) reported significant response of straw yield up to 105 kg N ha^{-1} however with regard to yield attributes like spike length, number of filled grains, 1000 grain weight and grain yield significant response was recorded only up to 90 kg N ha^{-1} in oats. Preplant application of sulphur @ 714 kg ha^{-1} in combination with 6.66% and 2.2 % foliar spray of urea and micronized sulphur in wheat crop led to the increase in grain, straw yield, protein content and plant height by 31.6, 26.1, 18.4 and 7.9 %.

Singh (2021) from Agra in a two-year study found that seed and straw yield of wheat crop increased significantly with the increase in nitrogen and sulphur up to 120 and 30 kg ha^{-1}, respectively. Dawar *et al,* (2022) recorded significant improvement in grains $spike^{-1}$, spikes m^{-2}, test weight, grain yield, nitrogen and sulphur content and uptake in wheat under co application of 120 kg N and 60 kg S.

2.1.3 Nutrient content and uptake

Increase in nitrogen, phosphorus and sulphur content in the wheat plant with the increase in the doses of nitrogen and sulphur up to 150 and 225 kg ha^{-1}, respectively was reported by Fageria *et al.* (2011) Nitrogen and sulphur application significantly increased the nitrogen content and uptake in seed and straw, however greater values of N content and uptake were witnessed with sulphur at elevated rate of nitrogen Salvagiotti *et al*. (2009). Devi *et al*. (2010) recorded significant effect of nitrogen application on the uptake of nitrogen both in seed, and straw of oat crop.

Addition of sulphur in combination with nitrogen to rice crop irrespective of dosage lead to elevation in the nitrogen content of grain with the percentage gain of 7% in the treatment fertilized with 105+40 kg N and S ha^{-1}, respectively in comparison to same rate of nitrogen (105 kg ha^{-1}) without sulphur (Habtegebrial *et al*., 2013).

Lafond *et al*. (2013) revealed that grain nitrogen concentration expressed a linear increasing trend with quadratic response however on contrary to nitrogen a decreased quadratic response of phosphorus concentration was displayed at elevated levels of nitrogen.

Malik et al. (2014) reported significant increase in nitrogen uptake of oat grain at 120 kg N ha^{-1}. On the contrary reported that application of 150 kg N ha^{-1} to oats resulted in significantly higher N uptake (38.33 kg ha^{-1}) than applying 120 kg N ha^{-1} (32.17 kg ha^{-1}) or 90 kg N ha^{-1} (25.76 kg ha^{-1}).

Application of sulphur @ 50 kg ha^{-1} in combination with 120 kg N ha^{-1} lead to an improvement in the concentration of nitrogen and sulphur by 1.3 and

1.5%, respectively against the control (Klikocka *et al.*, 2016). Verma *et al.* (2016) also reported significant increase in nutrient content and uptake of seed (17kgha^{-1}) and straw (12 kg ha^{-1}) of oat as influenced higher nitrogen levels of 120 kg ha^{-1} against lower level of 60 kg ha^{-1} nitrogen.

Pandey (2016) from Agra reported an increase in uptake of nitrogen and phosphorus in oat crop in the treatments receiving sulphur @ 20 kg ha^{-1} in combination with75% NPK.

Singh (2021) from two-year study reported a significant increase uptake of nitrogen, phosphorus, potassium and sulphur with increase in levels of nitrogen and sulphur levels up to 120 and 30 kg ha^{-1}, respectively.

With the increase in nitrogen rate from 80-120 kg N ha^{-1}, Kadam *et al.* (2022) registered significant increase in nitrogen, phosphorus and potassium content and uptake in both seed and straw of oat crop at 120 against 80 kg of N.

A significant increase in the content and uptake of nitrogen and sulphur nitrogen and sulphur in wheat under co- application of 120 kg N and 60 kg S was reported by Dawar et al., (2022).

2.1.4 Quality

Increment of 20 kg N ha^{-1} up to 120 kg brought significantly linear increase in grain protein content, but with respect to kernel plumpness a linear decrease with increase in nitrogen rate from 20 to 120 kg ha^{-1} was observed by Lafond et al., (2013). White and Finnan (2017) found that increasing N from 40 to 200 kg ha^{-1} had no effect on grain kernel content.

May *et al*. (2020) reported an increase in the groat percentage of oats peaking at 100 kg N ha^{-1}and falling sharply with the further increase in nitrogen from 120 to 140 kg ha^{-1}.

Increase in the nitrogen level up to 120 kg ha^{-1} engendered significant increase in crude protein content (Kumar *et al.,* 2001).

A substantial increase in crude protein content was recorded to a maximum level with the application of 240, 150 kg N ha^{-1} (Tiwana *et al.,* 2002; Kakol *et al.,* (2003).

May *et al.* (2004) noted a significant decline in the test weight and plump seed percentage with the increase in nitrogen supply. On the same lines statistically linear decrement in the seed quality with regard to kernel weight, test weight and plumpness of the seed with the increase in nitrogen level was recorded by Mohr *et al.* (2007). A sharp increase in the percentage of thin seeds (8%) with the progression of nitrogen rate was reported by May *et al*. (2020).

Singh (2021) reported a significant increase in the protein percent of the seed with the increase in nitrogen and sulphur levels up to 120 and 30 kg ha^{-1}, respectively.

2.1.5 Economics

Sharma *et al.* (2001) from Rajasthan stated an increase in net returns (Rs 21129) and benefit: cost ratio (3.24) with the elevation in N level from 40 to 80 kg ha^{-1}.

Patel *et al.* (2002) in their study reported that the most economical rate for oat seed production is 40 kg N ha^{-1} which gives higher seed yield of 21.84 q ha^{-1}.

Mishra and Mukherjee (2002) reported a maximum net return of up to 59.19 kg S ha^{-1}, respectively. In fodder oats high net returns and benefit cost ratio was registered at higher level of nitrogen (150 kg N ha^{-1}) by Kakol *et al*., (2003). Highest mean net returns and B:C ratio (1.82) were registered with the fodder oat crop fertilized with highest fertility level (150 +70+40 kg $N:P_2O_5:K_2O$) Jehangir *et al*. (2013) .

Chapter – 3

MATERIALS AND METHODS

A field experiment entitled **"Influence of nitrogen and sulphur on seed production of oat (*Avena Sativa* L.) under temperate conditions''** was conducted during *rabi* 2020, at experimental farm of the Division of Agronomy Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Faculty of Agriculture, Wadura. The details of the experiment and methods employed have been described in this chapter.

3.1 Experimental site

Research farm is located at 34°25′51 °N latitude and 74°24′10 E longitude at an altitude of 1580 meters above mean sea level.

3.2 Climate

The experimental site is in the temperate zone characterized by hot summers and very cold winters. The mean metrological data for cropping season recorded at metrological observatory Shalimar is presented in the Appendix-1 and depicted in the Fig. 1. The data shows that the mean maximum and minimum temperatures of 18.66 and 4.25°C were observed during the cropping season of 2020-21, respectively. Furthermore, the mean maximum relative humidity of 81.07% and mean minimum relative humidity of 56.12 % were noticed for the year 2020-21 respectively, whereas total precipitation (Rainfall)received during the cropping season of 2020-21 amounted to 989 mm.

3.3 Soil characteristics

Prior to the seeding of crop, composite soil samples from 0 to 15 cm soil depth were obtained from the experimental field and were subjected for physiochemical analysis. The results of the soil analysis presented in the Table 3.1 inferred that soil of the experimental site was medium in available nitrogen, phosphorus and potassium but low in sulphur with neutral in reaction.

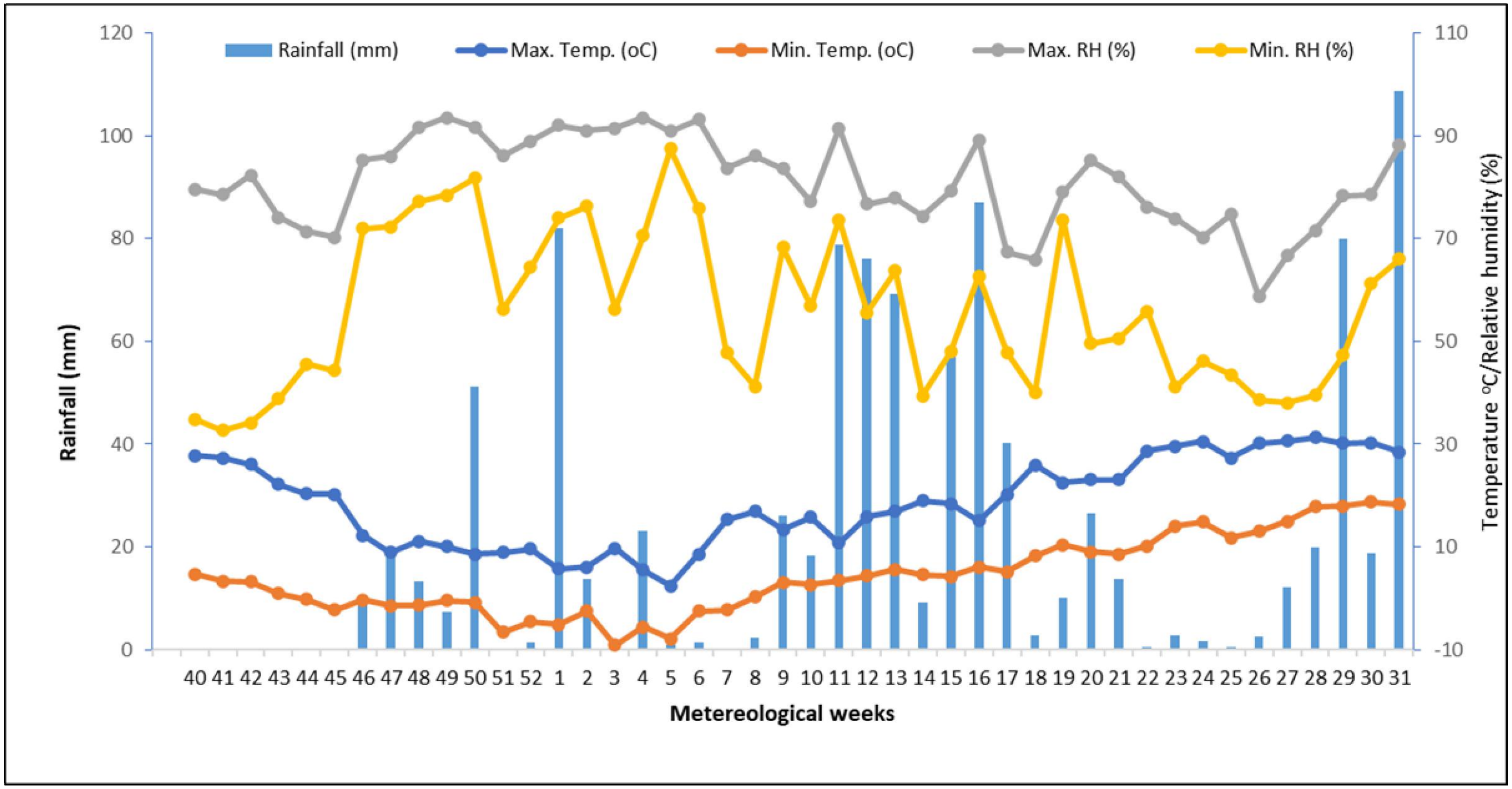


Fig 1: Mean meteorological data during 2020-21

Table 3.1: Chemical properties of soil (0-15 cm)

