Agronomic Performance and Forage Yield of Oat (Avena sativa L.) Varieties

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Research Article

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Agronomic Performance and Forage Yield of Oat (*Avena sativa* L.) Varieties

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Abstract

This study was conducted at the Debre Markos University farm demonstration site to investigate the agronomic traits of five Avena sativa varieties. The experimental design utilized a randomized complete block approach, which was replicated thrice to ensure robust results. The varieties examined were CI-1506, CI-2291, CI-2596, CI-2806, and CI-8251. The analysis revealed that a variety of agronomic traits, including leaf length, leaf width, leaf area, number of tillers per plant, panicle length, number of spikelets per panicle, forage dry matter, and seed yield, were significantly influenced by the variety used. Notably, CI-2291, CI-2596, and CI-8251 exhibited significantly higher ($P < 0.05$) plant heights and higher *numbers of tillers than did CI-1506, indicating their potential for enhanced growth. Additionally, varieties CI-8251 and CI-2596 demonstrated significantly higher leaf length, panicle length, and number of spikelets per panicle than CI-1506, highlighting their* higher *reproductive traits. Furthermore, CI-2291 and CI-2596 also had larger leaf widths and higher forage dry matter contents than the other varieties. Of particular significance, CI-2596 had the largest leaf area among the tested varieties, suggesting its potential to improve the photosynthetic capacity. In terms of yield performance, both CI-2291 and CI-8251 produced significantly higher seed and straw yields, followed by CI-1506, CI-2596, and CI-2806, emphasizing their viability in forage production. Overall, these findings suggest that specific A. sativa varieties can provide distinct agronomic advantages, warranting further exploration for optimal forage selection.*

Keywords: *Avena sativa*, Dry Matter, Traits, Varieties, Yield

1. INTRODUCTION

Livestock production and productivity in Ethiopia face several significant challenges, primarily stemming from inadequate feed quality and quantity, prevalent animal diseases, and low genetic quality of many indigenous breeds (Mengistu et al., 2021). These issues are particularly pronounced during the dry season, when the scarcity of nutritious feed is a critical limiting factor for livestock health and productivity (Alimi et al., 2024; Mengistu et al., 2021). In regions such as the East Gojjam zone, where this study was conducted, the availability of both the quantity and quality of feed resources remains a pressing concern (Desta, 2023, 2024b; Desta et al., 2023). This scarcity not only impacts the immediate well-being of livestock but also hampers overall agricultural productivity and food security in the region (Abu Hatab et al., 2021). Addressing these challenges is essential for enhancing livestock productivity and improving the livelihood of farmers who rely on these animals. Understanding the underlying factors contributing to these constraints is vital for developing effective strategies for optimizing livestock management and resource allocation in Ethiopia.

In the Ethiopian highlands, livestock primarily rely on natural pastures and crop residues as the main sources of feed (Tessema et al., 2024). However, rapid population growth in the country has intensified the demand for land, leading to a significant reduction in natural pasture areas, as more land is allocated for crop cultivation (Solomon et al., 2024). This shift adversely affected the remaining uncultivated pastures, were overgrazing (Birhan & Adugna, 2014) and declining soil fertility further diminished forage production (ASEFA, 2017). Consequently, crop residue has emerged as the predominant feed resource in traditional livestock production systems (Desta, 2024b). Unfortunately, these residues are typically of low quality, characterized by high fiber content (Desta, 2023) and low digestibility (Tessema et al., 2024), which ultimately contribute to decreased livestock productivity. This underscores the critical need for strategies to enhance feed quality and availability, which are essential for improving livestock performance and ensuring the sustainability of agricultural livelihoods (Paro et al., 2024).

The production of sufficient quantities of high-quality forage is fundamental for establishing a more efficient and productive livestock industry (Tulu et al., 2023). Improved forage plays a crucial role in addressing the challenges posed by the limited availability and quality of feed, particularly during the dry season, when forage scarcity is most acute (Musco et al., 2016). By incorporating high-quality forage into the diet, livestock can more effectively utilize low-quality cereals, thereby enhancing the overall feed efficiency. This integration not only supports better animal health and productivity but also contributes to the sustainability of livestock systems (Paul et al., 2020). Consequently, investing in the development and management of quality forage resources is essential to ensuring a reliable and nutritious feed supply, ultimately fostering the growth and resilience of the livestock sector (Tulu et al., 2023).

A. sativa, commonly referred to as oats, is widely recognized for its value as fodder for livestock and is cultivated across various regions of Ethiopia due to its remarkable adaptability (Amare et al., 2024). This crop can thrive in a broad spectrum of soil types, rainfall conditions, and altitudinal ranges, making it an excellent choice for farmers in diverse agricultural settings (Gadisa et al., 2023). Classified within the Poaceae family, *A. sativa* holds the distinction of being the sixth most important cereal crop in the world (Suttie & Reynolds, 2004). The plant typically produces four to five culms, with diameters ranging from 0.3 to 0.6 cm and heights varying between 60 and 150 cm (Bibi et al., 2021).

Nutritionally, *A. sativa* are quite beneficial, containing 9.23% fat, 3.56% protein, and 30.44% fiber, alongside essential minerals such as calcium (0.82%) and phosphorus (0.27%) (IKRAM & REHMAN, 2020). Both the leaves and grains are abundant in carbohydrates and carotene, enhancing their appeal as a nutritious feed source. Additionally, *A. sativa* is particularly valued as a forage crop due to its fine stem structure, higher palatability, and rapid growth rate (Gadisa et al., 2023). When harvested at the boot stage, it also serves as a high-quality silage option (Shaheen et al., 2021).

The role of *Avena sativa* (oats) as a forage crop in Ethiopia, particularly in the East Gojjam Zone of the Amhara Region, has gained attention due to its potential to improve livestock productivity and enhance soil fertility (Gataneh et al., 2021). However, despite its recognized benefits as an important forage and cereal crop, there is limited research on its specific characteristics as forage in this region, including its adaptability, nutritional content, and the overall productivity under local agro-climatic conditions. East Gojjam Zone, known for its mixed farming systems, heavily depends on livestock for the livelihoods of its rural population (Gashe et al., 2017). As such, improving the quality and quantity of forage crops like oats is crucial for addressing challenges related to feed scarcity, seasonal variability in forage availability, and the increasing demand for livestock products (Kebede et al., 2021; Kebede et al., 2020; Siloriya et al., 2014).

Although *Avena sativa* is well-documented globally for its high digestibility and palatability as a forage species (Sood et al., 2022), limited studies have investigated its performance in the unique agro-ecological conditions of Ethiopia, particularly in the Amhara Region. Preliminary observations suggest that *Avena sativa* may be well-suited to the region's highland areas, with its ability to thrive in cool, temperate climates. However, there is a paucity of research focusing on its growth patterns, biomass yield, and its comparative advantage over other forage crops grown in the region. Furthermore, issues related with the traits of oats in East Gojjam remain under-researched (Gataneh et al., 2021).

In the study area, evaluating the agronomic traits of *A. sativa* varieties is essential for sustainable livestock production. A key issue is the limited genetic diversity among the *Avena sativa* varieties available to farmers, which hampers breeding efforts to improve traits such as dry matter yield. This lack of diversity can result in an inconsistent forage supply, which negatively affects livestock nutrition. Therefore, this study aimed to evaluate the agronomic characteristics of *A. sativa* in the East Gojjam zone to provide valuable insights for improving its cultivation and use in livestock production systems.

Research hypothesis

- ❖ There was a significant difference in plant height, leaf length, width, and area among the five *Avena sativa* varieties.

- There was a significant difference in the number of tillers per plant, number of spikelets per panicle, dry matter, seed, and straw yields among the five *Avena sativa* varieties.
- The number of tillers per plant is positively correlated with the dry matter yield of *Avena sativa* varieties.
- *Avena sativa* varieties with longer panicles produce a higher number of spikelets per panicle.
- *Avena sativa* varieties with a higher leaf area and number of tillers per plant yield higher forage dry matter.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The research was carried out at Debre Markos University, East Gojjam Zone, Amhara Regional State, Ethiopia (Figure 1), at an altitude of 2,420 m above sea level. This location experiences a climate characterized by maximum temperatures reaching 27°C and minimum temperatures dropping to approximately 10°C. Additionally, the area receives an average annual rainfall of approximately 1,380 mm, which contributes to its unique ecological conditions. These climatic and geographical factors create a suitable environment for agricultural experimentation, particularly for studying the growth and productivity of various crops, including *A. sativa*. The combination of altitude, temperature, and rainfall patterns plays a critical role in shaping the agricultural practices and crop yield potential in this region.

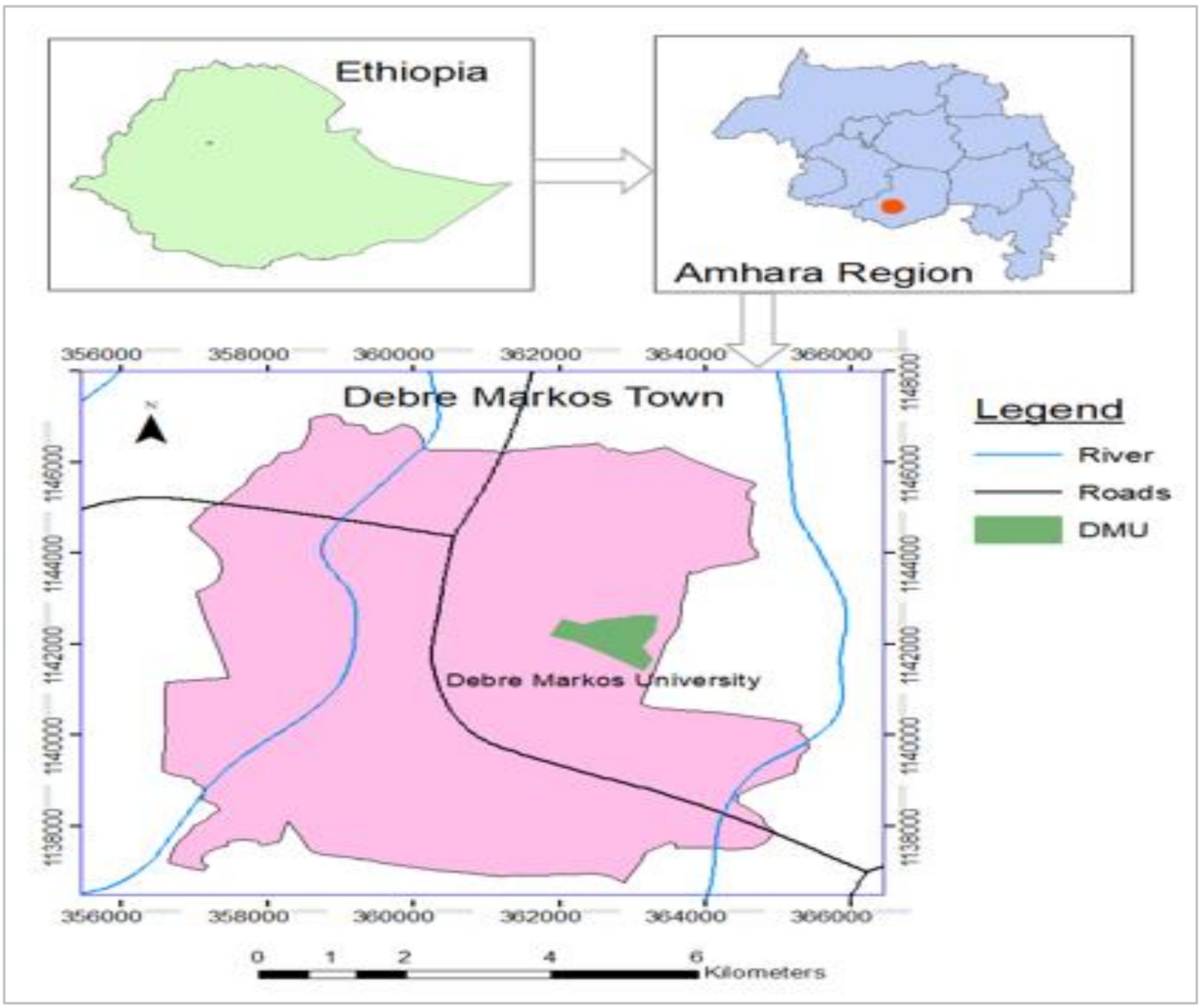


Figure 1. Map of the study areas.

2.2. Treatments and Experimental Design

A comprehensive study was conducted at the DMU demonstration site to investigate the agronomic traits of five *A. sativa* varieties. The experiment was structured using a randomized complete block design (RCBD), featuring three replicates to ensure the robustness of the results. A total of five distinct *Avena sativa* varieties, namely CI-1506, CI-2291, CI-2596, CI-2806, and CI-8251, were used in the experiment. The oat varieties were cultivated varieties obtained from Debre Markos University and were grown under experimental field conditions at the university. These varieties were specifically selected for their adaptability to local environmental conditions and availability of seeds in the region, making them ideal candidates for cultivation.

The seeds were sown at a density of 80 to 100 kg per hectare, a strategic choice designed to optimize growth potential. To provide essential phosphorus, 50 kg/ha diammonium phosphate (DAP) was applied, whereas nitrogen was introduced in the form of urea (100 kg/ha) delivered through single split doses following the establishment of the plants. Each experimental plot measured 2×3 m^2 and was meticulously prepared to ensure a well-structured seedbed conducive to healthy plant development. Intra-row spacing was set at 15 cm, whereas inter-row spacing was maintained at 25 cm to facilitate adequate air circulation and light exposure. To mitigate any potential interference between plots, a separation of 1 m was implemented between blocks, with individual plots spaced 0.50 m apart. This carefully designed experimental framework aimed to yield valuable insights into the performance of selected *A. sativa* varieties, ultimately contributing to enhanced agricultural practices in the region.

2.3. Land Preparation and Management

At the start of the rainy season, five seed varieties were sown in a systematic field experiment. Before planting, the land was thoroughly prepared by plowing the soil four times to enhance its structure and fertility. Careful cultivation was aimed at creating optimal conditions for seed germination and growth. In addition, the seeds were meticulously examined to remove weed seeds and irregular or dead specimens to ensure a higher germination success rate. To maintain healthy plant development, weeding was consistently performed four times throughout the growing period, from the time of sowing until the plants reached maturity. This comprehensive approach was designed to support robust growth and maximize yield across all experimental treatments.

2.4. Data Collection

In this study, plant height, leaf length, leaf area, tiller count, panicle length, and spikelet count were used to characterize A. sativa varieties. Plant height was investigated by measuring the distance from the ground to the tip of the main stem, using ten randomly selected plants at the 50% flowering stage from each plot (Gebremedhn Beyene et al., 2015). Leaf length was measured from the base to the tip of the leaf using a ruler on ten randomly chosen plants to ensure accuracy. The leaf area was assessed by randomly selecting ten plants from the middle rows. The measurements were calculated using the following formula: $\mathbf{A = \pi \frac{L}{2} \ X \ \frac{W}{2}}$

Where:

- A = area of the leaf
- L = length of the leaf (measured from the base to the tip)
- W = maximum width of the leaf (measured at the broadest point)

To determine leaf width, measurements were taken from the base, middle, and tip of the leaf, and the average of these three measurements was used. The number of tillers per plant was counted from the same ten sample plants to assess tillering characteristics. Panicle length was measured by selecting ten panicles randomly from each plot, with measurements taken from the base to the apex. Finally, the number of spikelets per panicle was counted to provide insights into the reproductive potential. Collectively, these measurements offered valuable insights into the growth dynamics and yield potential of the studied plant species.

Biomass yield was evaluated by sampling the vegetation from each plot using a 0.5 x 0.5 m^2 quadrant at the 50% flowering stage (Muhammad Saleem et al., 2015). The quadrant was randomly placed within the plot, and the average weight recorded from it was utilized to estimate the biomass yield. This average weight of the fresh fodder was then extrapolated to determine the dry matter yield per hectare (t ha^{-1}). To analyze dry matter, the freshly harvested biomass was partially dried in an oven at 60°C for 72 hours (Khan et al., 2014).

$$\boldsymbol{DM\ (t/ha) = (10 * TFW * SSDW)/(HA * SSFW)}$$ where:

10 = Constant for conversion of yields in kg/m^2 to t/ha

TFW = Total fresh weight from the harvesting area (kg)

SSDW = Subsample dry weight (g)

HA = Harvest area (m2)

SSFW = Subsample fresh weight (g)

Grain and straw yields were assessed at full maturity, specifically when the seeds reached 100% maturity. Whole plants within a 0.5 x 0.5 m² quadrant were harvested, tied together, and dried. The straw and grain were then collected separately. The weights of the grain and straw from each quadrant were measured and converted to tons per hectare (Muhammad Saleem et al., 2015).

$$DM = \frac{10000\ m2}{Y} * \frac{Z}{100}$$

Where Z = yield obtained from the sampling area (kg/m^2)

Y= Area of sampling site in m^2

2.5. Data Analysis

To analyze the traits of different *Avena sativa* varieties, GraphPad Prism was used for statistical evaluation. To compare the means of these varieties, the Least Significant Difference (LSD) test was employed at a significance level of 5%. This approach helps identify whether there are statistically significant differences between the means of the different varieties.

3. RESULTS AND DISCUSSIONS

3.1. Height of *Avena sativa* Varieties

This study investigated the plant height of various *Avena sativa* (*A. sativa*) varieties and revealed significant differences attributable to genetic factors. Among the varieties examined, CI-2596 emerged as the tallest with a height of 1.3 m, followed by CI-8251 and CI-2291. In contrast, the shorter varieties CI-1506 and CI-2806 measured 0.9 and 1.1 m, respectively (Figure 2). Statistical analysis confirmed that the taller varieties (CI-2596, CI-8251, and CI-

2291) were significantly taller than the shorter variety (CI-1506) at a significance level of $P < 0.05$ (Appendix Table 1). This result supports the findings of (Kebede et al., 2021), who noted that the heights of CI-2596, CI-8251, and CI-2291 were significantly higher than those of CI-1506. The genetic diversity within *A. sativa* varieties appears to play a crucial role in their growth potential, as suggested by (Gebremedhn Beyene et al., 2015).

In this study, the heights of the various *A. sativa* varieties were comparable to those of several previously reported varieties. For instance, Lampton reached a height of 1.23 m, while CV-SRCP X 80 Ab 2291 measured 1.00 m, and CV-SRCP X 80 Ab 2806 reached 1.12 m (Wada et al., 2019). Other notable heights included CI-8235 at 1.22 m and CI-8237 at 1.20 m (Wada et al., 2019). Conversely, some varieties exhibited significantly shorter heights, such as 579-D-27 at only 0.57 m and CI-8237, CI-8235, DZF 00551, and 6710, which ranged from 0.45 to 0.53 m (Alemu & Amare, 2016). On the other hand, the heights recorded in this study were generally lower than those of notably taller varieties like 80-SA130 and 8251-CI, both of which reached 1.4 m, along with 80-SA95 at 1.68 m, 8237-CI at 1.7 m, Lampton at 1.8 m, 8235-CI at 1.45 m, and Jasari at 1.4 m (Beyene et al., 2015).

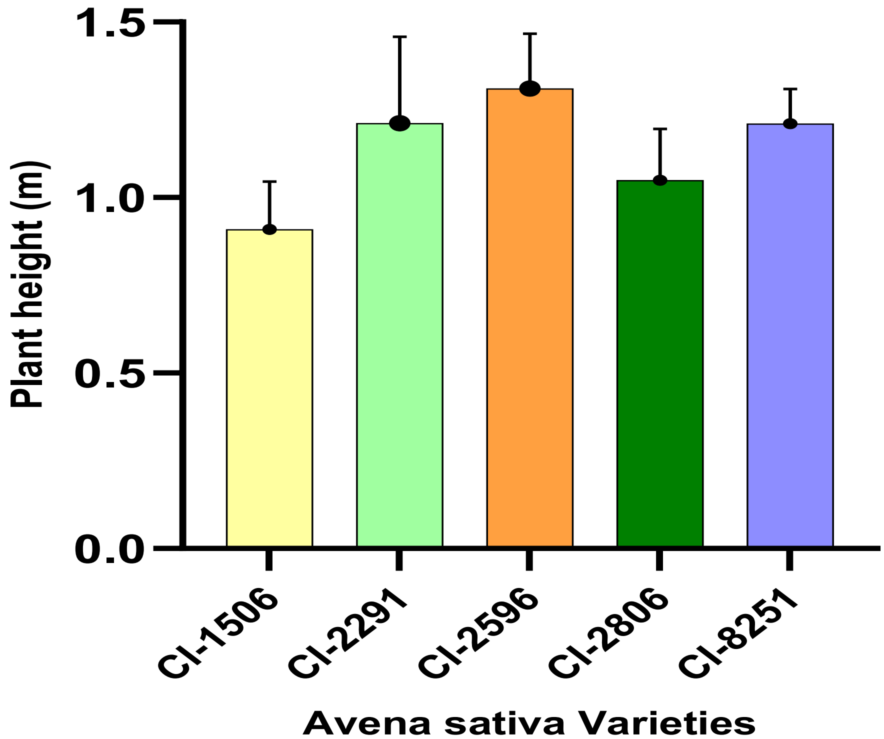


Figure 2. The heights of five the A. sativia varieties at 120 days of sowing

3.2. Number of Tillers per Plant

This study revealed notable variations in tiller production across different varieties of *Avena sativa* (Figure 3). Among the varieties tested, CI-2291 emerged as the most prolific, averaging 7.9 tillers per plant (Appendix Table 1), CI-8251 followed closely by an average of 7.4 tillers. In contrast, CI-2596 and CI-1506 produced 6.1 and 4.8 tillers, respectively, whereas CI-2806 produced the lowest tiller count at 3.9. Statistical analysis indicated that the top three varieties, CI-2291, CI-8251, and CI-2596, did not exhibit statistically significant differences in tiller counts ($P > 0.05$). However, these varieties were significantly higher ($P < 0.05$) than CI-1506 and CI-2806 varieties in terms of tiller production. This finding suggests a distinct advantage in tiller development among certain varieties of *Avena sativa*, which may have implications for biomass yield and overall plant health.

Analysis of tiller production in various *A. sativa* varieties revealed that several cultivars exhibit significantly higher tiller counts than those recorded in the current study. For instance, varieties such as Lampton (11.0 tillers), CV-SRCPX80Ab2291 (10.7 tillers), and CI-8235 (11.0 tillers) reported by (Wada et al., 2019) displayed robust tiller production, with counts surpassing those observed in the present analysis. Furthermore, CV-SRCP Ab 2806 achieved the higher recorded tiller count among the varieties at 12.0 tillers per plant. Other noteworthy varieties included 80-SA130 (9.2 tillers), 8251-CI (11.7 tillers), 80-SA95 (12.4 tillers), 8237-CI (13.3 tillers), 8235-CI (14.2 tillers), and Jasari (11.9 tillers) as indicated by (Beyene et al., 2015).

