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A Promising Genotype of *Lepidium sativum* for Enhanced Yield and Agronomic Performances Under Optimal Growth Conditions

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Abstract: *Lepidium sativum*, commonly known as garden cress, is a notable traditional medicinal plant within the Brassicaceae family, widely recognized for its health benefits in the globe. This study aimed to identify the seed colour variant best suited to the climate of Ethiopia, specifically in the Ataye region, by examining various agronomic traits. We conducted a comprehensive analysis of two distinct seed colour variants (brown and light blue) following standard agronomic protocols. Results indicated that the brown seed variant outperformed the light blue variant across multiple agronomic traits, demonstrating a shorter time to 50% germination, flowering, and maturation. Statistically significant differences were observed in these parameters. Additionally, plants derived from brown seeds exhibited superior growth characteristics, including greater plant height, longer primary branch length, and a higher number of primary branches per plant compared to those from light blue seeds. Furthermore, the brown seed variant displayed increased productivity, with more pods and seeds per plant, a greater one thousand seed weight, and a higher overall yield. The only traits showing no significant differences were the number of secondary branches per plant and internode length. Overall, the brown seed variant demonstrated strong adaptability to the Ataye climatic conditions, excelling in yield per hectare as well as in the number of seeds and pods produced. Based on these findings, we recommend the cultivation of brown seed colour variants for optimal performance in Ataye region, Ethiopia.

Keywords: agronomic traits; Ataye, Ethiopia; *Lepidium sativum*; optimum growth conditions; seed colour variants

Academic Editors: Yuyang Zhang and Luigi De Bellis

Received: 9 December 2024
Revised: 27 January 2025
Accepted: 28 January 2025
Published: 1 February 2025

Citation: Mohammed, S.; Tiku, K.; Daniel, F. A Promising Genotype of *Lepidium sativum* for Enhanced Yield and Agronomic Performances Under Optimal Growth Conditions. *Horticulturae* **2025**, *11*, 153. https://doi.org/10.3390/horticulturae11020153

1. Introduction

Garden cress (*Lepidium sativum* L.), known locally as fetto in Amharic and shimfu in Afaan Oromo, is a member of the Brassicaceae family and is revered as a traditional herbal healer for various ailments, particularly by rural populations in Ethiopia [1–3]. In recent years, there has been a global surge in interest regarding the health benefits of herbs and botanicals, with garden cress gaining recognition for its potential to alleviate nutritional deficiencies and its medicinal properties [3–5]. This aromatic plant is valued not only for its edible uses but also for its substantial content of essential oils, which contribute to its therapeutic effects [3]. Geographically, garden cress is utilized as a vegetable (in sprout form) across North Africa, West and Central Asia, and the United Kingdom, in addition to its significant medicinal applications. Research has identified the highland regions of Ethiopia and Eritrea as critical centres of origin and diversity for this plant, highlighting its cultural and economic importance in these areas [6–9]. Despite its potential, genetic improvement programmes for garden cress have been poorly established in both developed and developing countries [3], thereby reflecting its status as a neglected or under-utilized horticultural crop [1–3].

The morphological characteristics of garden cress seeds include their brown and light blue colour and elliptic shape with spatulate embryos [10]. The yellow seed colour variant of *L. sativum* is notable in Ethiopia; however, it is absent in the Ataye region. Consequently, this particular variant is not addressed in the current study. Previous studies have demonstrated that the seeds exhibit rapid germination at optimal temperatures, with minimal dormancy [10]. Furthermore, research has identified significant variations among various agronomic traits of *L. sativum*, such as shoot dry weight, petiole length, and days to flowering, highlighting the potential for selective breeding to enhance these attributes [9].

Despite this existing knowledge, a significant research gap remains regarding the selection of optimal seed colour variants of garden cress that can thrive in the specific climatic conditions of the Ataye region in North Shewa Zone, Ethiopia. There is limited information on the adaptability and performance of different seed colour variants in relation to agronomic traits and overall yield, especially in regions prone to agricultural challenges and disease risks. The current study aims to fill this gap by evaluating the performance of brown and light blue seed colour variants of garden cress in the Ataye region, focusing on their agronomic traits and yield. By identifying the more adaptable seed colour variant, this research not only contributes to agricultural knowledge but also assists local communities in maximizing the medicinal benefits of garden cress for treating various ailments, ultimately enhancing local livelihoods and health.

2. Materials and Methods

2.1. Seed Sources and Growing Conditions

In the Ataye region of the North Shewa Zone, we identified two distinct seed colour variants of *L. sativum*: brown and light blue. These seeds were freshly harvested from local farmers' cultivation areas, ensuring that the environmental conditions were consistent across collection sites. Upon collection, the seeds underwent a seven-day air-drying period at room temperature. Following this, we conducted viability assessments to evaluate seed quality. To maintain the fresh status of seeds, the seeds were stored at −20 °C until the commencement of experiments, adhering to protocols established by Baskin and Baskin [11] and Mohammed et al. [12]. The experimental trials were carried out at the Ataye Farmers Training Center from May to August 2022. Seeds were sown on May 5, 2022, following established agricultural practices. This duration allowed for optimal growth conditions, and data collection aligned with the specific phenological stages of the crops under investigation. The predominant soil types in the Ataye region are pellic vertisol, vertic cambisol, and rendzinas. Our experiments utilized natural soil conditions, without the addition of fertilizers and irrigation, to closely replicate the agricultural practices employed by local farmers in cultivating *L. sativum*. This approach ensured that our findings would be relevant and applicable to the farming community in the region.

2.2. Study Area: Ecological Setting

The study was conducted in Ataye, located in the Amhara Regional State of Ethiopia, specifically within the Efratana Gidim of the North Shewa Zone (Figure 1). Ataye is situated 269 km north of Addis Ababa and 139 km north of Debre Berhan (Figure 1). The region's climate is classified as (Aw) according to the Köppen–Geiger system, characterized by distinct wet and dry seasons. Rainfall is significantly lower during the winter months compared to the summer. The average annual temperature and precipitation for Ataye are 21.7 °C and 1085 mm, respectively. December experiences the least rainfall, averaging 22 mm, while August is marked by peak precipitation averaging 244 mm. June is the hottest month, with an average temperature of 25.4 °C, while December records the lowest average temperature of 18.7 °C (Figure 2).

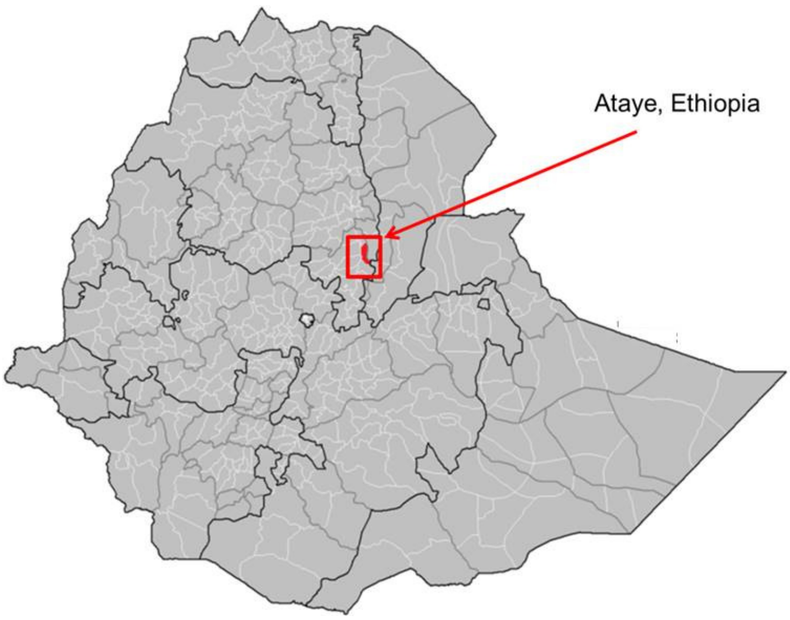

Figure 1. Map of Ethiopia highlighting the Ataye region, featuring the distribution of seed colour variants of *L. sativum*. Different seed colours represent the distinct seed colour variants observed in the region, illustrating the biodiversity of this species within the region.

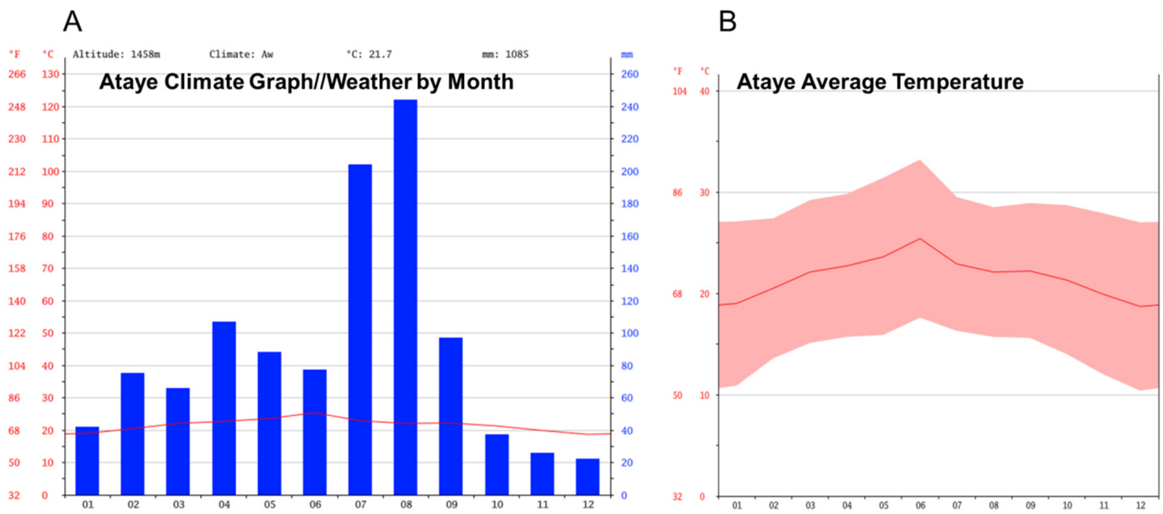

Figure 2. Climate conditions of Ataye, Amhara Regional State, Ethiopia. (**A**) Monthly climate graph illustrating the temperature and precipitation trends throughout the year. (**B**) Average monthly temperature data for Ataye, with January represented as month 01 and December as month 12.

(Source: https://en.climate-data.org/africa/ethiopia/amhara/ataye-928331/, accessed on 12 May 2022).

2.3. Field Experimental Design

The experimental setup was based on a split plot randomized complete block design (RCBD) with three replications (Figure 3). The field trials were conducted at the Ataye Farmer Training Center, utilizing a plot area measuring 5.5 m × 4.75 m for planting the two colour variants of *L. sativum*. For each seed colour variant, three replicates (blocks) each containing 50 seeds were sown, with a spacing of 25 cm between seeds. Each block consisted of 50 plants, with an inter-plant and inter-row spacing of 25 cm (Figure 3). To facilitate agronomic evaluations, five individual plants were randomly tagged within each block, resulting in a total of 15 tagged plants per seed colour variant across the three replicates.

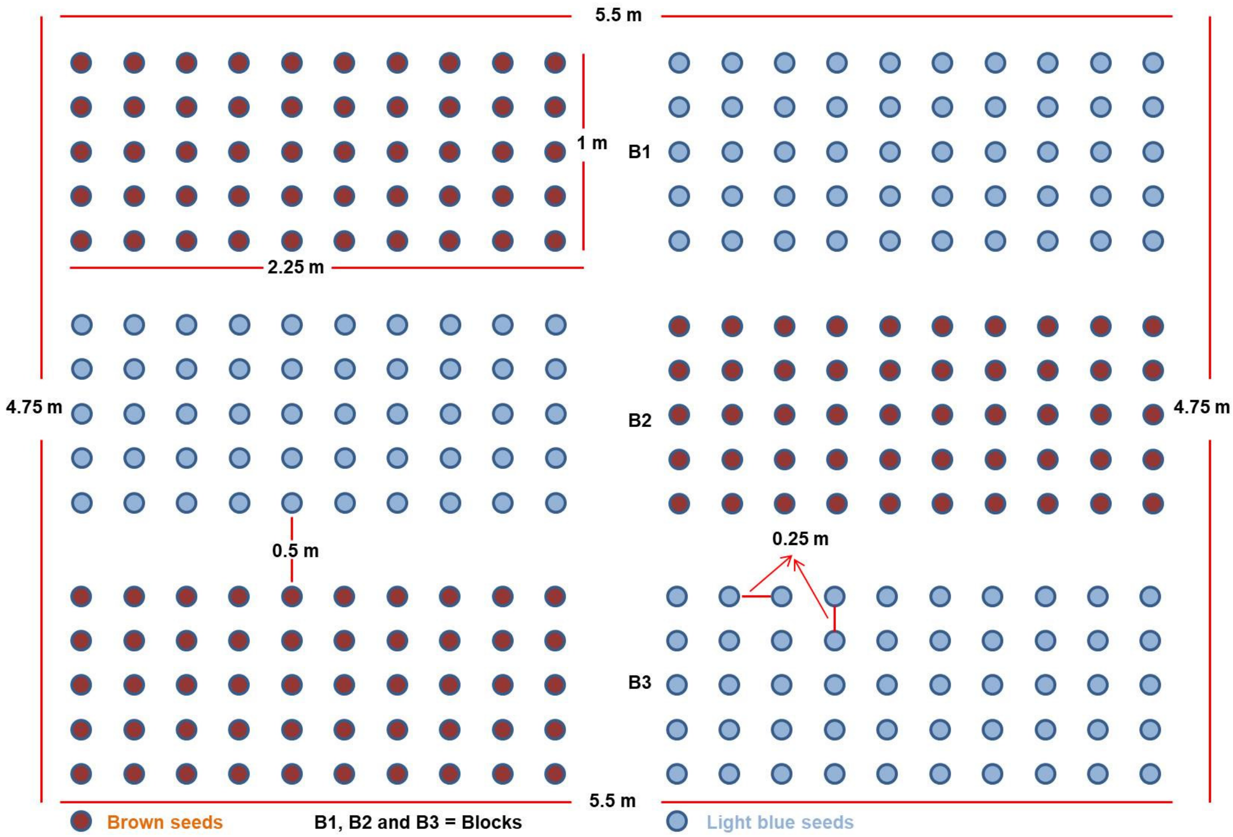

Figure 3. Experimental plot design for the study of agronomic traits in Ataye region. Two seed colour variants of *L. sativum* were sown in three replicates, with each replicate consisting of 50 seeds. Each plot occupied a land area of 1 m × 2.25 m, allowing for a standardized assessment of growth and development across the distinct variants.

2.4. Data Collection and Sampling Procedures

This study utilized primary data sources for the collection of agronomic traits. Data were recorded following the protocols established by Baza et al. [13]. All seeds sown in this study were monitored to record key growth parameters, including 50% days to germination, 50% days to flowering, days to maturity, and overall yield (Table 1). All sown seeds successfully germinated. To collect data on additional agronomic traits, a simple random sampling technique was employed, ensuring that the sample accurately represents the overall population. This approach facilitated the reliable assessment of the agronomic characteristics of the plants. For sample size and sampling techniques, 15 plants were tagged from each seed colour variant for agronomic assessments. Five plants from each block were randomly selected and tagged for further agronomic evaluation. The following agronomic traits were systematically collected and analyzed (Table 1). This structured approach ensures reliable and replicable results, contributing to the overall understanding of the adaptability and performance of two seed colour variants of *L. sativum* in the Ataye region.

Table 1. Quantitative agronomic traits of the two seed colour variants of *L. sativum*. This table summarizes key measurements including plant height, number of branches, pod count, seed weight, and yield, providing a comprehensive overview of the agronomic performance of each seed colour variant.

Variable	Data Recording Criteria
Days to germination (50%)	The number of days from planting until 50% of seeds germinate when visible protrusion of the radicle was recorded as the completion of germination.
Days to flowering (50%)	Number of days from the date of sowing to the date at which 50% of the plants in the plot showed blooming on about 50% of their flower buds.
Days to maturity	The number of days from the date of sowing to the stage when plants have reached their physiological maturity.
Plant height	The height of plants in each plot measured in cm from the ground surface to the top of the main stem at maturity.
Number of primary branch/plant	The average number of primary branches/plant.
Number of secondary branch/plant	The average number of secondary branch formed on primary branch/plant.
Length of primary branch/plant	The average length of randomly selected 3 primary branches per plant.
Number of seeds/plant	The average numbers of seed taken from five randomly selected plants that were tagged to take the whole quantitative data.
1000 seed weight	The weight in g of 1000 seeds sampled from each plot
Number of pods/plant	The average number of pods taken from 5 randomly selected plants per plot.
Inter node length	Measured as the average of 3 internodes distances randomly (from the base, middle, and upper parts) on the same stalk from the same plant.
Leaf length	The length of 5 purposively selected leaves/plant
Yield	Yield of accessions in kg/ha

2.5. Data Analysis

Data analysis was performed using one-way ANOVA to evaluate the differences in agronomic traits between the two seed colour variants. Statistical analyses were conducted using SPSS version 22 to assess the agronomic traits evaluated. For graphical representation and mean comparisons of the experiments, SigmaPlot version 13 (Systat Software, San Jose, CA, USA) was utilized. Quantitative data were transformed as necessary, and significant differences among means were determined using the Tukey homogeneity test at a 0.05 level. This rigorous statistical approach ensures a comprehensive understanding of the relationship between the two seed colour variants and their respective agronomic performance.

3. Results

3.1. Comparative Germination, Flowering, and Maturation Traits of Brown and Light Blue Lepidium sativum Seeds

The brown seeds germinated, on average, 3.7 days faster than the light blue seeds of *L. sativum*. These result showed that the light blue seeds delayed their germination, and this was significanlty different from the brown seed colour variant ($p < 0.001$, Figure 4A). The brown seeds of *L. sativum* produced flowers, on average, 76 days faster than the light blue seeds of *L. sativum*. Similar to (50%) germination, the brown seeds were rapidly flowering (50%), and this was siginicantly different from the light blue seeds ($p < 0.001$, Figure 4B). Again, the brown seeds mature faster, in 90 days, than the light blue seeds. This result showed that the light blue seeds delayed their maturation time, and this was statistically significantly ($p < 0.001$, Figure 4C).

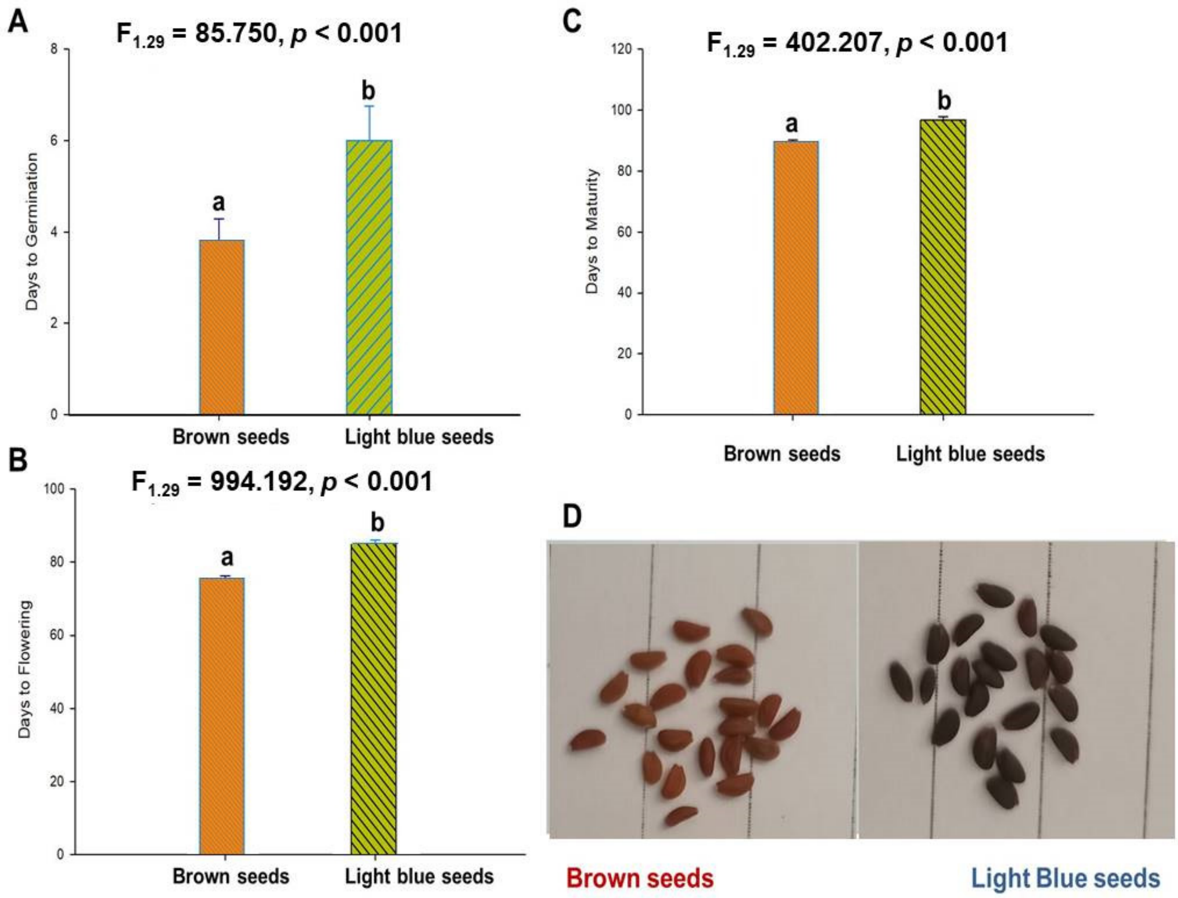

Figure 4. Agronomic traits of two seed colour variants of *L. sativum*. (**A**) Days to reach 50% germination, (**B**) days to reach 50% flowering, (**C**) days to maturation, and (**D**) visual comparison of the brown and light blue seed colour variants. These traits provide insights into the growth and development patterns associated with each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pairwise multiple comparison test ($p < 0.05$).

3.2. Distinct Growth and Morphological Characteristics of Brown and Light Blue Lepidium sativum Plants

The brown seeds of *L. sativum* plants were taller in plant height (66 cm) than plants from the light blue seeds. Results from the plant heights of plants obtained from the two seed colour variants showed that there was statistically significant differences between the two seed colour variants ($p = 0.020$, Figure 5A). Similarly, taller primary branch length (31 cm) was reported in plants from brown seeds than plants from the light blue seeds. Furthermore, there was statistically significant differences between the two seed colour variants ($p = 0.047$, Figure 5B) in primary branch length.

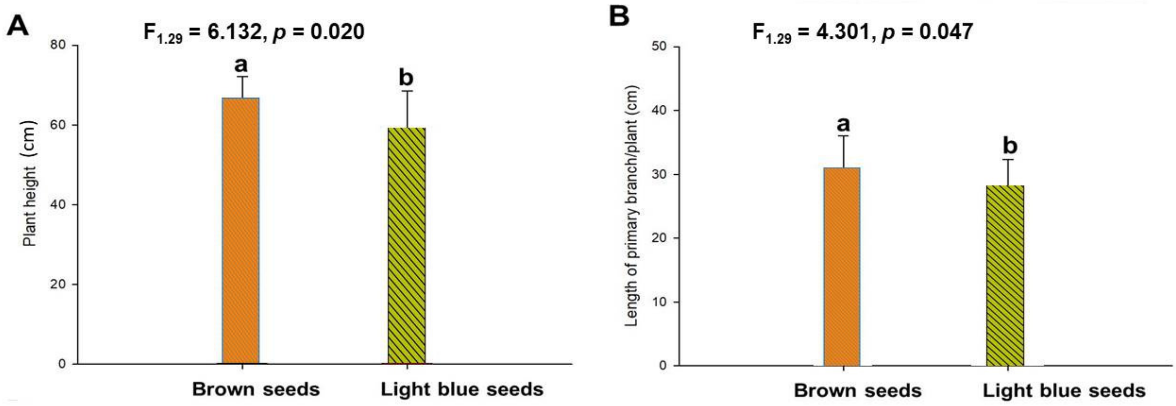

Figure 5. Agronomic traits of the two seed colour variants of *L. sativum*. (**A**) Measurement of plant height for each variant and (**B**) length of the primary branch per plant. These metrics are crucial for evaluating the growth performance and agronomic traits associated with each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pair-wise multiple comparison test ($p < 0.05$).

Plants obtained from the two seed colour variants showed differences in the number of primary branches. Plants from the brown seeds have on average 18 primary branches more than the light blue seeds. It showed that there was statistically significant differences in number of primary branches between the two seed colour variants (p =0.050, Figure 6A). On the other hand, the number of secondary branches per plant from brown seeds was approximately 77 higher than the light blue seeds. Unlike the above agronomic traits studied, there was no statistically significant differences in number of secondary branches in plants from the two seed colour variants ($p = 0.093$, Figure 6B).

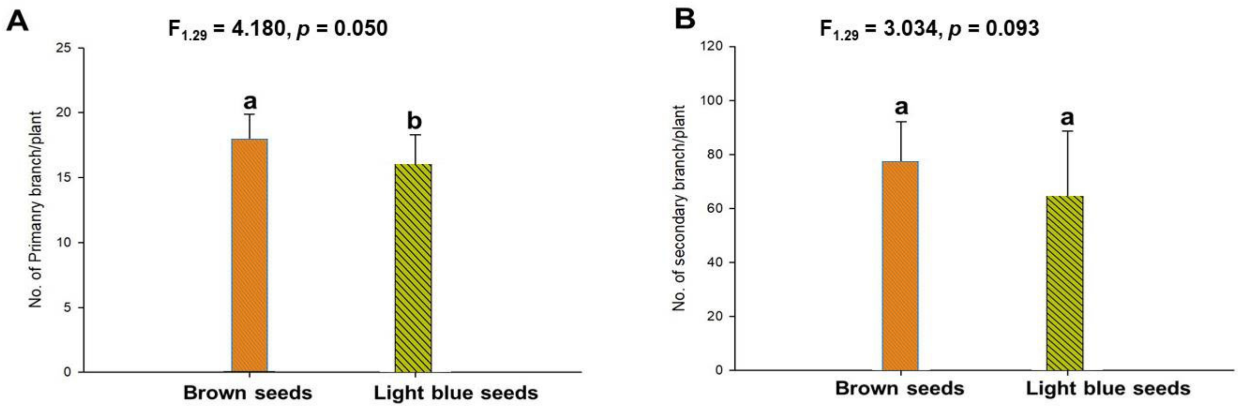

Figure 6. Agronomic traits of the two seed colour variants of *L. sativum*. (**A**) Number of primary branches per plant and (**B**) number of secondary branches per plant. These data provide insights into the branching characteristics and overall growth architecture of each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pair-wise multiple comparison test ($p < 0.05$).

3.3. Comparative Leaf Morphology and Pod Production of Brown and Light Blue Lepidium sativum Plants

As shown in Figure 7A, plants from brown seeds have longer leaf length (10.5 cm) than plants from the light blue seeds. There was a statistically significant difference in leaf length of plants from the two seed colour variants ($p < 0.001$, Figure 7A). The average internode length of plants from the brown seeds was 4.37 cm higher than the light blue seeds. Similar to the number of secondary branches, no significant differences were recorded between plants from the two seed colour variants in terms of internode length (p = 0.105, Figure 7B).

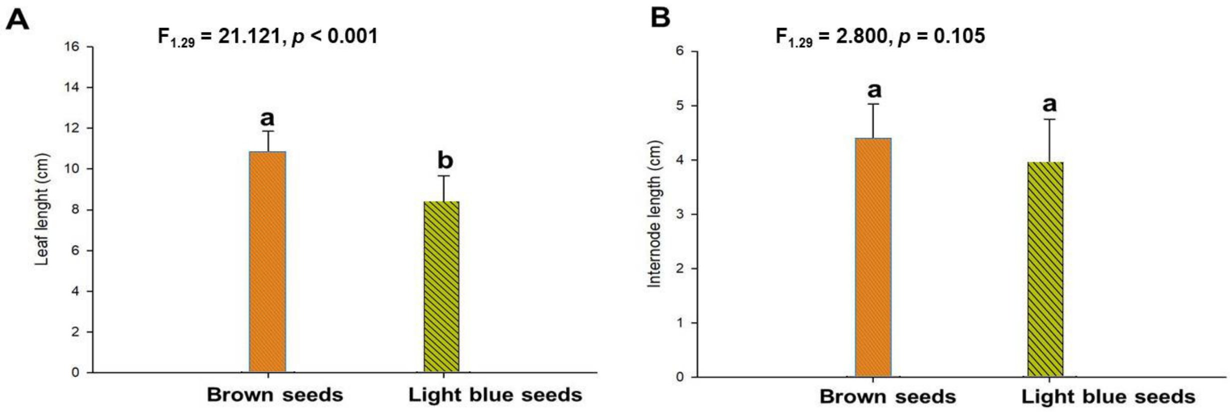

Figure 7. Agronomic traits of the two seed colour variants of *L. sativum*. (**A**) Leaf length measured in centimetres and (**B**) internode length measured in centimetres. These attributes contribute to the understanding of the vegetative structure and growth patterns of each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pairwise multiple comparison test (p < 0.05).

There were differences in the number of pods per plant and the number of seeds per plant between plants obtained from the two seed colour variants. The number of pods per plants in plants from brown seeds was 1700 higher than the light blue seeds. In this study, statistically significant differences in the number of pods per plant were reported from plants from the two seed colour variants (p < 0.001, Figure 8A). Furthermore, the number of seeds per plants in plants from brown seeds was around 2793 higher than the light blue seeds, and this was statistically significant (p < 0.001, Figure 8B).

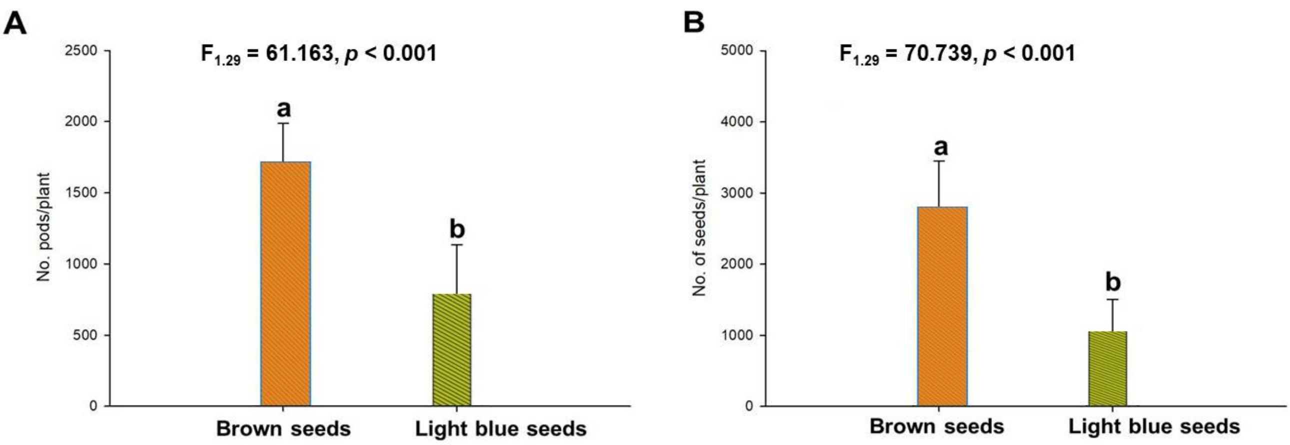

Figure 8. Agronomic traits of the two seed colour variants of *L. sativum*. (**A**) Number of pods per plant and (**B**) number of seeds per plant. These measurements are important for assessing the reproductive performance and productivity of each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pairwise multiple comparison test (p < 0.05).

3.4. Seed Weight and Yield Performance of Brown and Light Blue Lepidium sativum Variants

Similarly, there were significant differences in the one thousand seed weight and yield between plants from the two seed colour variants ($p < 0.001$, Figure 9). The 1000 seed weights of brown seeds were about 1.87 gm higher than the light blue seeds. Statistically, there was a significant difference in 1000 seed weight between the two seed colour variants of *L. sativum* ($p = 0.046$, Figure 9). The brown seed production per hectare was higher (1866.5 kg) than the light blue seeds. Again, there were statistically significant differences in production between the two seed colour variants ($p < 0.001$, Figure 9).

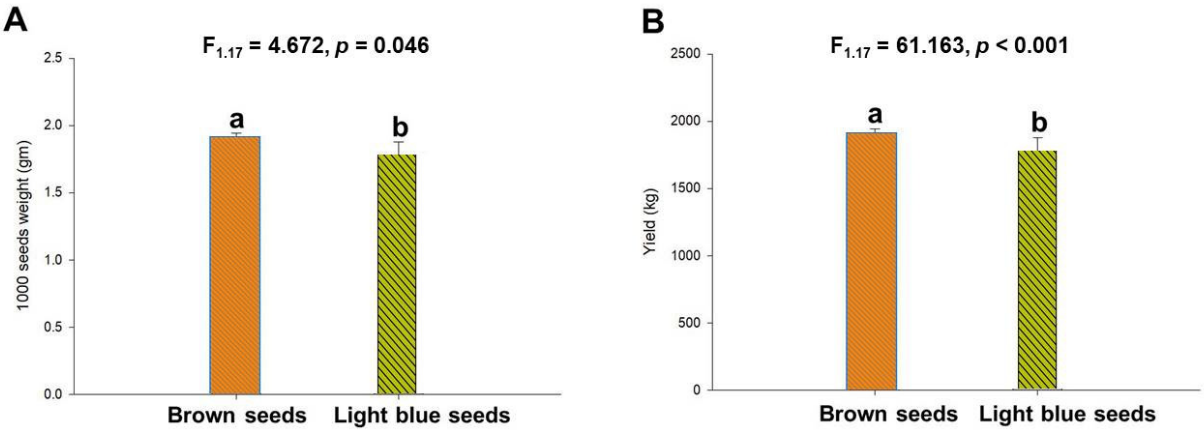

Figure 9. Agronomic traits of the two seed colour variants of *L. sativum***.** (**A**) One thousand seed weight measured in grams and (**B**) yield expressed in kilograms per hectare. These parameters are crucial for evaluating the economic viability and productivity of each seed colour variant. Different letters (a, b) indicate significantly different means as determined using the Tukey pairwise multiple comparison test ($p < 0.05$).

4. Discussion

4.1. Origin, Distribution, and Genetic Diversity of Lepidium sativum Seed Colour Variants

L. sativum, commonly referred to as cress, has a rich history of cultivation and use; the highland regions of Ethiopia and Eritrea are critical centers of origin and diversity for this plant, highlighting its cultural and economic importance in these areas [6–9,14,15]. Today, this versatile plant is cultivated extensively across India, especially in regions such as Uttar Pradesh, Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh [16–18]. Its distribution further extends to Africa, including Ethiopia [8,19], and includes areas in West and Central Asia, as well as North America and Europe [18]. Despite its wide distribution and established use, the origin of the specific seed colour variants of *L. sativum*, namely the brown and light blue seeds, remains unclear. While both colour variants are recognized and utilized in various agronomic and medicinal contexts, the genetic and environmental factors contributing to these colour differences are not well documented. The dominant brown seed variant's ability to survive in various climates, as observed in this study, suggests a potential adaptation to specific environmental conditions, yet the underlying genetic basis for this advantage remains to be fully elucidated. Moreover, the lack of detailed research on the phenotypic variation associated with different seed colour variants calls for further exploration. Understanding the origins, genetics, and adaptive mechanisms of these colour variations could provide valuable insights into the cultivation and use of *L. sativum*, particularly in regions where climate change poses significant challenges to agriculture.

4.2. Exploring the Potential of Lepidium sativum Seed Colour Variants for Enhanced Therapeutic Applications

L. sativum, commonly known as garden cress, is widely recognized for its numerous medicinal properties and nutritional benefits. Traditionally utilized as a gastrointestinal stimulant, laxative, and digestive aid, it also provides therapeutic effects for a variety of ailments, including diabetes, asthma, and rheumatic pain [14,20–23]. Furthermore, the plant exhibits antidiabetic, antibacterial, diuretic, and antihypertensive effects, affirming its role in traditional medicine and modern therapeutic applications [1,5,24–28]. The nutritional profile of *L. sativum* is equally impressive, with significant levels of vitamins, minerals, and dietary fibre. It is a potent source of folic acid, vitamin C, iron, and protein, contributing to its reputation as a health-promoting food [28–31]. Additionally, the seeds are rich in linoleic fatty acids and mucilage, enhancing their potential therapeutic applications [27,32–36]. However, while the medicinal benefits of *L. sativum* are well established in general, the specific contributions of different seed colour variants, namely the brown and light blue seeds, remain inadequately explored.

4.3. Agronomic Performance and Adaptive Potential of Brown and Light Blue Seed Variants of Lepidium sativum in Climates

This study focused on the agronomic differences between these two seed colour variants, contributing valuable insights into their adaptability to climates like that of Ataye in the Amhara Regional State of Ethiopia. Our findings indicate that the brown seed variant is better suited to these conditions, exhibiting superior performance across most of the agronomic traits assessed. Specifically, the brown seeds demonstrated enhanced growth parameters, which may be attributed to genetic factors that confer resilience in response to environmental stresses prevalent in various settings. In contrast, the light blue seed variant exhibited comparatively lower performance across most agronomic traits, suggesting that it may not be as well adapted to the climatic challenges faced in various regions. This distinction between the two seed colour variants reinforces the importance of considering genetic diversity when selecting plant cultivars for specific environmental conditions. The distinct morphological features of *L. sativum*, including its small, oval-shaped seeds characterized by a smooth texture and a wing-like extension, also merit consideration. The presence of a mucilage layer that forms upon seed hydration could influence germination rates and subsequent plant establishment, particularly under varying moisture conditions. The implications of this mucilaginous layer warrant further investigation, especially in the context of seed colour variants and their adaptive strategies [16–18].

4.4. Brown Seed Variant: Enhanced Germination and Adaptation to Environments

The superior germination rates observed in the brown seed variant are critical for achieving a successful crop stand. Germination is a complex biological process influenced by environmental conditions, particularly temperature, which has been noted as a major factor affecting seed germination [37–39]. This finding highlights the necessity for local farmers in various regions to utilize high-quality seeds to promote better establishment and growth practices rooted in good agricultural protocols [40]. Given the challenges faced by medicinal plants regarding insufficient data on environmental adaptability, our results emphasize the importance of further investigating the specific environmental conditions that favour the germination of different seed colour variants.

4.5. Brown Seed Variant: A Superior Genotype for Enhanced Growth and Yield

Our analysis of agronomic traits indicates that the brown seed variant of *L. sativum* exhibits significant advantages across several key areas essential for maximizing agricultural productivity. