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Research Article

Seeding and blended nitrogen phosphorus sulphur and boron (npsb) fertilizer rate effect on yield and yield components of oat varieties (*Avena sativa* L.) at Chencha, South Ethiopia

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Abstract

Oat is one of most important cereal crops mainly cultivated in highlands of Ethiopia. However, its production remains constrained due to limited varietal options, absence of site-specific recommendations for blended fertilizer application, and optimal seeding rates. Therefore, this study was conducted to determine the rate of seeding and blended NPSB fertilizer on yield and yield components of oat varieties during 2023/24 cropping season at Chencha, South Ethiopia. The study consisted three seeding rates combined with two oat varieties (main plot) and four levels of blended NPSB fertilizer (sub plot) laid out in split plot design in three replications. Data on crop phenology, growth, yield and yield components were collected and subjected to analysis of variance. The results showed that days to heading, days to maturity, plant height, biomass yield, grain yield, thousand seed weight and harvest index were significantly ($p \leq 0.05$) affected due to seeding rate combined with oat variety and blended NPSB fertilizer rates. The Souris variety proved superior, achieving the highest biomass (21,348.3 kg ha^{-1}) at a 100 kg ha^{-1} seeding rate and the maximum grain yield (3,589.5 kg ha^{-1}) at the 130 kg ha^{-1} rate. Separately, the optimal fertilizer level was 100 kg ha^{-1} of blended NPSB, which produced the highest average biomass (15,994 kg ha^{-1}) and grain yield (2,344 kg ha^{-1}). Therefore, cultivating the Souris variety at a seeding rate of 100 kg ha^{-1}, coupled with the application of 100 kg ha^{-1} of blended NPSB fertilizer, is recommended to achieve balanced and optimal oat production in Chencha and comparable agro-ecological zones.

Keywords: Blended fertilizer; Oat; Seeding rate; Soil fertility

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1. Introduction

Oat (*Avena sativa* L.) is an annual cereal crop widely cultivated across the world for food and feed. The crop is abundantly known in central highlands of Ethiopia (Gezahagn *et al*., 2016). It is economically important cereal crop following corn, rice, wheat, barley, sorghum, and millet

(Boczkowska *et al*., 2016) and adapted to a wide range of climatic conditions and geographic regions from 1750 to 3000 m.a.s.l (Getnet *et al.,* 2003). Oat is rotational crop being cultivated in marginal lands (Zhou *et al*., 2013). It requires light to heavy soils with sufficient moisture conditions for better growth and production (Khan *et al*., 2014). Oat is cultivated under hardy and stress nature with very minimal managerial inputs (Gebremedhn *et al*., 2015).

Global oat area coverage and production in tons during 2020 was 9,800,337 ha and 25, 321,359.64 tons (FAO, 2020). In Africa and Ethiopia, 177,783.69 tons was obtained from 131,977 ha and 39,514.7 tons from 19,631 ha, respectively (FAO, 2020) with Ethiopia leading in sub-Saharan Africa. Oat grain production in sub-Sahara Africa during 1993–2021 has been estimated to be 55,000 tons per year from 53,000 hectares of land, where Ethiopia accounts for the production of 43,878 tons per year from 21,333 ha of land and Kenya 3834 tons per year from 3400 ha of land and small amounts from Zimbabwe (FAO, 2021). However, the productivity in Ethiopia (2 t/ha) (CSA, 2023) lags behind the global average of 2.6 t/ha, a yield gap largely driven by the use of unimproved varieties, suboptimal seeding rates, and poor soil fertility management. These constraints are reflected in local farming systems, where producers often rely on traditional and highly variable rates for seed and fertilizer application.

A common practice in non-intensive systems is to cultivate oats without fertilizer, relying on residual soil nutrients from previous crops (Kolmanič et al., 2022). However, this method of successive cropping often leads to significant soil nutrient depletion, which in turn reduces both the biomass yield and the nutritional quality of the fodder (Getnet & Ledin, 2001). Consequently, livestock fed on such nutrient-poor forage can suffer from deficiencies in essential minerals and protein, negatively affecting their overall health and productivity (Tolera et al., 2007). In addition, soils deficient in zinc (Zn) and boron (B) limited the development of crops (Fageria, 2002). The amount of seed per an area of land is also associated with the type of crop variety and fertility level of the soil. Production of dry matter in oat is increased with the amount of fertilizer applied. Various authors documented effects of fertilizer application on plant growth and leaf area which contribute to the dry matter production of the fodder oat. Dawit and Teklu (2014) showed high lodging, reduced seed size and quality of oat varieties during increasing seed rate and blended NPSB fertilizer. An increase in green forage yield in response to elevated levels of nitrogen fertilization has also been reported by Khan et al. (1996) and Sultana et al. (2005). The crop was widely promoted and introduced to production through local NGO in Chencha; however, the

technologies lack recommendation on seeding and fertilizer rates. In order to increase oat production in the high land area of the region, studies and recommendation of blended fertilizer rate with various nutrient content, seed rate and a variety adapting to the farming system is quite important. Therefore, this study was initiated to determine oat variety related with seeding and blended NPSB fertilizer rate on yield and yield components of oat cultivation at Chencha, South Ethiopia.

2. Materials and Methods

2.1. Study area description

The experiment was conducted at Chencha, Ganidogumolel, located at an altitude of 2663 m.a.s.l. and $06^0$91' 89.8'' N latitude and 34^0 28' 96'' E longitudes during 2023/24 *kharif* cropping season (July to October). The area is characterized by a bimodal rainfall pattern, with a mean annual precipitation of approximately 1,200 mm. The maximum and minimum temperatures average 21.8°C and 12.6°C, respectively. The dominant soil type is strongly acidic Nitisol. The experimental site soil was tested and attributed with clay in texture with pH 7.2, medium organic carbon content of (1.2%), medium total nitrogen content (0.16 %), medium available phosphorus (41.2 mg per 100g soil), very high CEC (23.06 mg per 100 g soil) and electrical conductivity (226.2 micro simus) which is salt free.

2.2. Treatments and experiment design

The field experiment consisted of four rates of blended NPSB fertilizer composed of 18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B at 0, 50, 100 and 150 NPSB kg ha^{-1} rate as factor 1 and two oat varieties [Souris and Goslin] combined with three seeding rates (70, 100 and 130 kg seed rate ha^{-1}) as factor 2. The treatments were made in factorial experiment with split plot design in three replications. The oat varieties combined with rates of seeding were assigned as main plot and blended NPSB fertilizer rate as sub plot treatments. Each treatment was randomly assigned in a plot of 1.8 m by 3 m area consisting six rows spaced at 30cm where the middle four rows were used for observation. The spacing between adjacent plots and blocks was 0.5m and 1.5m respectively.

2.3. Data collection and analysis

Data on days to heading, days to maturity at 50% and 90% of the plot plant head and mature, respectively, plant height, number of tillers, spike length, thousand seed weight, biomass yield,

harvest index and grain yield were recorded following standard procedures. The data collected was subjected to analysis of variance (ANOVA) according to the Generalized Linear Model using SAS version 9.0 (SAS, 2004). Differences between treatments means were separated according to the least significant difference (LSD) (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Crop phenology