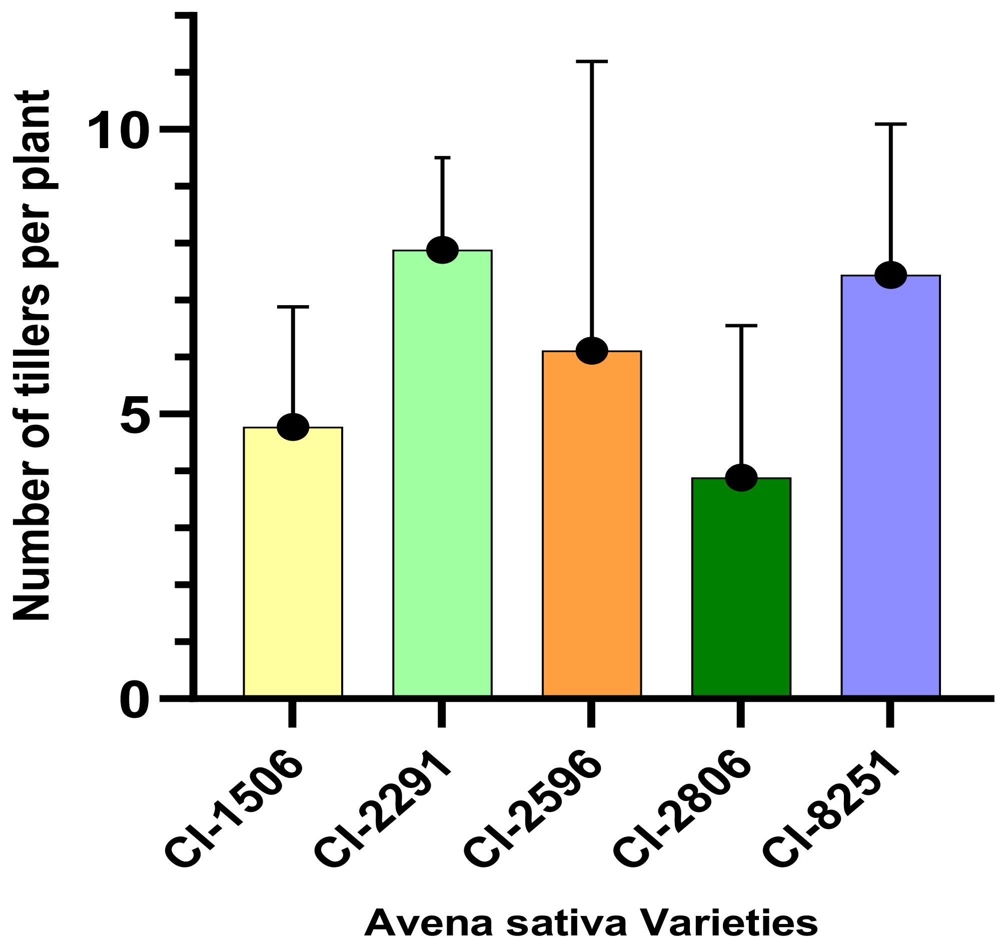


Figure 3. The number of tillers per plant five the *A. sativia* varieties at 120 days of sowing

3.3. Length and Width of Leaf of *Avena sativa* Varieties

The analysis conducted on various varieties of *Avena sativa* revealed statistically significant differences in both leaf length and width ($P < 0.05$). Leaf length measurements indicated a notable range, from a minimum of 34.9 cm for the CI-1506 variety to a maximum of 49.4 cm for CI-8251, which had the longest leaves recorded in this study. The second-longest leaves were found in CI-2596, measuring 47.4 cm, while CI-2291 had a leaf length of 41.5 cm (Appendix Table 1 and Figure 4). These results demonstrated considerable variability in leaf size across the examined varieties, highlighting CI-1506 as the variety with the shortest leaves.

The analysis of leaf length among the various *Avena sativa* varieties indicated significant differences in leaf dimensions (Figure 5), with varieties CI-8251 displaying significantly longer leaves ($P < 0.05$) compared to CI-2291, CI-1506, and CI-2806. Specifically, CI-1506 was found to have significantly shorter leaves ($P < 0.05$) than both CI-8251 and CI-2596, highlighting notable variability in leaf length across the examined varieties. In terms of leaf width, CI-2291 and CI-2596 not only possessed longer leaves but also exhibited significantly higher widths ($P < 0.05$) than CI-8251, CI-1506, and CI-2806. Conversely, the leaf width of CI-2806 was significantly lower ($P < 0.05$) than that of four varieties (Appendix Table 1). These findings suggest that CI-2291 and CI-2596 may benefit from enhanced capacity for photosynthesis and overall plant vigor due to their advantageous leaf dimensions (Long et al., 2006)