Particulars	Status	Ratings	References
Soil pH	6.50	**Neutral**	1:2.5 soil water suspensions with glass electrode pH meter (Jackson, 1973)
Electrical conductivity (dSm^{-1}) at 25°C	0.27	**Normal**	Solu-bridge conductivity meter (Jackson, 1973)
Organic carbon (%)	0.76	**Medium**	Rapid titration method (Walkley and Black 1934)
Available nitrogen (kg ha^{-1})	314	**Medium**	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	18.95	**Medium**	Extraction with 0.5 N $NaHCO_3$ at pH 8.5 (Olsen *et al.,* 1954)
Available potassium (kg ha^{-1})	205	**Medium**	Extraction with normal neutral ammonium acetate and flame photometric determination (Pratt 1982)
Available sulphur (kg ha^{-1})	14	**Low**	Turbidimetric method (Williams and Steinberg, 1969)

3.4 Cropping history

The cropping history of experimental field is given in Table 3.2.

Table 3.2: Cropping history of experimental field

Year	Kharif	Rabi
2016	Maize	Oats
2017	Maize	Oats
2018	Maize	Oats
2019	Maize	Oats
2020	Maize	Experimental Field (Oats)

3.5 Experimental details

The experiment consisting of seven treatments was laid out in to a randomize block design with three replications as per lay out plan presented in Fig

3.5.1 The details of the treatments under study are given below :

3.5.1.1 Treatments

F_1 : N_0S_0 N @ 0 kg ha^{-1} + S @ 0 kg ha^{-1}

F_2 : $N_{60}S_0$ N @ 60 kg ha^{-1} + S @ 0 kg ha^{-1}

F_3 : $N_{60}S_{20}$ N @ 60 kg ha^{-1} + S @ 20 kg ha^{-1}

F_4 : $N_{60}S_{40}$ N @ 60 kg ha^{-1} + S @ 40 kg ha^{-1}

F_5 : $N_{80}S_0$ N @ 80 kg ha^{-1} + S @ 0 kg ha^{-1}

F_6 : $N_{80}S_{20}$ N @ 80 kg ha^{-1} + S @ 20 kg ha^{-1}

F_7 : $N_{80}S_{40}$ N @ 80 kg ha^{-1} + S @ 40 kg ha^{-1}

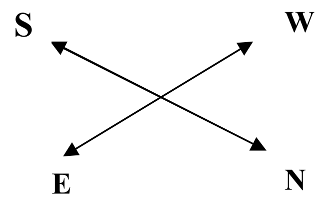
3.5.2 Other treatment details

Design	:	RCBD
Replications	:	03
Number of plots	:	21
Crop	:	Oat (Sabzar)
Spacing	:	20 cm
Net plot size	:	2×3 m = 6 m^2

3.6 Details of Field operations

The details of field operation are given below

Operations	Date	Details
Preparatory tillage	30.10.2020	One ploughing with tractor drawn plough, one harrowing and one planking
Layout	02.11.2020	The layout was done as per plan dividing the field into blocks and plots and each plot was leveled with spade.
Sowing	02.11.2020	As discussed in section 3.6.3
Basal application of nitrogen (1^{st})	02.11.2020	Half dose of nitrogen along with full dose of phosphorus, potassium, and sulfur were applied as Basel dose just before sowing as per treatments.
First top dressing of nitrogen	02-03-2021	Th oat crop was top dressed with nitrogen as per treatment
Second top dressing of nitrogen	15-04 -2021	
Hoeing and weeding	15.05.2021	By manual weeding
Harvesting	28.06.2021	The crop was harvested manually at physiological maturity.
Threshing	11.07.2021	Threshing was done manually.



MAIN ROAD				
R1	PATH	R2	PATH	R3
N_0S_O		$N8_OS_O$		$N_{60}S_{40}$
$N_{80}S_{40}$		$N_{60}S_{40}$		$N_{80}S_{20}$
$N_{60}S_{40}$		$N_{60}S_0$		$N_{80}S_{40}$
$N_{60}S_0$		$N_{80}S_0$		$N_{80}S_0$
$N_{80}S_{20}$		N_0S_0		$N_{60}S_{40}$
$N_{60}S_{40}$		$N_{60}S_{40}$		$N_{60}S_{20}$
$N_{80}S_0$		$N_{80}S_{40}$		$N_{60}S_0$

Fig .2: Layout plan

3.7 Description of variety

The variety ‘Sabzar’, a selection from UPO-212 amber coloured bold seeded with an average internode length of 30cm, plant height of 120-125 cm, high tillering ability, average flowering duration 175-185 days as in average forage yield of 300-400 q ha $^{-1}$ with a potential of producing fresh fodder in the range of 650-750 q ha^{-1}.

3.8 Land Preparations

Field was disc ploughed followed by one turn with rotavator to bring the soil to fine tilth. Replication borders, plot path, and irrigation channels were made manually. Proper leveling of plot was done before sowing of seeds.

3.8.1 Seed and sowing

Sowing operation was done by putting the seed manually in each furrow at a rate of 80 kg ha^{-1}, with a row spacing of 20 cm, Seeds were planted 2.5 cm deep and covered with a thin layer of soil.

3.8.2 Fertilizer Application

Inorganic fertilizers in the form of nitrogen and sulfur were applied as per the treatment in the form of urea and gypsum. Half of the nitrogen along with full dose of gypsum and recommended levels of phosphorous and potassium were applied as basal dose. The remaining half of nitrogen was applied in two equal splits during the first week of March and third week of April as per the treatment.

3.8.3 Intercultural operations

As the weeds remained suppressed during winter, only one hoeing-cum-weeding operation was performed during the first week of March.

3.8.4 Harvesting and threshing

Harvesting was done manually using sickle at physiological maturity. Prior to harvesting of net plot area, the border rows and penultimate rows from each plot were cut and maintained separately. An area of 6 m^2 (net plot) was harvested from each treatment to record seed and biological yields. The harvest was tied in bundles, labelled, and was subjected to sun drying for 3 days. After sun drying biological weight was recorded as per treatments and was subjected to manual threshing by beating the produce with the help of sticks.

3.9 Details of observation recorded

For growth parameters, the penultimate rows of each plot were selected for recording the growth parameter. Half-meter row lengths were marked with pegs in both rows. Without disturbing net plots, observations on various growth parameters were obtained from 5 tagged plants in half-meter row lengths, and the means were derived from this one-meter row length.

3.9.1 Growth characters

3.9.1.1 Plant height (cm)

The height of five tagged plants from each plot of one meter row length was averaged and measured in cm from the ground level to the base of the last fully opened leaf from first week of march (120 DAS) up to flowering at 15 days intervals. At harvest the height of the same representative was recorded from the ground level to the base of the panicle and values were then averaged to get the same.

3.9.1.2 Leaf area index

The leaf area index from each plot was recorded using canopy analyzer (Accu PAR LP-80) from 120 DAS at fifteen days interval up to harvest.

3.9.1.3 Tiller count

The number of tiller m^{-1} row length at marked spots in penultimate rows of each plot was counted at 15 days interval from first week of March upto harvest. The number of tillers were then converted into tiller m^{-2}.

3.9.1.4 Dry matter accumulation

Plant samples from 25 cm row length from the penultimate rows of each plot were harvested at 15 days interval from Ist week of March upto harvest. The samples were sun dried for two days before being oven dried to a consistent weight at 60°C. The weight was measured in grams before being converted to q ha^{-1}.

3.10 Yield attributes

3.10.1 Effective tillers

A steel made quadrant of one square meter area was used randomly before harvesting in the plot. Then the number of tillers bearing spikes in the quadrant were counted as the number of tillers m^{-2}.

3.10.2 Spike length

Five spikes were randomly chosen and measured from the base of the spike to the topmost grain. The length of each spike was measured in cm and then averaged to get the mean spike length.

3.10.3 Number of grains per spike

Five randomly chosen spikes were subjected to grain separation manually and then averaged to get the number of grains per spike

3.10.4 Test weight (1000 grain weight)

From the produce of each net plot well dried seed sample was drawn to measure the weight of 1000 grains (test weight) in grams using digital balance.

3.10.5 Seed yield

The seed yield from each net plot was thoroughly cleaned, sun dried and weighed in kg plot^{-1} and then converted in q ha^{-1}.

3.10.6 Straw yield

Straw from each net plot was computed by deducting grain yield from biological yield and expressed in kg $plot^{-1}$ and then converted into q ha^{-1}.

3.10.7 Harvest index (%)

This was calculated by using the following formula.

$$\text{Harvest index} = \frac{\text{Seed yield}}{\text{Biological Yield}} \times 100$$

3.11 Quality attributes

3.11.1 Plump seed and Thin seed (%)

Eighty-gram seed sample from each net plot was taken and subjected to sieving. The portion of the grain samples mass that remained on the top of 2.18× 19 mm screen was recorded as plump seed and the portion which fell through the same sieve was considered as thin seed. Then the figures of the measured quantity of the samples was taken in percentage.