3.1.1 Days to heading

Analysis of variance revealed that days to 50% heading was significant ($P \leq 0.05$) due to seeding rate combined with oat variety factor. However, days to heading not significantly affected due to blended NPSB fertilizer application rate and the interaction (Table 1) indicating the level of blended fertilizer rate not sufficient to bring significant different in crop phenology under the study. Days of heading ranged from 83.3 to 75.5 where the maximum days to heading recorded from variety Souris combined with 70 kg ha^{-1} seeding and minimum or early days to heading was attained from Goslin combined with seeding rate of 130 kg ha^{-1}. The result suggested as Goslin heads earlier than Souris indicating genetic difference among the cultivars. The increasing seeding rate per hectare from 70 kg of Souris to 100 kg of Goslin early days to heading by about a week suggesting the effect of increasing competition on crops maturity. The observation that the Goslin cultivar heads earlier than the Souris cultivar under similar conditions strongly suggests an underlying genetic difference in phenological development between the two varieties (McCabe and Burke, 2021). Furthermore, the finding that increasing the seeding rate highlights the effect of intraspecific competition on crop maturity. Higher plant density intensifies competition for resources like light, water, and nutrients, which can accelerate the plant's transition to the reproductive phase as a stress response mechanism (Slafer & Rawson, 1995). This aligns with previous findings, such as those by Dawit and Teku (2014), who also documented that increased seeding rates consistently reduced the number of days to heading in cereal crops.

3.1.2 Days to maturity

Days of maturity was significantly ($P \leq 0.05$) affected due to seeding rate combined with oat variety, while effect of blended NPSB fertilizer application rate and interaction was not significant (Table 1) indicating the level of blended fertilizer rate not sufficient to bring significant different in crop phenology under the study. Days to maturity ranged from 139.2 to 125.5. Oat

variety Souris at 70 kg ha^{-1} matured late than Goslin at 100 kg ha^{-1} seeding rate. As like days to heading, oat variety Souris took long days to maturity when compared to Goslin indicating the genetic difference among the oat varieties. The earliness to maturity at high seeding rate or the prolonged days to maturity at low population density might be due to plant competition for available resources and the genetic difference among the cultivars. Similarly, Dawit and Teklu (2014) reported early days to maturity due to increasing seeding rate.

Table.1. Days to heading and maturity as affected by oat varieties combined with seeding and blended NPSB fertilizer rates at Chencha during 2023/24 cropping season.

Treatment	Days to heading	Days to maturity
Combination of variety and seed rate (kg ha^{-1})		
Souris at 70 kg ha^{-1}	83.3^{a}	139.2^{a}
Souris at 100 kg ha^{-1}	82.8^{ab}	136.5^{ab}
Souris at 130 kg ha^{-1}	77.5^{bc}	128.0^{bc}
Goslin at 70 kg ha^{-1}	79.6^{c}	132.4^{abc}
Goslin at 100 kg ha^{-1}	75.5^{cd}	127.5^{bc}
Goslin at 130 kg ha^{-1}	70.9^{d}	125.5^{c}
LSD $_{(0.05)}$	5.5	9.6
SEM±	1.1	2.1
CV $_{(\%)}$	7.8	8.1
Blended NPSB fertilizer rate (kgha^{-1})		
0	79.0^{a}	133.5^{a}
50	78.1^{a}	132.4^{a}
100	78.4^{a}	129.8^{a}
150	77.5^{a}	130.3^{a}
Grand mean	78.2	131.5
SEM±	0.9	1.7
CV $_{(\%)}$	5.2	5.5
Interaction $_{(P)}$	NS	NS

Means followed by the same letter(s) in the column are not significantly different at 5% probability level.

3.2. Growth analysis

3.2.1 Plant height (cm)

Plant height was significantly ($P \leq 0.05$) affected due to seeding rate combined with oat variety and blended NPSB fertilizer application rate. The interaction effect was not significant for plant height (Table 2). Plant height varied significantly, ranging from a minimum of 83.7 cm for the Goslin variety at a 70 kg/ha seeding rate to a maximum of 131.0 cm for the Souris variety at 130 kg/ha. This result indicates two main points: first, that Souris is a genetically taller cultivar than Goslin; and second, that plant height increased with higher seeding rates for a given variety.