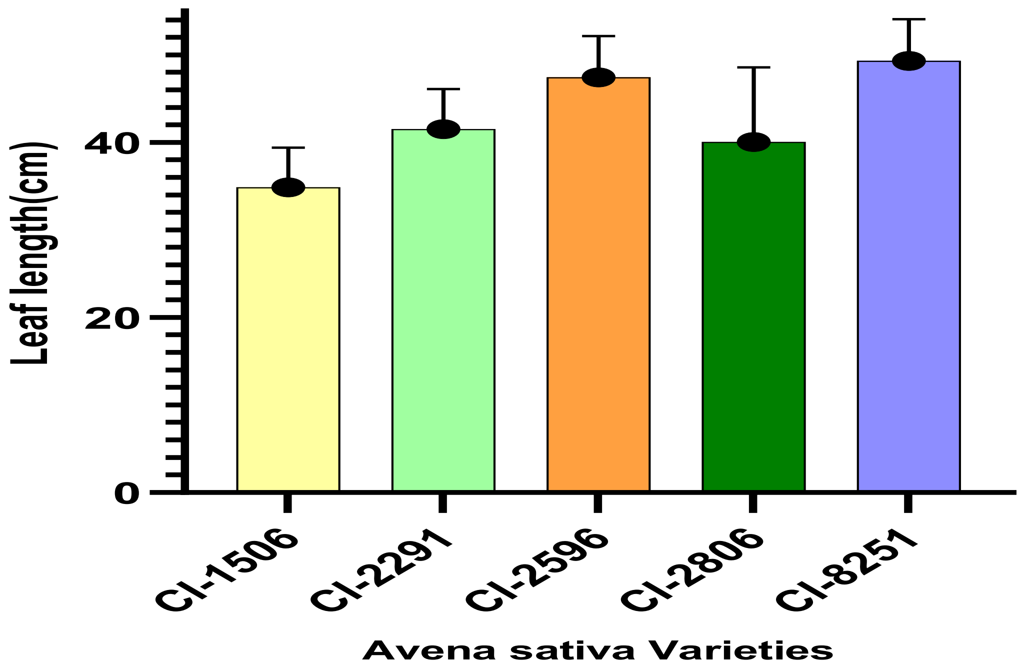


Figure 4. Leaf length of the five A. Sativia varieties

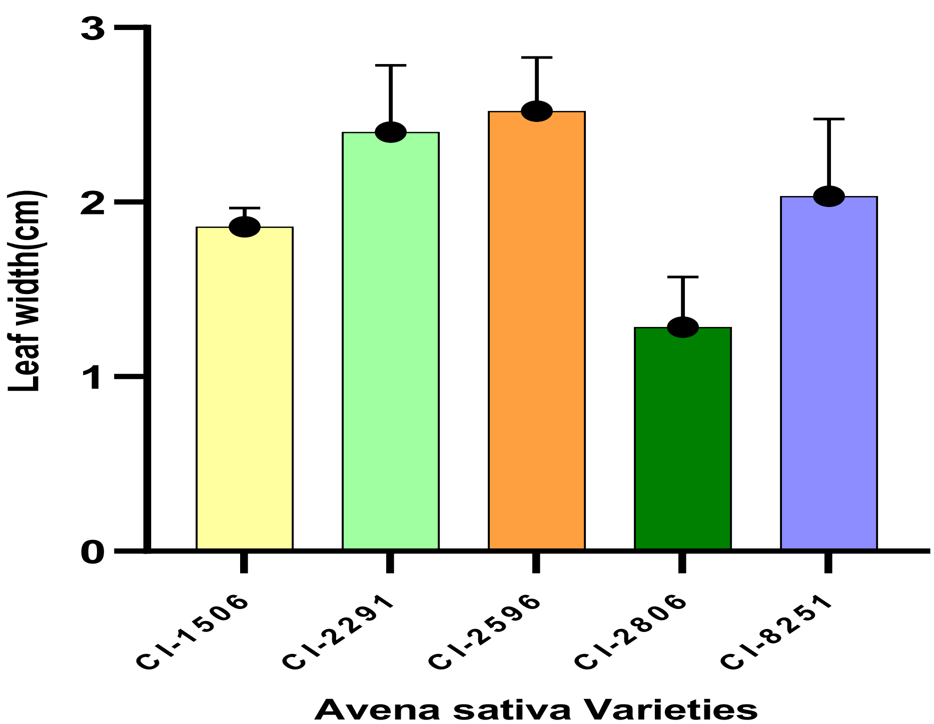


Figure 5. Leaf width of the five A. Sativia varieties

3.4. Leaf Area of *Avena sativa* Varieties

The study revealed statistically significant differences in leaf area among various *A. sativa* varieties ($P < 0.05$) (Appendix Table 1). The measurements of leaf area ranged from a minimum of 40.7 cm^2 in the CI-2806 variety to a maximum of 93.8 cm^2 in CI-2596 (Figure 6), indicating substantial variation in this important trait. Following CI-2596, variety CI-8251 exhibited a leaf area of 79.5 cm^2, while CI-2591 had a closely comparable area of 78.4 cm^2. On the other end of the spectrum, the smallest leaf areas were recorded for CI-2806 at 40.7 cm^2 and CI-1506 at 50.9 cm^2. Notably, these findings contrast with those of (Amanullah et al., 2013), who reported leaf areas ranging from 33.2 cm^2 to 479.9 cm^2 per *A. sativa* plant. This discrepancy may be attributed to various factors, including the genetic diversity of the varieties examined, differences in fertilizer application rates, the growth stages at which measurements were taken, and the adaptability of each variety to its specific environmental conditions.

The analysis of single leaf area among various *Avena sativa* varieties demonstrated significant differences, particularly with CI-2596, CI-8251, and CI-2291 exhibiting larger leaf areas compared to CI-1506 and CI-2806 ($P < 0.05$). This variation indicates a clear distinction in leaf morphology among the different varieties, suggesting that certain genetic traits contribute to enhanced leaf development. Interestingly, while CI-1506 and CI-2806 did not show a statistically significant difference in leaf area ($P > 0.05$), their smaller leaf sizes compared to the higher-yielding varieties suggest a potential correlation between leaf area and overall plant performance(Wilson et al., 1999).

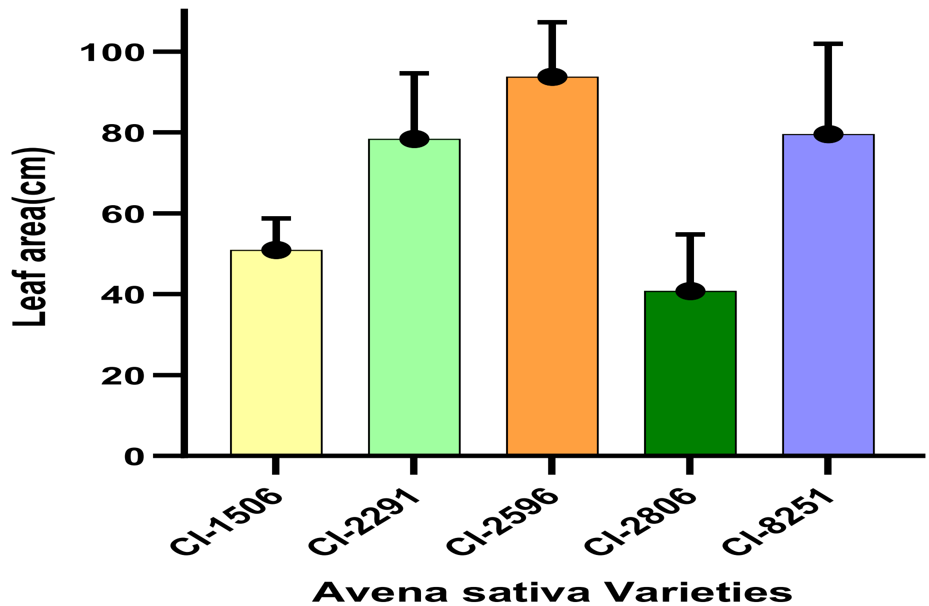
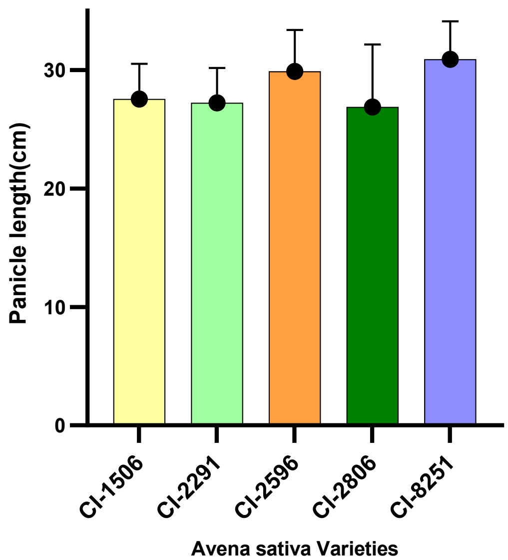


Figure 7. leaf area of the five *A. sativia* varieties at 120 days of sowing

3.5. Panicle Length and Spikelet Numbers of *Avena sativa* Varieties

The study revealed notable variations in panicle length among different *A. sativa* varieties, with measurements ranging from 26.9 cm for CI-2806 to 30.9 cm for CI-8251 (Figure 7), indicating a statistically significant difference across the varieties. Notably, CI-2596 and CI-8251 exhibited significantly longer panicles ($P < 0.05$) compared to CI-2291, CI-1506, and CI-2806 (Appendix Table 1). Additionally, the spikelet counts varied considerably, with CI-1506 producing the fewest spikelets at 10.4, while CI-8251 boasted the highest count at 21.9 (Figure 8). The findings showed that both CI-2596 and CI-8251 had significantly ($P < 0.05$) more spikelets per panicle than the other varieties, contributing to a markedly higher seed yield. In contrast, CI-1506 displayed a significantly lower ($P < 0.05$) spikelet count per panicle, which likely limits its yield capacity. Interestingly, the spikelet number for CI-8251 in this study (21.9) exceeded the figure recorded in a previous study (17.8) (Tessema & Getinet, 2020). Overall, these results highlight the critical role of panicle length and spikelet number in determining the productivity of *A. sativa*, emphasizing the importance of selecting high-performing varieties for improved forage production (Parida et al., 2022).



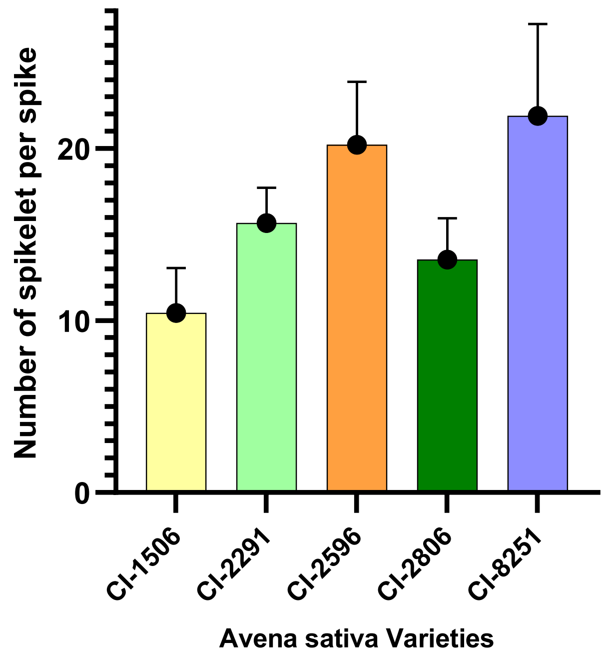


Figure 8. Panicle length of the five the *A. sativia* varieties **Figure 9.** Number of spikelets per spike of the five *A. sativia* varieties

3.6. Dry Matter Yield of *Avena sativa* Varieties

Analysis of dry matter yields among various *A. sativa* varieties revealed statistically significant differences (P < 0.05), with yields ranging from 8.4 to 14.2 t/ha (Figure 9). The CI-2596 variety emerged as the highest-yielding variety, producing 14.2 tons per hectare (t/ha), while CI-2291 and CI-8251 yielded intermediate amounts. In contrast, the CI-1506 variety had the lowest yield of 8.4 t/ha. Notably, both CI-2291 and CI-2596 varieties demonstrated significantly higher (P < 0.05) yields than the other varieties tested, including CI-8251, CI-1506, and CI-2806. Furthermore, CI-1506 and CI-2806 yielded significantly lower yields (P < 005) than CI-8251, highlighting a clear disparity in yield performance among the varieties. The dry matter yields recorded in this study differ markedly from those reported by (Kebede et al., 2020), and the yields for the *Avena sativa* varieties CI-1506, CI-2291, CI-2596, CI-2806, and CI-8251 ranged from 14.3 to 15.4 t/ha, which were significantly higher than the yields observed in the present study.

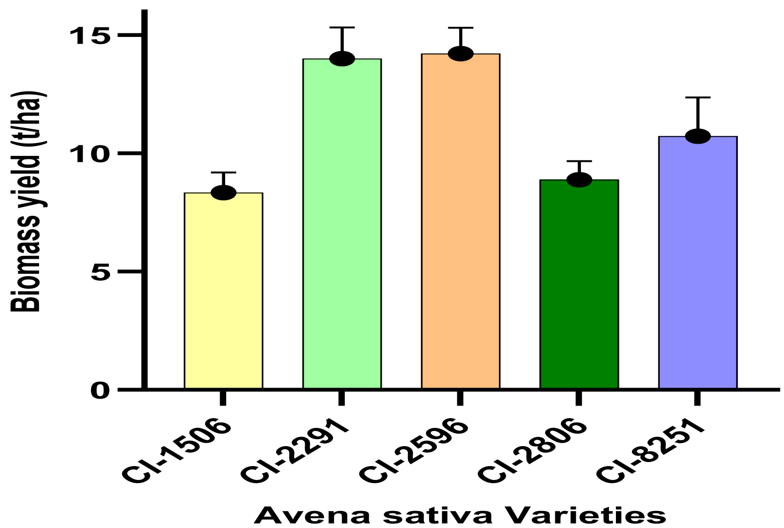
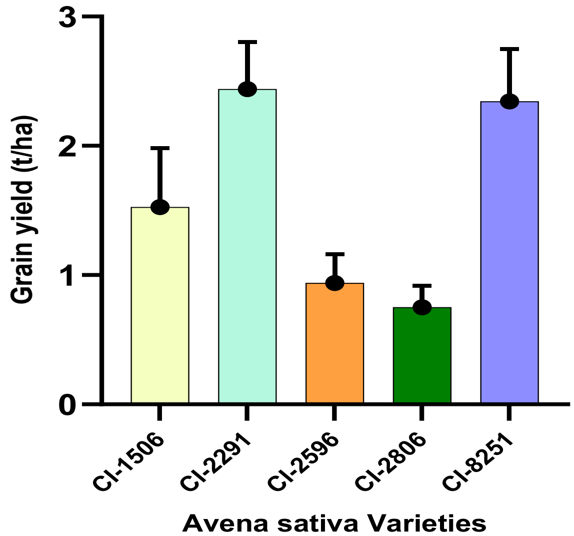


Figure 10. The biomass yield of the five *A. Sativia* varieties at 120 days of sowing

3.7. Seed and Straw Yield of *Avena sativa* Varieties

The seed yields of five A. sativa varieties evaluated in this study exhibited considerable variability, ranging from 0.75 to 2.40 t/ha, with an average yield of 1.60 t/ha (Figure 10). Among the tested varieties, CI-2291 was identified as the top performer, yielding the highest quantity of seeds, followed by CI-8251, CI-1506, CI-2596, and CI-2806. The growth metrics for the *A. sativa* varieties CI-2291 and CI-8251 exhibited notable enhancements, including increased leaf area and tiller number. This improved efficiency is associated with increased rates of photosynthesis, leading to higher dry matter accumulation, and consequently, higher seed yields (Siloriya et al., 2014). Conversely, the CI-2596 variety showed a significantly lower mean seed yield ($P < 0.05$) compared to CI-2291 and CI-8251. In the present study, there were significant variations in straw yield among different varieties of *A. sativa*. The recorded straw yields for CI-1506, CI-2291, CI-2596, CI-2806, and CI-8251 were 10.3, 16.0, 6.0, 5.0, and 15.5 t/ha, respectively (Figure 11). These results differ markedly from those reported in earlier research by (Kebede et al., 2021), which documented straw yields of 12.1, 7.7, 10.3, 11.7, and 10.1 tons per hectare for the same varieties.



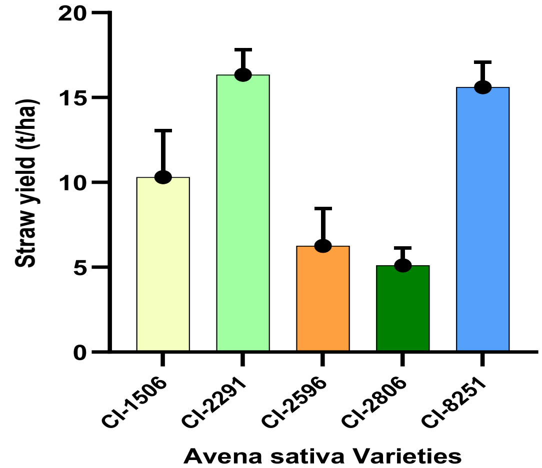


Figure 12. Biomass yield of the five *A. sativia* varieties **Figure 13.** Straw yield of the five *A. Sativia* varieties

4. DISCUSSIONS

4.1. Height of *Avena sativa* Varieties

The observed differences in plant height among *A. sativa* varieties underscore the significance of genetic factors in influencing growth and biomass yield. The notable heights of CI-2596, CI-8251, and CI-2291 suggest that these varieties possess higher genetic traits that may contribute to better growth performance under the conditions tested. This aligns with the findings of (Dhumale & Mishra, 1981; Yiberkew et al., 2020), who emphasized the importance of plant height in relation to biomass yield. Interestingly, the average heights recorded in this study were lower than those reported by (Beyene et al., 2015), which raises questions regarding the factors influencing plant growth in different environments. The observed differences in plant height can be primarily attributed to the genetic diversity inherent in *A. sativa* varieties, which affects their growth potential (Gebremedhn Beyene et al., 2015). The comparable heights of certain *A. sativa* varieties to those previously reported by (Kebede et al., 2021) indicate the reliability of the current findings within the broader context of *A. sativa* research, suggesting a stability in the growth performance of these varieties across different studies. However, the significantly shorter heights of varieties such as 579-D-27 compared to taller ones highlight the importance of genetic diversity in *A. sativa.* (Alemu & Amare, 2016) noted that such disparities reflect the inherent genetic potential of each variety. Furthermore, taller varieties such as 80-SA95 and Lampton, which reached heights exceeding those observed in this study, exemplify the upper limits of growth potential under optimal conditions (Beyene et al., 2015).

Variations in the sowing timing and soil fertility contribute to these discrepancies. For instance, soil fertility is known to affect nutrient availability, which in turn can influence growth outcomes (Zaman et al., 2006). Additionally, specific climatic conditions, such as temperature and rainfall patterns during the growth period, may also play a role in limiting plant height (Lodhi et al., 2009). As suggested by (Ali et al., 2016; Zaman et al., 2006), environmental factors can significantly influence the hormonal balance and cell division rates in plants. For example, variations in temperature, moisture, and nutrient availability can affect plant development and ultimately lead to differences in height (Onwuka & Mang, 2018). The interaction of these factors with genetic characteristics further complicates the understanding of growth patterns in *A. sativa.*

4.2. Number of Tillers per Plant

The significant differences in tiller production observed in the present study underscore the potential impact of tiller number on biomass yield (Beyene et al., 2015). The leading varieties, CI-2291 and CI-8251, demonstrate that higher tiller counts can enhance photosynthetic capacity, thereby improving overall growth and productivity. This is consistent with the findings of (Rotili et al., 2024), who emphasized that increased tillering correlates with higher photosynthetic activity and biomass accumulation. The lack of statistically significant differences between the CI-1506 and CI-2806 varieties suggests that they share similar genetic traits or environmental adaptability that facilitate optimal tiller development (Wada et al., 2019). The poor performance of CI-1506 and CI-2806 indicates that these varieties may possess inherent limitations in tiller production, which could hinder their potential biomass yield (Beyene et al., 2015).

The diversity observed among *Avena sativa* varieties is a key factor contributing to the differences in tiller production. As indicated by (Beyene et al., 2015), variations in traits can significantly influence physiological processes, such as how efficiently a plant can uptake nutrient and establish growth patterns. These physiological differences are crucial because they directly affect a plant's ability to produce tillers. Tiller production is an important determinant of overall biomass yield, and understanding the genetic traits associated with this characteristic is vital for breeding programs aimed at enhancing the productivity of *Avena sativa*. As noted by (Singh et al., 2020), targeted breeding strategies that prioritize the selection of varieties with higher genetic traits related to tillering can optimize forage production. Such strategies may lead to the cultivation of varieties that not only produce more tillers, but also require fewer inputs, ultimately enhancing the sustainability of forage production. This approach aligns with the increasing global demand for food, necessitating improved crop yields through the identification and utilization of high-performing genetic traits (Singha & Singha, 2024).

The need for further exploration of the genetic basis of tiller formation cannot be overstated. (Li et al., 2021) highlighted that a deeper understanding of the molecular mechanisms that regulate tiller development can provide critical insights for breeding programs. Identifying specific genes and genetic markers associated with robust tiller production could pave the way for innovative breeding techniques that enhance the yield potential of *Avena sativa*. The genetic basis of tiller production in *Avena sativa* varieties plays a crucial role in shaping their growth patterns and responses to environmental stimuli. Different varieties possess inherent genetic traits that dictate their ability to adapt and thrive under various conditions. As highlighted by (Bhardwaj et al., 2024), these traits not only influence growth rates but also determine how effectively plants can respond to factors such as soil quality, nutrient availability, and climatic conditions. For instance, certain varieties may exhibit a genetic predisposition to produce more tillers, which is beneficial for biomass yield and overall productivity. (Wang et al., 2017) emphasize that enhanced tiller production can lead to a more robust biomass yield, making these traits critical for successful crop cultivation.

4.3. Length, Width and Area of Leaf of *Avena sativa* Varieties

The overall average leaf length in these studies is consistent with those of (Amanullah et al., 2013), who reported an average leaf length of 42.7 cm for *A. sativa*. This alignment with previous research implies that soil quality, moisture levels, and climatic influences may play crucial roles in leaf growth and elongation. Genetic diversity among *A. sativa* varieties is likely a contributing factor to the observed variations in leaf length, suggesting that selective breeding could enhance desirable traits such as leaf length (Joshi et al., 2001). Varieties with longer leaves, such as CI-8251 and CI-2596, may exhibit better photosynthetic capacity, potentially leading to improved biomass accumulation and grain yield (Joshi et al., 2001). According to (Lawson & Blatt, 2014), leaf length plays a crucial role in determining plant photosynthetic efficiency. Larger leaves typically capture more sunlight, facilitating increased photosynthesis rates, which in turn contributes to higher biomass production (Vogelmann & Gorton, 2014). This is particularly important for crops, such as *A. sativa*, where maximizing growth and yield is vital for meeting feed or food production demands (Albahri et al., 2023).

The significant variation in leaf width observed in this study is critical because these traits directly influence a plant's photosynthetic efficiency, growth, and yield potential. Longer and broader leaves, such as those found in CI-2291 and CI-2596, can enhance the ability of a plant to capture sunlight, which is essential for maximizing photosynthetic activity. (Long et al., 2006) emphasize that the relationship between leaf width and photosynthesis is fundamental to understanding plant productivity. The findings of this study support this notion, as the higher leaf width of certain varieties may confer a competitive advantage in terms of light interception and resource utilization. Furthermore, the absence of significant differences in leaf width between some varieties indicates a level of stability in certain traits, suggesting that breeding programs could focus on enhancing specific leaf characteristics to optimize performance (Albahri et al., 2023). The ability to select and breed varieties with favorable leaf traits is crucial, particularly in forage settings that maximize biomass yield and improve resilience to environmental stressors are key objectives. (Wang et al., 2016) highlight the importance of leaf characteristics in influencing a plant's overall growth and yield potential. By identifying varieties with higher leaf dimensions, farmers can improve the forage productivity and adaptability of *A. sativa*, ultimately contributing to sustainable forage production.

Understanding variations in leaf area is essential, as larger leaf areas can significantly enhance a plant's capacity for photosynthesis, thereby leading to improved growth and yield potential. (Walker et al., 2014) highlighted that the relationship between leaf area and photosynthetic efficiency is crucial for maximizing crop productivity. The discrepancies in leaf area measurements compared to previous studies, such as those by (Amanullah et al., 2013), suggest agronomic practices and environmental conditions (Lodhi et al., 2009). The significant differences in leaf area among the *A. sativa* varieties can largely be attributed to their unique characteristics and adaptability to varying environmental conditions, as noted in a previous study by (Lodhi et al., 2009). The larger leaf areas observed in CI-2596, CI-8251, and CI-2291 were indicative of their higher genetic traits, which might confer advantages in competitive growth scenarios.

4.4. Panicle Length and Spikelet Numbers of *Avena sativa* Varieties

Varieties such as CI-2596, which have both longer panicles and a higher number of spikelets (Figure 7 and 8), suggests that these varieties are particularly well suited for high-yield environments (Chapko & Brinkman, 1991). This is an important consideration in *A. sativa* breeding programs aimed at maximizing forage biomass productivity (Figure 9). Panicle length is a critical morphological trait because longer panicles generally have the potential to carry more spikelets, thereby increasing the overall number of seeds produced (Finnan et al., 2019). However, the results suggest that panicle length alone may not be as crucial as spikelet count when considering a variety's yield potential (Stephens, 1942).

The variation in spikelet count, particularly the large difference between CI-1506 and CI-8251, further emphasizes the role of this trait in determining seed yield. Higher spikelet numbers per panicle, such as those seen in CI-8251 (21.9), directly translate to more potential seeds (Appendix Table 1), which is a key factor in maximizing the yield of seed production. This pattern is consistent with general agricultural principles, in which a higher number of spikelets per panicle is often associated with higher overall seed yield (Tolk & Schwartz, 2017). An important aspect of the study was that the increased spikelet count of CI-8251 in this study was higher than that reported by (Tessema & Getinet, 2020), which was 17.8 spikelets. This increase could be attributed to better environmental conditions (such as optimized soil fertility, irrigation, or pest management. This difference underscores the dynamic nature of agricultural production, in which both environmental and genetic factors interact to influence crop performance (Savicki et al., 2023).

4.5. Dry Matter Yield of *Avena sativa* Varieties

The results of this study provide compelling evidence for the importance of varietal selection in optimizing the dry matter yield of *A. sativa*. The significantly higher yields of the CI-2596 and CI-2291 varieties suggested that these cultivars may possess morphological advantages, particularly in terms of plant height, number of tillers, and leaf area (Appendix Table 1). Previous research supports this hypothesis, indicating that enhanced dry matter yields in *A. sativa* are closely associated with higher leaf area which facilitate photosynthesis (Irvine, 1975). The ability of these high-yielding varieties to capture more sunlight translates into enhanced photosynthetic efficiency, allowing the accumulation of larger amounts of assimilates. This increased efficiency is a critical factor contributing to the higher dry matter yield (Bhardwaj et al., 2024).

The differences in dry matter yields between the present study and those reported by (Kebede et al., 2021) can be attributed to the rate of fertilizer application, which has been shown to significantly affect plant growth and nutrient availability. As noted by (Reddy et al., 2023), optimal fertilizer management can enhance the nutritional status of plants, thereby improving growth and yield. Inconsistent fertilizer practices across different studies could explain the observed yield variations (Abay et al., 2022). Another important factor is the timing of harvesting. Plants harvested at the optimal maturity stages typically yield more dry matter than those harvested too early or too late. (Desta, 2024a) Emphasized the significance of harvesting practices in maximizing the yield potential, suggesting that timing can be a critical determinant of the overall productivity of *A. sativa* cultivars.

4.6. Seed and Straw Yield of *Avena sativa* Varieties

The significant variability observed in seed yields among the different *A. sativa* varieties can be primarily attributed to hereditary differences. CI-2291 and CI-8251 were identified as the top performers in terms of seed and straw yields, which can be explained by their favorable growth traits, such as the number of tillers (Appendix Tables 1 and 2). These characteristics corroborate previous studies (Zarrough et al., 1983), which identified a correlation between seed yield and tillering capacity in A. sativa varieties, contributing to increased plant biomass and higher seed production. The discrepancies in both seed and straw yields between this study and earlier studies by (Kebede et al., 2020) can be attributed to several factors, including differences in soil fertility, agronomic practices (e.g., seed rate and fertilizer application), and environmental adaptability of the varieties. For example, variations in seed and fertilizer application rates may lead to differences in crop performance, particularly in terms of nutrient availability, which can directly affect both seed and straw yields (Malhi et al., 2011). Additionally, environmental factors such as rainfall patterns and temperature fluctuations could have varied between the years of the study, further influencing the overall productivity of the varieties (Patton et al., 2007).

4. CONCLUSIONS

The findings revealed distinct characteristics across different varieties of *Avena sativa*, each exhibiting specific traits that set them apart in terms of yield and growth performance. The variety CI-2291 had the greatest number of tillers per plant, which contributed significantly to its higher seed and straw yields than the other varieties. This characteristic makes CI-2291 the best performer in terms of both seed and straw production, highlighting its potential for high forage biomass production. In contrast, the variety CI-8251 excelled in terms of leaf length, panicle length, and number of spikelets per panicle. These traits suggest that CI-8251 may have advantages in terms of its overall reproductive structure, which could influence its potential to increase seed production under certain growth conditions. CI-2596 was distinguished by its higher plant height, leaf width, leaf area, and dry matter yield. The increased dry matter yield in this variety can be attributed to its larger plant size and broader leaf structure, which likely enhance its photosynthetic capacity. The higher plant height and leaf width of this variety were important factors in its higher biomass accumulation, making it particularly favorable for use when dry matter yield is a priority. In general, CI-2596 exhibited the greatest dry matter yield owing to its larger plant structure and leaf dimensions, CI-2291 was the leading variety for seed and straw yield because of its higher tiller production. The strength of each variety makes it suitable for different agricultural goals, with CI-2596 being ideal for high biomass production, and CI-2291 for maximizing seed and straw yield.

Declaration

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Appendix Table 2. Mean performance of various *A. sativa* varieties in the study area

Agronomic Traits

Varieties	Plant height(m)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Number of tillers per plant	panicle length(cm)	Number of Spikelet per panicle	Biomass yield (t/ha)
CI-1506	0.9 ± 0.1^{c}	34.9 ± 1.9^{c}	1.9 ± 0.2^{b}	50.9 ± 5.8^{c}	4.8 ± 1.1^{b}	27.6 ± 1.3^{b}	10.4 ± 1.1^{c}	8.4 ± 2.4^{c}
CI-2291	1.2 ± 0.1^{ab}	41.5 ± 1.4^{bc}	2.4 ± 0.1^{a}	78.4 ± 4.1^{b}	7.9 ± 0.7^{a}	27.3 ± 0.9^{b}	15.4 ± 0.7^{b}	14.0 ± 2.4^{a}
CI-2596	1.3 ± 0.1^{a}	47.4 ± 1.9^{ab}	2.5 ± 0.2^{a}	93.8 ± 6.5^{a}	6.1 ± 1.1^{a}	30.0 ± 1.3^{a}	20.2 ± 1.1^{a}	14.2 ± 2.4^{a}
CI-2806	1.1 ± 0.1^{bc}	40.0 ± 1.9^{bc}	1.3 ± 0.2^{c}	40.7 ± 5.8^{c}	3.9 ± 1.1^{b}	26.9 ± 1.3^{b}	13.6 ± 1.1^{b}	8.9 ± 2.4^{c}
CI-8251	1.2 ± 0.1^{ab}	49.4 ± 9^{a}	2.0 ± 0.2^{b}	79.5 ± 5.8^{b}	7.4 ± 1.1^{a}	30.9 ± 1.3^{a}	21.9 ± 1.1^{a}	10.7 ± 2.4^{b}
Overall	1.2 ± 0.1^{ab}	42.5 ± 1.4^{bc}	2.1 ± 0.2^{b}	68.7 ± 4.1^{ab}	6.3 ± 1.1^{a}	28.3 ± 1.3^{b}	16.0 ± 1.1^{b}	11.2 ± 2.4^{b}

Means within the same column with different superscript letters are significantly different (P < 0.05) among Avena sativa varieties.

Appendix Table 3. Grain and straw production of *A. sativa* varieties in the study areas

Varieties	Grain yield (t/ha)	straw yield (t/ha)
CI-1506	1.53 ± 0.17^{b}	10.25 ± 0.97^{b}
CI-2291	2.40 ± 0.13^{a}	16.35 ± 0.52^{a}
CI-2596	0.93 ± 0.08^{c}	6.26 ± 0.78^{c}
CI-2806	0.75 ± 0.06^{c}	5.11 ± 0.36^{c}
CI-8251	2.34 ± 0.15^{a}	15.60 ± 0.52^{a}
Overall	1.60 ± 0.07^{b}	10.55 ± 0.00^{b}

Means within the same column with different superscript letters are significantly different (P < 0.05) among Avena sativa varieties