3.11.2 Crude protein (%)

Crude protein content of ground seed sample was subjected to nitrogen content estimation which was then multiplied by the factor 6.25 for determining crude prude protein content.

3.11.3 Hulling (%)

100g seed sample was taken from each plot and was subjected to removal of hull manually the mass of hull less kernels were divided by the whole oat and was multiplied by 100 to get the hulling percentage.

3.12 Nutrient studies

3.12.1 Nutrient content in seed

At harvest, seed sample from each plot were collected and dried in an oven at 65°C until a consistent weight was recorded. Following that, the samples were ground to a fine powder in a stainless-steel grinder with a 60-mesh filter for the determination of nutrient content in seed. The following methodologies were used to estimate specific nutritional elements:

i. Nitrogen- Modified micro-k jeldhal method (Jackson, 1967)
ii. Phosphorus- Vandomolyb date phosphoric acid yellow color method (Jackson, 1973)
iii. Potassium- Di-acid mixture (900 ml conc. HNO_3^- and 400 ml of perchloric acid) determined by flame photometer method (Jackson, 1973)
iv. Sulphur- Barium sulphate turbidimetric method using spectrophotometer at 420 nm (Williams and Steinberg, 1969).

3.12.2 Nutrient uptake in seed

The uptake of each nutrient (NPK and S) by seeds was computed by multiplying the rest content of each nutrient with the seed yield and recorded in kg ha^{-1}.

3.13 Relative Economics

Relative economics of each treatment combination was computed as per the existing market rates. The cost of cultivation varied as per the variation the dosage of the treatment (Nitrogen and Sulphur). The net returns were computed by subtracting the cost of cultivation from gross returns. The benefit cost ratio (returns per rupee invested) was computed using the formula.

$$Benefit\ cost\ ratio = \frac{Net\ returns}{Total\ cost\ of\ cultivation}$$

3.14 Statistical Analysis

The data collected on various observation were analyzed statistically using the analysis of variance technique provided by Gomez and Gomez (1984). The significance level for the 'F' and 't' tests was set at $P \leq 0.05$. Wherever the 'F' test was significant, critical difference values were used to compare the treatment means. The software used for the analysis was OP stat.


TREATMENT DETAILS:
FERTILIZERS
DESIGN: RCBD

Plate 1: View of experimental field

Chapter-4

EXPERIMENTAL FINDINGS

An experiment entitled "Influence of nitrogen and sulphur on seed production of oat (*Avena sativa* L.) under temperate condition" was conducted at the Agronomy Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during 2020-21. The results on various characters studied during the course of investigation have been described, interpreted and presented in tables and suitable figures where ever necessary.

4.1 Growth characters

4.1.1 Plant height

Plant height is the primary indicator of vegetative growth potential of crop. The data pertaining to plant height of oat at various intervals of growth have been presented in Table 4.1. and graphically depicted through Fig.3 The results indicated that plant height was significantly influenced by the treatments. F_7 ($N_{80}S_{40}$) recorded significantly higher values for plant height from 150 DAS upto maturity though remaining at par with F_6 and F_5 from 150 DAS upto harvest and from 210 DAS to harvest, respectively. At maturity maximum plant height of 125.45was registered with F_7 ($N_{80}S_{40}$), remaining at par with F_6 ($N_{80}S_{20}$), and F_5($N_{80}S_0$) but significantly superior to the rest of the treatments.

Table 4.1: Periodic plant height (cm) of oat as influenced by nitrogen and sulphur combinations

Treatments	Days after sowing								
	120	**135**	**150**	**165**	**180**	**195**	**210**	**225**	**Harvest**
F1: N_0S_0	8.07	17.76	43.53	63.16	96.61	100.20	102.55	104.25	104.88
F2: $N_{60}S_0$	9.53	18.25	46.61	65.93	102.03	106.50	107.98	109.46	109.67
F3: $N_{60}S_{20}$	9.31	18.53	46.81	67.99	106.83	110.53	113.60	114.32	114.46
F4: $N_{60}S_{40}$	9.47	18.73	46.86	68.49	107.17	111.36	113.48	115.27	115.42
F5: $N_{80}S_0$	9.08	18.75	47.00	68.77	107.49	112.79	115.01	116.15	117. 70
F6: $N_{80}S_{20}$	9.99	18.92	49.43	72.70	113.78	118.03	120.04	121.97	123.12
F7: $N_{80}S_{40}$	9.97	18.45	51.23	73.48	115.15	119.50	122.37	124.60	125.45
CD ($p \leq 0.05$)	**0.64**	**0.50**	**3.07**	**4.24**	**7.58**	**6.47**	**8.40**	**9.20**	**9.82**
SE (m) ±	0.21	0.16	0.98	1.36	2.43	3.24	3.81	2.69	3.15

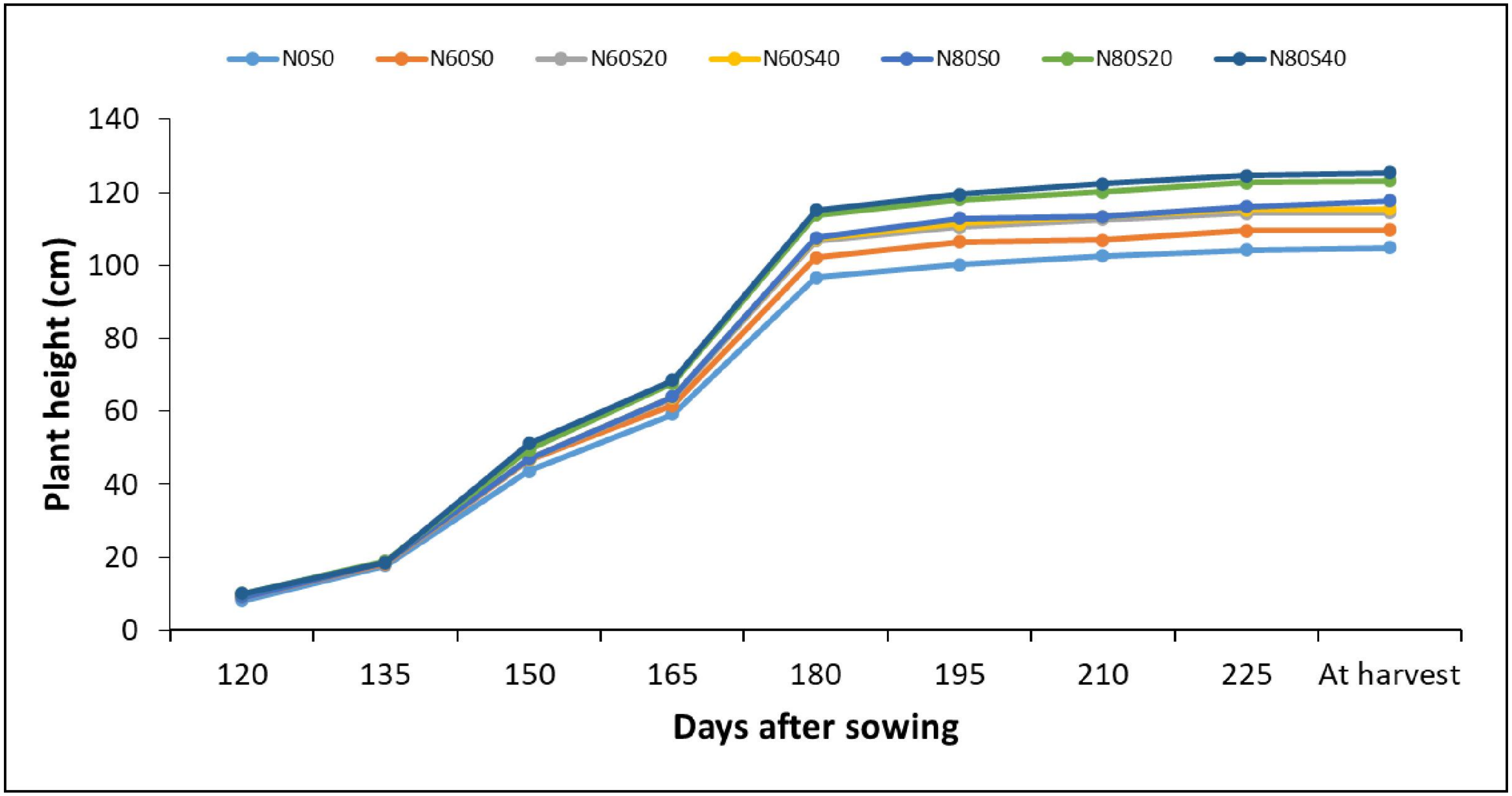


Fig. 3: Periodic plant height (cm) of Oats as influenced by nitrogen and sulphur combinations

4.1.2 Leaf area index (LAI)

Leaf area index is an important growth parameter which influence the growth and yield on account of being responsible for longevity and efficiency of photosynthetic activity of the plant. The data pertaining to leaf area index has been presented in the table 4.2 and graphically depicted in the Fig 4. From the data it is evident that irrespective of the treatments, LAI increased consistently from 120 DAS upto180 DAS and thereafter decreased up to harvest. Application of F_7:($N_{80}S_{40}$) registered significantly higher LAI at all growth intervals though remaining at par with F_6: ($N_{80}S_{20}$) from 150 DAS up to harvesting. Furthermore, significantly higher LAI of (5.17) was registered with F_7: ($N_{80}S_{40}$) at 180 DAS, thereafter a consistent decrease upto harvest was noticed.

4.1.3 Tiller Count

` The data on number of tillers m^{-2} at 15 days interval from first week of march (120 DAS) upto harvest has been presented in Tab 4.3 and graphically depicted in the Fig 5. The examination of the data reveled that application of the nitrogen @80kg/ha in combination with sulfur @40kg/ha recorded significantly higher number of tillers m^{-2} though remaining at par with F_6:($N_{80}S_{20}$) at all intervals of the growth, maximum number of tillers m^{-2} (354.14) was registered at 180 DAS. Tiller count increased consistently from 120 DAS to 180 DAS and there after a gradual decrease in tiller count to harvest was recorded.

4.1.4 Dry matter accumulation

The effect of various treatments on dry matter production at different intervals of crop growth have been presented in Tab 4.4 and graphically depicted in the Fig 6 .Results revealed that increase in nitrogen from 60 to 80kg ha^{-1} in combination with 40 kg ha^{-1} F_7:($N_{80}S_{40}$) brought significant increase in the dry matter accumulation at all growth intervals though being at par with higher level of nitrogen along with sulfur @20kg /ha F_6:($N_{80}S_{20}$) Moreover irrespective of the treatment, a rapid increase in dry matter production was registered from 150 to 180 DAS, thereafter an increase with decreasing rate up to harvest was recorded.

Table 4.2: Leaf area index (LAI) of Oat as influenced by nitrogen and sulphur combinations

Treatments	Days after sowing								
	120	**135**	**150**	**165**	**180**	**195**	**210**	**220**	**At harvest**
F1: N_0S_0	1.35	1.76	2.03	3.17	3.93	2.66	2.21	1.74	1.50
F2: $N_{60}S_0$	1.41	1.83	2.29	3.39	4.15	2.90	2.43	1.91	1.58
F3: $N_{60}S_{20}$	1.56	2.05	2.68	3.64	4.50	2.95	2.52	1.99	1.74
F4: $N_{60}S_{40}$	1.62	2.13	2.90	3.81	4.90	3.12	2.60	2.07	1.81
F5: $N_{80}S_0$	1.75	2.35	2.92	3.87	4.99	3.19	2.61	2.13	1.92
F6: $N_{80}S_{20}$	1.78	2.39	2.98	4.06	5.04	3.42	2.85	2.25	2.01
F7: $N_{80}S_{40}$	1.79	2.41	3.07	4.19	5.17	3.42	2.87	2.32	2.03
CD ($p \leq 0.05$)	**0.22**	**0.13**	**0.123**	**0.28**	**0.43**	**0.22**	**0.21**	**0.17**	**0.23**
SE (m) ±	0.07	0.11	0.039	0.13	0.14	0.12	0.10	0.06	0.075

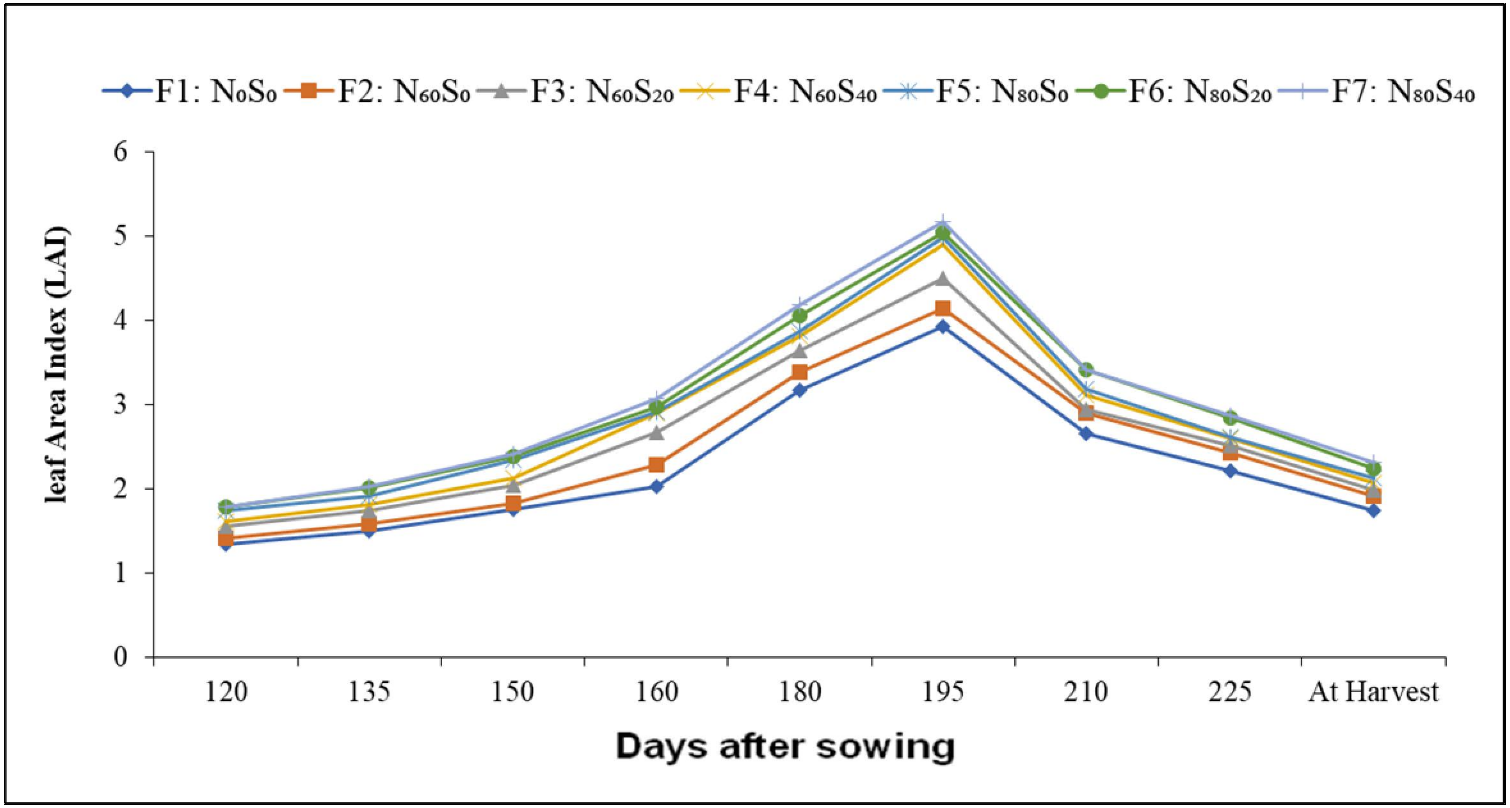


Fig. 4: Periodic leaf area index (LAI) of Oats as influenced by nitrogen and sulphur combinations

Table 4.3: Tiller count (No.m^{-2}) of oat as influenced by nitrogen and sulphur combinations

Treatments	Days after sowing								
	120	**135**	**150**	**165**	**180**	**195**	**210**	**225**	**At harvest**
F1: N_0S_0	135.66	190.33	235.22	244.60	235.00	216.70	204.00	198.73	197.86
F2: $N_{60}S_0$	145.80	202.76	283.54	300.84	285.90	274.62	262.35	255.85	253.84
F3: $N_{60}S_{20}$	151.00	209.43	291.97	315.94	298.97	287.80	280.82	266.89	265.31
F4: $N_{60}S_{40}$	151.35	212.13	295.20	326.70	312.82	301.11	286.96	276.51	271.92
F5: $N_{80}S_0$	156.68	219.66	305.72	339.54	320.51	305.26	290.82	278.35	272.94
F6: $N_{80}S_{20}$	162.35	234.76	327.19	363.26	348.00	330.03	315.19	303.71	299.68
F7: $N_{80}S_{40}$	166.22	240.36	332.24	371.97	354.14	339.50	325.98	315.20	310.07
CD ($P \leq 0.05$)	**11.14**	**15.22**	**14.28**	**23.48**	**22.89**	**14.57**	**17.78**	**21.49**	**25.14**
SE (m) ±	3.57	4.88	4.58	7.53	7.35	4.68	5.70	6.89	8.07

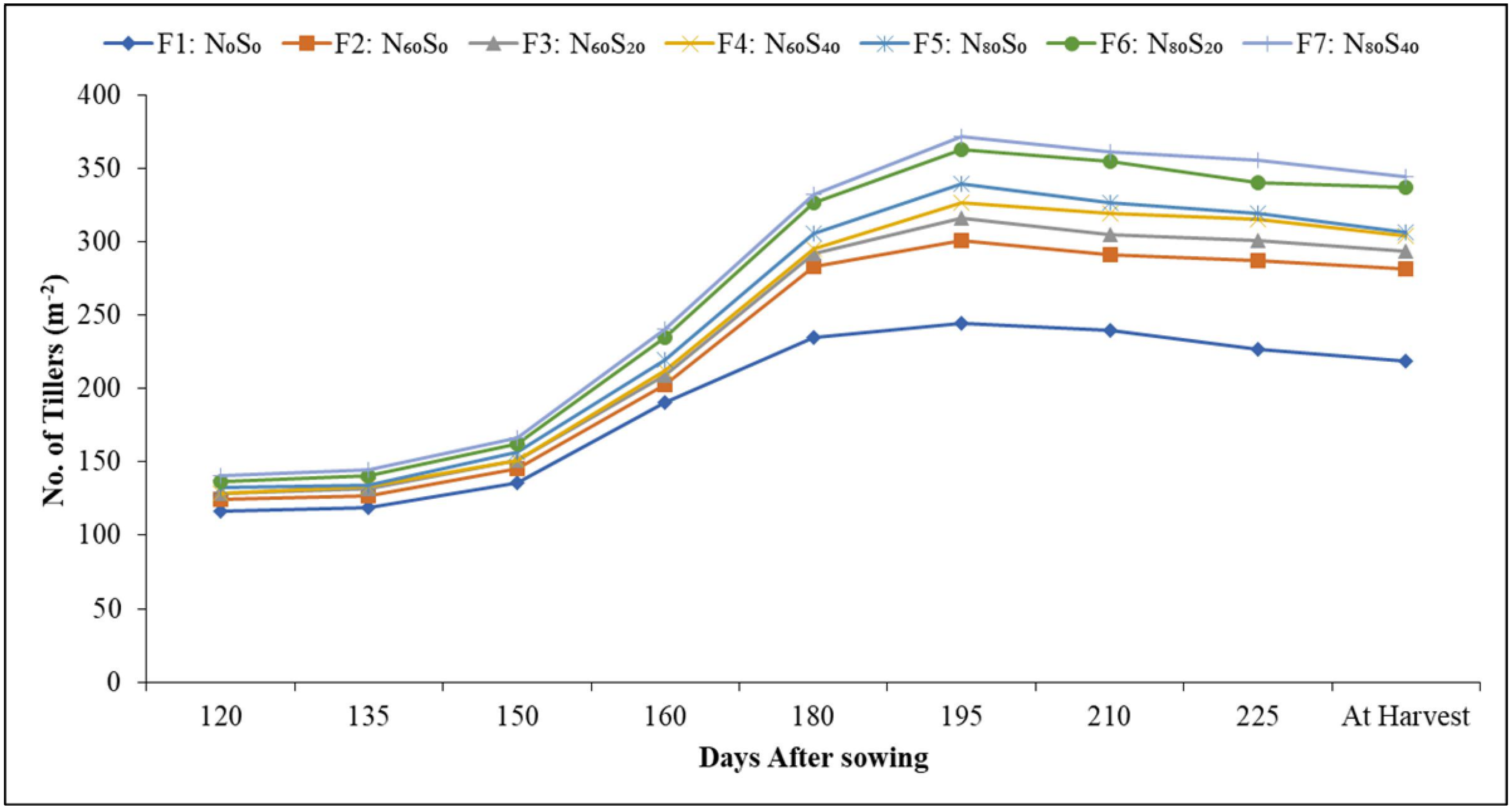


Fig. 5. Periodic tiller count (No.m^{-2}) of oats as influenced by nitrogen and sulphur combinations

Table 4.4: Periodic dry matter accumulation (q ha^{-1}) of Oat as influenced by nitrogen and sulphur combinations

Treatments	Days after sowing								
	120	**135**	**150**	**165**	**180**	**195**	**210**	**225**	**At Harvest**
F1: N_0S_0	8.07	12.40	17.12	30.74	42.80	43.54	43.76	43.85	43.86
F2: $N_{60}S_0$	9.05	14.20	21.09	35.80	53.33	56.91	57.43	57.59	57.64
F3: $N_{60}S_{20}$	9.31	15.80	22.17	36.75	55.06	58.49	59.04	59.27	59.37
F4: $N_{60}S_{40}$	9.45	16.50	24.57	37.92	56.88	59.82	60.46	60.70	60.82
F5: $N_{80}S_0$	9.09	17.30	24.33	37.69	54.98	58.66	59.30	59.78	59.81
F6: $N_{80}S_{20}$	9.99	18.00	25.53	38.39	57.89	62.07	62.65	62.78	62.87
F7: $N_{80}S_{40}$	9.97	17.50	27.24	39.35	58.75	64.80	65.41	65.70	65.82
CD ($P \leq 0.05$)	**0.64**	**1.29**	**1.75**	**1.41**	**2.20**	**3.62**	**4.70**	**3.51**	**4.35**
SE (m) ±	0.21	0.41	0.56	0.36	0.71	1.16	1.16	1.28	1.39

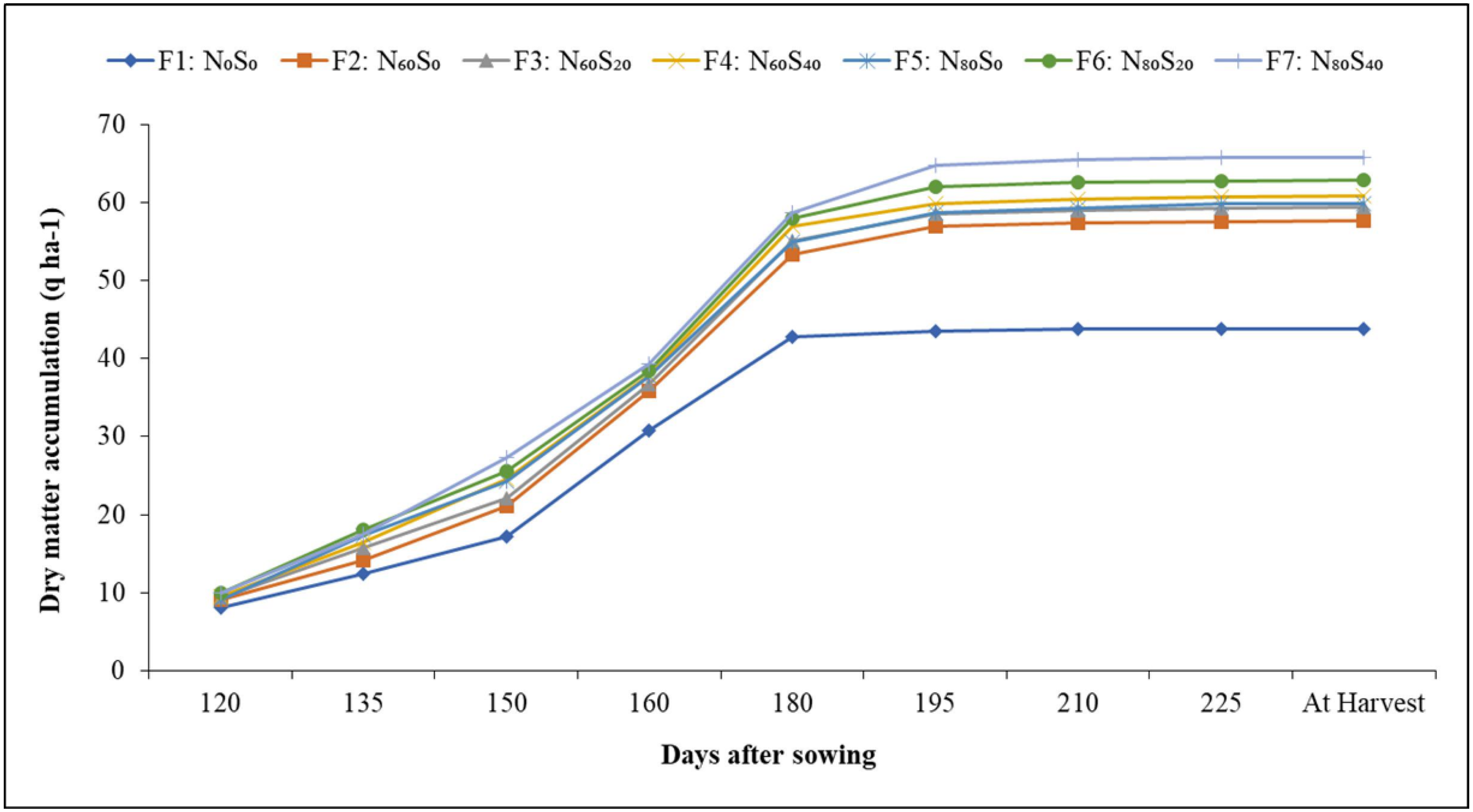


Fig. 6: Periodic dry matter accumulation (q ha^{-1}) of oats as influenced by nitrogen and sulphur combinations

4.2 Yield Attributes

4.2.1 Effective tillers (m^{-2})

The data pertaining to the effect of different treatments on number of effective tillers has been presented in Table 4.5. The data revealed that number of effective tillers differed significantly among the treatments, with the maximum number of effective tillers m^{-2} (291.30) recorded with. F_7:($N_{80}S_{40}$) However, it was found to remain statically at par with F_6:($N_{80}S_{20}$) while the lowest number of effective tillers 190.29 was recorded with control F_1:(N_0S_0)

4.2.2 Spike length (cm)

A perusal of the data presented in Table 4.5 indicated that spike length was significantly affected by nitrogen and sulphur treatments. Spike length was found to increase with increase in level of nitrogen and Sulphur. The longest spikes(35.24 cm) were recorded in treatment receiving higher level of nitrogen supplemented with 40 kg of sulphur followed by F_6:($N_{80}S_{20}$) with 35.08 cm length and the shortest spikes were recorded in control F_1:(N_0S_0).

4.2.3 Number of grains per spike

The data on number of grains per spike have been given in Table 4.5. The same has also been presented graphically in Fig 4. From the observations recorded during experiment it is evident that the treatment receiving $N_{80}S_{20}$ produced significantly higher number of grains per spike (40.92) followed by F_7:($N_{80}S_{20}$) with the superiority of (45.31) and (43.11) % respectively, over control F_1:(N_0S_0)

4.2.4 Test weight (1000 grain weight)

Test weight showed significant response to the application of nitrogen in combination with higher level of sulphur. Significantly higher test weight of (34.76g) was recorded with higher level of nitrogen supplemented with higher level of sulphur F_7:($N_{80}S_{20}$) though remaining at par with F_6:($N_{80}S_{20}$), F_5($N_{80}S_0$) and F_4($N_{60}S_{40}$).

Table 4. 5: Yield attributes and yield of oat as influenced by nitrogen and sulphur combinations

Treatments	Effective tillers(m^{-2})	Spike length (cm)	No. of grains $Spike^{-1}$	Test wt.(g)	Seed Yield (q/ha)	Straw Yield(q/ha)	Harvest Index (%)
F1: N_0S_0	190.29	25.19	28.16	31.04	16.92	46.77	26.58
F2: $N_{60}S_0$	235.38	31.65	35.24	31.52	22.013	60.67	26.65
F3: $N_{60}S_{20}$	250.47	31.91	35.80	32.42	25.32	66.69	27.67
F4: $N_{60}S_{40}$	261.36	32.96	38.97	32.98	27.54	70.71	28.03
F5: $N_{80}S_0$	257.59	33.25	38.95	33.69	27.43	70.78	27.92
F6: $N_{80}S_{20}$	287.59	35.08	40.92	34.16	28.97	78.28	27.16
F7: $N_{80}S_{40}$	291.39	35.24	40.30	34.76	30.43	79.02	27.87
CD ($P \leq 0.05$)	**20.61**	**1.88**	**1.19**	**1.83**	**2.79**	**10.89**	**NS**
SE (m) ±	6.62	0.60	0.38	0.59	1.27	3.49	1.40

4.2.5 Seed yield (q ha^{-1})

The data on the seed yield of oat has been presented in the table 4.5 and depicted graphically in the Fig. 7. From the results it is evidenced that seed yield was significantly influenced by nitrogen and sulphur combinations at various levels. Application of F_7:($N_{80}S_{20}$) produced significantly higher seed yield of 30.43 q/ha. with the yield superiority of 10.93 and 5.03 % over sole application of nitrogen @80kg/ha F_5:($N_{80}S_0$) and F_6:($N_{80}S_{20}$), respectively.

4.2.6 Straw yield (q ha^{-1})

The effect of different treatments on straw yield has been presented in Table 4.5 same has also been represented graphically in the Fig. 7 An examination of data revealed that combined application of the nitrogen and sulfur F_7:(N_{80}:S_{40}) at par with F_6:(N_{80}:S_{20}), F_5:(N_{80}:S_0), and F_4:(N_{60}:S_{40}), produced significantly higher straw yield of (79.02) q/ha.

4.2.7 Harvest index

A perusal of the data presented in the Table 4.5 indicated that harvest index which indicates the partitioning of the photosynthates between sink and source was not significantly affected by combined application of various nitrogen and sulphur levels. Further the higher values of HI were registered with F4 though closely followed by F_6:($N_{80}S_{20}$) and F_7:($N_{80}S_{40}$) and the lowest HI was registered with control (F_0S_0).

4.3 Quality attributes

4.3.1 Plump seed

The plum seed percent influenced by various treatments is presented in Table 4.6. The perusal of data indicated the plump seed percentage did not vary significantly among the treatments receiving nitrogen supplemented with sulphur irrespective of the dosage. However, F_1:(N_0S_0) though remaining at par with F_2:($N_{60}S_0$), registered significantly lower percentage of plump seed.

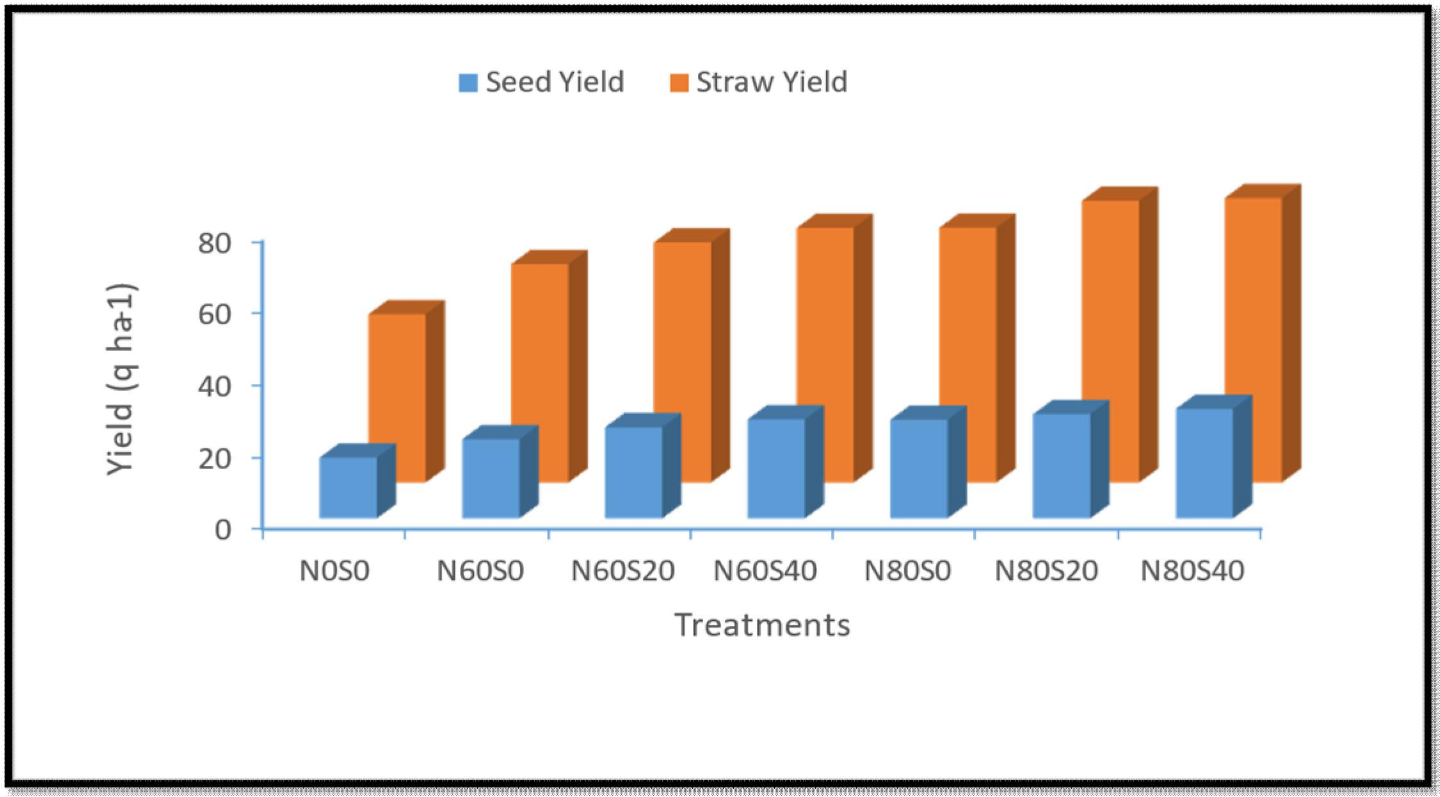


Fig. 7: Seed and straw yield of oats as influenced by nitrogen and sulphur attributes

4.3.2 Thin seed

The effect of different treatments on percentage of thin seed has been presented in Table 4.6. Thin percentage of the seeds was significantly affected by the application of different treatments. Significantly higher percentage of thin seeds was recorded with $F_1:(N_0S_0)$. Furthermore, among the treatments comprising of variable rate of nitrogen supplement with higher levels of sulfur a decrease in the percentage of thin seeds was recorded.

4.3.3 Crude protein

A perusal of the data presented in Table 4.6 indicated that crude protein percentage of seeds was significantly influenced by nitrogen and sulphur combinations at variable rates. Significantly higher crude protein percentage of 10.24 was recorded with $F_7:(N_{80}S_{40})$, though being at par with $F_6:(N_{80}S_{20})$ but significantly superior to other treatments.

4.3.4 Hulling percent

The data pertaining to the effect of different nitrogen and sulfur combination has been presented in the Table 4.6. It was found that complementing the nitrogen irrespective of dose with sulfur improved the hulling percentage of oat. Significantly higher value of hulling percentage was recorded with 80 kg of nitrogen in combination with 40kg of sulphur, though being at par with $F_6:(N_{80}S_{20})$.

Table 4.6: Quality of the oat grain as influenced by nitrogen and Sulphur combinations

Treatments	Plump seeds (%)	Thin seeds (%)	Crude Protein (%)	Hulling (%)
F1: N_0S_0	89.7	5.41	7.97	92.57
F2: $N_{60}S_0$	90.7	3.91	9.06	95.66
F3: $N_{60}S_{20}$	92.5	3.68	9.45	95.78
F4: $N_{60}S_{40}$	92.4	3.41	9.50	95.81
F5: $N_{80}S_0$	91.3	4.51	9.78	95.81
F6: $N_{80}S_{20}$	91.9	3.67	10.05	95.83
F7: $N_{80}S_{40}$	92.0	3.20	10.24	95.85
CD ($P \leq 0.05$)	**0.66**	**0.21**	**0.27**	**0.023**
SE (m)±	0.21	0.07	0.12	0.008

4.4 Nutrient studies

4.4.1 Nutrient content in seed

The data in the nutrient content has been presented in the Table 4.7

4.4.1.1 Nitrogen content

The data revealed that complementing the nitrogen with sulfur improved the nitrogen content in grain irrespective of the level of nitrogen or sulfur. However, significantly higher nitrogen content was recorded with higher level of nitrogen in combination of sulfur F_7:($N_{80}S_{40}$) though remaining statically at par with F_6:(N_{80} S_{20}) but remained significant superior to the rest of the treatments.

4.4.1.2 Phosphorus content

The data pertaining to the effect of different treatments on phosphorus content reflected that the treatments had significant impact on phosphorous content of the oat grain. Significantly higher value of phosphorus content (0.42%) was registered with F_7:($N_{80}S_{40}$) but remained at par with F_6:(N_{80} S_{20}) and the lowest phosphorus content was were recorded with F_1:(N_0 S_0).

4.4.1.3 Potassium content

The result infers that potassium content of the grain was significantly influenced by nitrogen and sulphur combinations. Addition of the sulfur to each level of nitrogen improved the potassium content in the oat grain. Significantly higher values of potassium content were registered with F_7:($N_{80}S_{40}$) and F_6:(N_{80} S_{20}) though found at par with sole application of nitrogen at higher level F_5:(N_{80} S_0) and lower level of nitrogen complemented with higher rate of sulphur F_4:($N_{60}S_{40}$).

4.4.1.4 Sulphur Content

The results revealed that complementing the nitrogen application with sulfur improved the sulphur content of grain. Significantly highest sulfur content (0.25%) was registered with F_7:($N_{80}S_{40}$) and the lowest sulphur content was recorded with F_1:(N_0S_0).

Table 4.7: Nutrient content of oat grain as influenced by nitrogen and sulphur combinations

Nutrient content in grain (%)				
Treatments	**Nitrogen**	**Phosphorus**	**Potassium**	**Sulphur (%)**
F1: N_0S_0	1.27	0.29	0.64	0.130
F2: $N_{60}S_0$	1.45	0.30	0.73	0.14
F3: $N_{60}S_{20}$	1.51	0.33	0.77	0.23
F4: $N_{60}S_{40}$	1.52	0.38	0.78	0.23
F5: $N_{80}S_0$	1.56	0.39	0.79	0.14
F6: $N_{80}S_{20}$	1.61	0.40	0.81	0.22
F7: $N_{80}S_{40}$	1.64	0.42	0.81	0.25
CD (P≤0.05)	**0.04**	**0.02**	**0.03**	**0.02**
SE (m)±	0.14	0.01	0.01	0.01

4.4.2 Nutrient uptake in seed

The data pertaining to the effect of combined application of nitrogen and sulfur at variable rate is presented in the Table 4.8 and depicted graphically in the Fig4.8

4.4.2.1 Nitrogen Uptake

The result indicates F_7:($N_{80}S_{40}$) at par with F_6:($N_{80}S_{20}$) recorded significantly higher values of nitrogen uptake than rest of the treatments and the lowest values for nitrogen uptake were registered with F_1:(N_0S_0)

4.4.2.2 Phosphorus uptake

The data pertaining to the effect of different treatments on phosphorus uptake in the plants have been presented in Table 4.8. An examination of the data indicated that application of combination of nitrogen and sulfur and its increase in rate invariably increased phosphorus uptake. Furthermore, significantly higher phosphorus uptake was observed in treatment F_7:($N_{80}S_{40}$) found at par with F_6:($N_{80}S_{20}$) which in turn was observed to remain at par with F_5:($N_{80}S_0$) and F_4:($N_{60}S_{40}$) but significantly superior to rest of the treatments.

4.4.2.3 Potassium uptake

A perusal of the data presented in Table 4.8 indicated that combined application of nitrogen and sulfur at variable rates significantly influenced the potassium uptake in oat**.** From the data it is evident that application of nitrogen and sulphur at higher rate F_7:($N_{80}S_{40}$) though being at par with F_6:($N_{80}S_{20}$) recorded significantly higher uptake of potassium and the significantly lowest values of potassium uptake was recorded with no application of nitrogen and sulphur (F_1:N_0S_0).

4.4.2.4 Sulphur uptake

A perusal of the data presented in Table 4.8 indicated that the increment in sulfur dosage at each level of nitrogen resulted in corresponding increase in sulfur uptake though the percentage improvement in sulfur uptake was comparatively lower at higher level of nitrogen. Furthermore, F_7:($N_{80}S_{40}$) resulted in significantly higher values of sulfur uptake closely followed by F_6:($N_{80}S_{20}$).

4.5 Relative Economics

The result presented in Table 4.9 revealed that the treatment combination F_7:($N_{80}S_{40}$) recorded the highest net return of ₹ 125493 $ha^{-1}$and B:C ratio 1.72 the said treatment combination also recorded the highest gross return ₹ 198369**.**The lowest gross return of ₹ 110875 ha^{-1}, net return of ₹ 40283 $ha^{-1}$and benefit cost ratio of ₹ 0.57 were registered with the treatment combination F_1(N_0S_0).

Table 4. 8: Nutrient uptake of oat grain as influenced by nitrogen and sulphur combinations

Nutrient uptake (Kg ha^{-1})				
Treatments	**Nitrogen**	**Phosphorus**	**Potassium**	**Sulphur**
F1: N_0S_0	21.55	4.85	10.87	2.20
F2: $N_{60}S_0$	31.91	6.53	15.98	3.01
F3: $N_{60}S_{20}$	38.29	8.45	19.44	5.86
F4: $N_{60}S_{40}$	41.87	10.56	21.46	6.42
F5: $N_{80}S_0$	42.95	10.77	21.75	3.87
F6: $N_{80}S_{20}$	46.62	11.65	23.40	6.37
F7: $N_{80}S_{40}$	49.85	12.79	24.68	7.49
CD ($P \leq 0.05$)	**4.50**	**1.18**	**2.23**	**0.82**
SE (m)±	1.45	0.53	0.71	0.26

Table 4.9: Relative economics of oats seed crop as influenced by different treatment combinations.

Treatment	Cost of cultivation	Gross returns	Net returns	B: C
F1: N_0S_0	70592	110875	40283	0.57
F2: $N_{60}S_0$	71278	144205	72928	1.02
F3: $N_{60}S_{20}$	71944	165264	93320	1.30
F4: $N_{60}S_{40}$	72610	179367	106758	1.47
F5: $N_{80}S_0$	71544	178758	107214	1.50
F6: $N_{80}S_{20}$	72210	189505	117295	1.62
F7: $N_{80}S_{40}$	72876	198369	125493	1.72

- **Input cost**: Cost of N = Rs 13.2 kg^{-1}
- Cost of P_2O_5 = 50.17kg^{-1}
- Cost of K_2O = 28.3kg^{-1}
- Cost of Sulphur = Rs 33.3 kg^{-1}
- Cost Of labour = Rs 400 day^{-1}
- Tractorization cost = Rs 10,000 ha^{-1}
- **Output cost:** Cost of Seed =Rs 60/kg
- Cost of straw = Rs200 q^{-1}

Chapter-5

DISCUSSION

The present investigation pertains to **"Influence of Nitrogen and Sulphur on Seed Production of Oat (*Avena sativa* L.) under Temperate Condition."** The results described in the preceding chapter have been discussed here with suitable reasoning establishing cause and effect relationship in the light of available evidence.

5.1 Growth Characters

The result inferred that there was significant increase in the plant height with the increase in nitrogen levels complemented with sulphur at all growth intervals. Significantly taller plants were observed with higher levels of nitrogen and sulphur F_7:($N_{80}S_{40}$) in combinations. This increase in the plant height can be attributed to greater availability of nutrients particularly of nitrogen and sulphur. As nitrogen is an integral part of protein and helps in maintaining higher auxin concentration which might have resulted in taller plants. Further, sulphur is involved in the synthesis of sulphur containing amino acids and several enzymatic processes, favoring greater meristematic activities, and improved apical growth resulting in higher plant height. These results are in close agreement with the findings of Singh (2021). Moreover, the prolonged supply of nitrogen and sulphur might have favored the internode elongation, thus favoring the plant to gain the maximum length. Similar finding has been reported by Shah *et al*. (2018); Amanullah *et al*. (2013); Choi *et al.* (2016); Ross *et al.* (2005); Keshyap *et al.* (2017); and Javed *et al.* (2018).

The results indicated that the leaf area index differed significantly in response to varied treatment combinations of nitrogen and sulphur. Leaf area index increased consistently upto 180 DAS and thereafter decreased till maturity (Table 4.2). The study revealed that LAI was found significantly higher in treatment F_7($N_{80}S_{40}$) though being statically at par with F_6:($N_{80}S_{40}$) at all growth intervals. This increase in LAI at higher levels of nitrogen and sulphur level can be attributed to the favorable influence of nitrogen and sulphur on the physiological processes of the crop leading to overall improvement of the crop growth in terms of more number and retention of leaves for longer period of growth. Our results are in corroboration with the findings of Jehangir *et al.* (2013) who reported higher values of LAI at higher fertility level in fodder oats.

Significantly higher dry matter accumulation was recorded with F_7:($N_{80}S_{40}$) but was found at par with F_6:($N_{80}S_{40}$) all growth intervals except at 120 and 135 DAS where it was found at par with F_6, F_5, F_4, and F_5 respectively. The reason for higher dry matter accumulation at higher level of nitrogen and sulphur can be attributed to larger photosynthetic area with prolonged supply of photosynthates accounting for greater crop growth in terms of LAI and plant height leading to enhanced dry matter production. Similar results of higher dry matter under combined application of nitrogen and sulphur in maize have also been reported by Amanullah *et al.* (2013) also have observed higher LAI values for higher dry matter production at different intervals of crop growth owing to better light interception.

Tillers are important growth attribute in crops for determining the overall yield of a crop. Tiller count was found to be significantly affected by the different treatments. The number of tiller m^{-2} increased significantly from 120 to 165 DAS and thereafter decreased drastically till maturity (Table 4.3). This decrease in number of tillers m^{-2} can be attributed to senescence of lower tillers due to shading resulting in tiller death. There result is in agreement with Jehangir *et al.,* (2013). Maximum tiller count was observed in treatment $F_{7:}$($N_{80}S_{40}$) at all the intervals except at 180 DAS where it was found at par with $F_{6:}$($N_{80}S_{20}$). The increase in in the tiller's numbers at higher levels of nitrogen in combinations with S can be attributed to the synergetic effect of sulphur and nitrogen. Since nitrogen and sulphur promotes the production of chlorophyll which might have enhanced the process of photosynthesis leading to more translocation of assimilates to the sink and thereby increasing tillers count as also reported by the finding of Habtgeriaal *at el*. (2013) Malhai (2004) and shah *at el.* (2018). have also reported higher tiller number at higher levels of nitrogen and sulphur.

5.2 Yield Attributes

The results revealed that yield attributing characters like effective tillers m^{-2}, spike length, no of grain per spike and test weight were significantly influenced by different treatments. Application of F_7:($N_{80}S_{40}$) in combination recorded significantly higher values for all the yield attribute but was statistically at par with F6:($N_{80}S_{20}$). The reflection of higher values for the yield attributes of oat in F_7:($N_{80}S_{40}$) can be attributed to improved growth characters and better partitioning of Photosynthates from source to sink under sufficient and prolonged supply of nitrogen and sulphur (These results are supported by the findings of Shah *at el.* (2018) and Singh (2021).

YIELD

Seed yield

The results revealed that highest grain and straw yield (30.43 and 79.02 q ha^{-1}) was recorded in treatment F_7:($N_{80}S_{40}$) but was statistically at par with F_6:($N_{80}S_{20}$) which recorded grain and straw yield of (28.97) and (78.28) q ha^{-1}, respectively (Table 7). It was found that both seed and straw yield increased significantly due to the combined effect of nitrogen and sulphur particularly at higher doses. This significant improvement in the yield can be attributed to the fact that application of nitrogen and sulphur leads to improved photosynthetic rate in crop plants which in turn increases their dry matter and grain yield. Furthermore, significant improvement in the growth and yield parameter's in F_7:($N_{80}S_{40}$) might be the reason for higher yield. These results corroborate the findings of Habteggebrial *et al.* **(**2013). Moreover, the combined effect of nitrogen and sulphur nutrient might had the synergetic effect on growth and yield of oats resulting in better translocation of photosynthates from source to sink.

5.3 Quality Attributes

The use of nitrogen and sulphur at variable rates directly influenced the quality parameters of oats such as plump seed, thin seed, crude protein and hulling percentage. The maximum plump seed percentage (92.5 %) was observed in F_3 ($N_{60}S_{20}$) closely followed by F_4 ($N_{60}S_{40}$) and F_7 ($N_{80}S_{40}$) with the percentage of 92.4 and 92 %, respectively, whereas the lowest plump seed % was observed in control treatment. Furthermore, with increment in the dosage of sulphur with nitrogen dosage of 60 kg ha^{-1}, plumpness of the seed increased as has been earlier reported by May *et al*. (2004) and Lafond (2013). The highest percentage of thin seed was observed in in F1 (control) which can be attributed to poor availability of nutrients to the crop. Treatment with F_7:($N_{80}S_{40}$) recorded the highest crude protein (10.24 %) and hulling percentage (95.85%). The higher crude protein content could be attributed to the additive effect of sulphur and nitrogen, which might had improved the utilization of nitrogen and sulphur effectively, thereby enhanced the crude protein content of grain. Similar result of increase in the crude protein with the application of nitrogen and sulphur. The higher hulling percentage might be ascribed to effective translocation of assimilates to hull under higher levels of nitrogen and sulphur. Similar findings are in agreement with Palliwal *et al*. (1992) who reported an increase in hulling percentage with the increment in nitrogen and sulphur alone or in combinations, respectively.

5.4 Nutrient content and uptake

The study indicated that combined application of the nitrogen and sulphur at variable rate had significant influence on the nutrient content in oat grain. Complimenting the sulfur with nitrogen irrespective of dosage had improved the concentration of major nutrients like N, P, K and S, respectively. Significantly higher values of nitrogen, phosphorus, potassium, and sulphur were registered with F_7:($N_{80}S_{40}$) though reaming at par with F_6: ($N_{80}S_{20}$). The improvement in N, P, K and S content of the grains can be attributed to sulphur mediated uptake of minerals nutrients. Furthermore, sulphur improves efficiency of nitrogen in the plants (which might have influenced the absorption of other nutrients like N, P, K and S resulting in their higher content. Similar results have been also reported by Shah *at el.* (2018). Earlier Klilockacha *et al*. (2016) also found improvement in nitrogen and sulphur content of grain with a combined application of nitrogen and sulphur over its sole application in wheat. It was found that the application of nitrogen and sulphur at various levels caused a significant influence on the nutrient uptake in oat grain. Application of F_7:($N_{80}S_{40}$) produced significantly higher values though reaming at par with F_6:($N_{80}S_{20}$) but significantly superior to rest of the treatments. This might be due to the fact that higher dry matter yield along with higher concentration of nutrients registered with the same treatment have resulted in higher uptake of the nutrients. Earlier Shah *at el*. (2018) attributed the improvement in the uptake and assimilations of nutrients to the synergistic effect of nitrogen and sulphur.

5.5 Relative Economics

The result presented in table 4.9 revealed that the treatment combination F_7:($N_{80}S_{40}$) recorded the highest gross returns (198369 □ ha^{-1}), net return of (125493 □ ha^{-1}) and B.C ratio (1.72) as compared to other treatments, The higher returns and B:C ratio in F_7:($N_{80}S_{40}$) could be attributed to the fact that it recorded significantly higher grain and straw yield as compared to other treatment's making it economically significant.

Chapter -6

SUMMARY AND CONCLUSION

The present **investigation "Influence of Nitrogen and Sulphur on Seed Production of Oat (Avena *sativa* L.) under Temperate Condition."** was conducted at the Experimental Farm of Division of Agronomy at Faculty of Agriculture Wadura of Sher-e-Kashmir University of Agriculture Sciences and Technology in Kashmir. The observations for various parameters, were recorded as per the objectives and aims of the present investigation.

6.1 Growth Characters

- The growth in plant height followed a linear pattern up to harvest stage. Combined application of application of nitrogen and sulphur in treatment F_7 ($N_{80}S_{40}$) recorded highest plant height as compared to other treatment.
- The application of nitrogen and sulphur in treatment F_7 ($N_{80}S_{40}$) observed maximum leaf area index (LAI).
- Different combination of treatments application increased the number of tillers per meter row length till 165 DAS and gradual decline after 165 DAS. Treatment F_7 ($N_{80}S_{40}$) recorded highest number of tillers m^{-2} as compared to other treatments,
- Highest dry matter accumulation was observed with treatment F_7:($N_{80}S_{40}$) whereas the lowest dry matter accumulation was recorded in control treatment.

6.2 Yield Attributes

- Different combination of treatments increased the effective tillers significantly. The highest number of effective tillers were recorded in F_7:($N_{80}S_{40}$) followed by F_6:(N_{80} S_{20}).
- The application of nitrogen and sulphur in treatment F_7 ($N_{80}S_{40}$) recorded highest value for spike length, number of grains per spike and test weight.

- The application of higher dose of nitrogen and sulphur in treatment F_7:($N_{80}S_{40}$) recorded highest seed and straw yield followed by F_6:($N_{80}S_{20}$). The highest harvest index was observed in treatment F_7:($N_{80}S_{40}$) followed by F_6:($N_{80}S_{20}$) and F_5:($N_{80}S_0$).

6.3 Quality Attributes

- The application of treatments showed variable results on the percentage of plump seed. The maximum plump seed % was recorded in treatment F_3 ($N_{60}S2_0$) followed by F_4 ($N_{60}S2_{40}$) whereas the lowest plump seed % was observed in control treatment.
- Highest percent of thin seed was observed in treatment F_1:(N_0S_0) followed by F_5:($N_{80}S_0$). The highest crude protein was observed in treatment F_7:($N_{80}S_{40}$) followed by F_6:($N_{80}S_{20}$).
- Different treatments had significant influenced on the hulling percent of oat. The maximum hulling percent was observed with treatment F_7:($N_{80}S_{40}$) followed by F_6:($N_{80}S_{20}$).

6.4. Nutrient Studies

- There was corresponding increase in the nitrogen, phosphorus, potassium, and sulphur content of the grain with increased dosage of nitrogen and sulphur. The highest nutrient content (N, P, K and S) was observed in treatment F_7:($N_{80}S_{40}$) followed by F_6:($N_{80}S_{20}$) and F_5:($N_{80}S_0$).
- The application of higher levels of nitrogen and sulphur resulted in greater uptake of nitrogen, phosphorus, potassium and sulphur. The maximum uptake of N, P, K and S was observed in treatment F_7:($N_{80}S_{40}$) followed by F6:($N_{80}S_{20}$) and F_5:($N_{80}S_0$).

CONCLUSIONS

The results of this experiment lead to the conclusion that combined application of nitrogen and sulphur at higher rates registered improved growth, yield, and quality of crop for seed production in oats. Application of nitrogen and sulphur in treatment F_7($N_{80}S_{40}$) observed significantly higher values and for all the growth yield and quality attributes with higher BC ratio of 1.72. Therefore, combined application of nitrogen and sulphur with higher levels F_7 ($N_{80}S_{40}$) should be followed for effective seed production of oats under temperate conditions of Kashmir.

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Appendix-Ì

Standard weekly meteorological data for 2020-2021 of Wadura, sopore

	Rainfall (mm)	**Max. Temp. (°C)**	**Min. Temp. (°C)**	**Max. RH (%)**	**Min. RH (%)**
40	0.00	27.79	4.69	79.57	34.86
41	0.00	27.29	3.30	78.57	32.71
42	0.00	26.08	3.24	82.29	34.14
43	0.00	22.21	0.96	74.14	38.86
44	0.00	20.31	-0.14	71.43	45.57
45	0.00	20.21	-2.29	70.29	44.29
46	9.80	12.21	-0.29	85.29	72.00
47	20.00	8.93	-1.43	86.00	72.29
48	13.20	11.13	-1.29	91.57	77.14
49	7.40	10.13	-0.46	93.57	78.43
50	51.20	8.57	-0.73	91.71	81.71
51	0.00	8.93	-6.64	86.14	56.14
52	1.50	9.57	-4.57	89.00	64.43
1	82.00	5.79	-5.09	92.00	74.00
2	13.86	6.03	-2.50	91.00	76.29
3	0.00	9.79	-9.09	91.43	56.29
4	23.00	5.50	-5.50	93.57	70.57
5	1.00	2.43	-7.79	90.86	87.43
6	1.50	8.57	-2.43	93.14	75.86
7	0.00	15.29	-2.29	83.71	47.71

8	2.40	16.94	0.27	86.14	41.29
9	26.00	13.39	3.07	83.57	68.29
10	18.20	15.80	2.64	77.14	56.86
11	78.80	10.79	3.43	91.43	73.71
12	76.00	15.93	4.34	76.71	55.57
13	69.20	16.93	5.61	77.86	63.71
14	9.20	18.93	4.64	74.29	39.43
15	57.40	18.43	4.31	79.29	48.00
16	87.00	15.14	6.07	89.14	62.71
17	40.20	20.29	5.17	67.43	47.86
18	2.80	26.00	8.21	65.86	40.00
19	10.20	22.50	10.43	79.00	73.71
20	26.60	23.14	9.07	85.14	49.57
21	13.80	23.14	8.64	82.00	50.57
22	0.40	28.64	10.21	76.14	55.86
23	2.80	29.64	14.07	73.86	41.14
24	1.64	30.50	14.93	70.29	46.14
25	0.60	27.27	11.79	74.71	43.57
26	2.60	30.21	13.00	58.71	38.57
27	12.10	30.66	15.00	66.71	38.00
28	19.80	31.26	17.84	71.57	39.57
29	80.00	30.13	17.96	78.29	47.29
30	18.80	30.23	18.70	78.57	61.29
31	108.60	28.51	18.26	88.14	66.00

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CERTIFICATE

Certified that all the corrections/ amendments as suggested by the external examiner **Dr. Vikas sharma**, Professor (Agronomy)**,** Incharge**,** RARS- Rajouri SKUAST-J, during viva-voce examination held on **06-03-2023** have been incorporated in the final manuscript entitled, **"Influence of Nitrogen and Sulphur on Seed Production of Oat (*Avena Sativa* L.) under Temperate Conditions"** submitted by **Faisal Hayat (Regd. No. MSA-2019-1261).**

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