This increase in height at higher plant densities is a classic response to intraspecific competition, particularly for light (Ballaré *et al*., 1990). As the plant population per unit area increases, mutual shading triggers a physiological response known as shade avoidance, where plants allocate more resources to vertical stem elongation to outcompete their neighbors for access to sunlight (Franklin, 2008). This physiological mechanism explains the findings of Singh and Sarlach (2012) who indicated effect of seeding rates on plant height and stem thickness because of plant competition for space, nutrients and water uptake and light absorption. Furthermore, Rahim *et al.* (2012) reported that plant height increased with increasing seeding rate indicating competition for light.

The effect of blended NPSB fertilizer application was significant ($P \leq 0.05$) for plant height (Table 2). Plant height was ranged from 96.3cm to 118.8cm where the maximum height was recorded from 100 kg ha^{-1} blended NPSB fertilizer rate and the minimum from no fertilizer applied plot indicating the significance of fertilizer application on plant growth. The result agrees with Arif *et al*. (2006) and Mathewos *et al*. (2019) who reported that macro and micro nutrients (nitrogen, phosphorous with sulfur and born) increased plant height with increasing doses of blended NPSB fertilizer rates. Findings of Bizuwork *et al*. (2007) also showed that highest plant height recorded at higher dose of blended NPSB fertilizer application rate and attributed to the simulative effect of N on vegetative growth, production of carbohydrate through photosynthesis, and plant cell division.

3.2.2 Number of tillers

Number of tillers was significantly ($P \leq 0.05$) affected due to seeding rate combined with oat variety, while the effect of blended NPSB fertilizer application rate and the interaction was not significant (Table 2). The number of tillers ranged from 9.2 to 12.2 where the maximum was recorded from oat variety Souris at 70 kg ha^{-1} and the minimum attained from Goslin at 130 kg ha^{-1}. The result indicated that Souris produced more tiller than Goslin and decrease in tiller production with increase in seed rate suggesting competition for resources and the variation in tiller numbers among oat varieties for genetic background, breeding history, and environmental conditions in which the oats were grown. This result was in line with Jelic *et al.* (2016) and Hozayn *et al.* (2012) findings who reported decrease in number of tiller per plant with the increase in plant density.

Table 2. Plant height and number of tiller as affected by oat varieties combined with seeding and blended NPSB fertilizer rates at Chencha during 2023/24 cropping season.

Treatment	Plant height (cm)	Number of tillers
Combination of variety seed rate (kg ha^{-1})		
Souris at 70 kg ha^{-1}	115.4^{b}	12.2^{a}
Souris at 100 kg ha^{-1}	124.2^{ab}	10.8^{abc}
Souris at 130 kg ha^{-1}	131.0^{a}	10.7^{bc}
Goslin at 70 kg ha^{-1}	83.7^{d}	11.3^{ab}
Goslin at 100 kg ha^{-1}	87.9^{cd}	9.7^{cd}
Goslin at 130 kg ha^{-1}	93.9^{c}	9.2^{d}
LSD $_{(0.05)}$	9.3	1.4
SEM±	2.9	0.3
CV $_{(\%)}$	9.6	15.3
Blended NPSB fertilizer rate (kg ha^{-1})		
0	96.3^{c}	10.8^{a}
50	104.1^{b}	10.6^{a}
100	118.8^{a}	10.5^{a}
150	104.9^{b}	10.6^{a}
Grand mean	106.0	10.6
LSD $_{(0.05)}$	6.9	NS
SEM±	2.4	0.2
CV $_{(\%)}$	9.6	11.1
Interaction	NS	NS

3.3 Yield and yield components

3.3.1 Thousand-seed weight

Thousand-seed weight was significantly (*P≤0.05*) affected due to application of seeding rate combined with oat variety and blended NPSB fertilizer application rate. However, the interaction effect was non-significant (Table 3). Thousand seed weight ranged from 29.1g to 50.9g where the maximum thousand seed weight attained from Souris at 70 kg ha^{-1} seeding rate while the minimum recorded from Goslin at 130 kg ha^{-1} seeding rate. The result indicated that Souris showed more thousand seed weight when compared to Goslin and decrease in thousand seed weight with increase in seeding rate suggesting competition for resource resulting in reduced seed weight. Similarly, Getnet *et al.* (2003) reported that the lowest thousand seed weight produced from the highest seed rate and the effect of competition for nutrients and moisture related with grain filling. Furthermore, Alemayehu *et al*. (2015) reported that the negative effect of increasing seed rate on thousand grain weight.

The thousand seed weight ranged from 33.9g to 43.6g due to blended NPSB fertilizer application rate. The highest thousand seed weight recorded at 100 kg ha^{-1} and lowest recorded from no fertilizer applied plot. The result indicated the effect of increasing blended NPSB fertilizer

application and excess blended NPSB fertilizer application. Similarly, Dawit and Teklu (2014) reported that highest grain yield attained at highest blended NPSB fertilizer rates for the production of fodder oats in the highlands of Ethiopia,

3.3.2 Biomass yield (kg ha^{-1})

Biomass yield was significantly (*P≤0.05*) affected due to seeding rate combined with oat variety and blended NPSB fertilizer application rate. Neverthless, the interaction effect was not significant (Table 3). The biomass yield ranged from 9,927.5 kg ha^{-1} to 21,348.3 kg ha^{-1} where the highest biomass yields was recorded from Souris at 130 kg ha^{-1} seeding rate and the lowest recorded at Goslin at 100 kg ha^{-1} seeding rate. The result indicated high biomass production at Souris compared to Goslin and increase in biomass production with increase in seeding rate until the maximum carrying capacity or the resources available. This result was in agreement with the finding of Getnet and Ledin (2001), Dawit and Teklu (2014) who stated that increased seeding rate resulted in increased biological yield related to the law of maximum carrying capacity of a land.

Biomass yield increased with fertilizer application, ranging from 14,204 kg ha^{-1} in unfertilized plots to a maximum of 15,994 kg ha^{-1} at the 100 kg ha^{-1} blended NPSB rate. This indicates the oat variety responded positively as the fertilizer rate increased. Our results are consistent with the findings of Melkamu Hordofa (2023), who reported that insufficient NPSB fertilizer caused nutritional imbalances and consequently reduce dry matter production.

3.3.3 Grain yield (kg ha^{-1})

As presented in Table 3, grain yield was significantly (*P≤0.05*) affected due to seeding rate combined with oat variety and blended NPSB fertilizer application rate while the interaction was non-significant (Table 3). The oat grain yield ranged from 1495.0 kg ha^{-1} to 3589.0 kg ha^{-1} where the maximum grain yield recorded from Souris at 100 kg ha^{-1} and the minimum from Goslin at 130 kg ha^{-1} seeding rate. The result indicated that increasing effect of seeding rate on grain yield until the highest carrying capacity of the plot and reduction above the carrying capacity of the plot indicating the competition for light and nutrients. The initial increase suggests the better resource capture by the plant canopy, while the subsequent decrease is caused by intense inter-plant competition as documented in Yidersal *et al*. (2020) for seeding rate and nitrogen application effect on oat. The result also showed grain yield of Souris was greater than Goslin indicating the genetic difference among the varieties (Kebede *et al.* 2023) who documented high genetic diversity

between oat genotypes. Similarly, Dawit and Teklu (2014) who recorded the maximum grain yield from plot applied with high seed rate and low yield from plot with low seeding rate. The rates of seeding in oat vary depending on the location and purpose for which the crop is cultivated (Jelic *et al.* (2013).

The grain yield ranged from 2198.6 kg ha^{-1} to 2344.0 due to blended NPSB fertilizer application rate. The highest grain yield recorded at 100 kg ha^{-1} of blended NPSB fertilizer application rate, which is on par with blended NPSB fertilizer rate at 50 kg ha^{-1} and lowest grain yield was recorded at no fertilizer applied plot indicating blended NPSB fertilizer application effect on grain yield. The result indicated the increase in grain yield with increase in fertilizer rate effect to 100 kg and decrease above indicating the optimum blended fertilizer level for oat production. Similarly, Khan *et al*. (2014) and Hassibi (2018) reported that grain yield of spring oats was influenced by the fertilization system, as key factors affecting yield and its quality.

Table 3. Thousand seed weight, biomass yield, grain yield and harvest index as affected by seeding rate combined with oat varieties and blended NPSB fertilizer rates at Chencha during 2023/24 cropping season.

Treatment	Thousand seed Weight (g)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Combination of variety seed rate (kgha^{-1})				
Souris at 70 kg ha^{-1}	50.9^{a}	17102.2^{c}	2830.8^{b}	18.0^{a}
Souris at 100 kg ha^{-1}	41.5^{b}	19858.0^{b}	3589.5^{a}	17.3^{ab}
Souris at 130 kg ha^{-1}	36.7^{c}	21348.3^{a}	2053.1^{c}	14.0^{d}
Goslin at 70 kg ha^{-1}	34.2^{cd}	10877.8^{de}	1615.4^{e}	16.2^{bc}
Goslin at 100 kg ha^{-1}	32.0^{de}	9927.5^{e}	1871.5^{d}	15.8^{c}
Goslin at 130 kg ha^{-1}	29.1^{e}	11423.9^{d}	1495^{e}	14.9^{cd}
LSD $_{(0.05)}$	3.9	1156.9	145	1.3
SEM±	1.0	239.8	57.1	0.2
CV $_{(\%)}$	11.5	8.4	7.1	9.3
Blended NPSB fertilizer rate(kgha^{-1})				
0	33.9^{c}	14204^{c}	2165.0^{b}	16.4^{a}
50	38.3^{b}	14873^{b}	2262.4^{ab}	15.9^{a}
100	43.6^{a}	15994^{a}	2344.0^{a}	16.0^{a}
150	34.0^{c}	15287^{b}	2198.6^{b}	15.9^{a}
LSD $_{(0.05)}$	2.3	561.6	134	NS
SEM±	0.8	195.8	46.6	0.2
CV $_{(\%)}$	9.3	5.5	8.8	12.8
Interaction	NS	NS	NS	NS
Grand mean	37.4	15090	2242.5	16.1

3.3.4 Harvest index

Harvest index was significantly (*P≤0.05*) affected due to seeding rate combined with oat varieties. However, effect of blended NPSB fertilizer application rate and the interaction was non-

significant (Table 3). The harvest index ranged from 14.0 % to 18.0 % where the highest was recorded Souris at 70 kg ha^{-1} seed rate and the lowest recorded from Souris at 130 kg ha^{-1} that is on par with Goslin at 130 kg ha^{-1}. The result also indicated decrease in harvest index with increase in seeding rate. Similar to the present finding, Iqbal *et al*. (2012) stated that highest harvest index obtained at seeding rate of 150 kg ha^{-1} as compared to 125 and 175 kg ha^{-1}.

4. Conclusion

Oat varieties in combination with seeding rates and application of blended NPSB fertilizer rate significantly affected crop growth, yield and yield components during 2023/24 cropping season. Oat variety Souris was late in maturing however, scored high thousand seed weight, harvest index, biomass and grain yield when compared to oat variety Goslin. Seeding rate of 100 kg ha^{-1} scored high in plant height, biomass and grain yield. Therefore, Souris combined with 100 kg ha^{-1} seed rate and 100 kg ha^{-1} Blended NPSB rate is found better for oat growth and yield at Chencha and similar agro ecologies.

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Contribution of authors

The first author of the manuscript is MSC student involved in writing, designing and collecting data of the field research for degree accomplishment. The title of thesis is ‘effect of seed rate and blended NPSB fertilizer on growth, yield and yield components of oat varieties (*Avena sativa* l.) in Chencha district, Southern Ethiopia’. The other two authors are thesis supervisors and contributed in supervising the research, data analysis, reviewing and editing thesis, preparing the thesis write up and manuscript for publication.

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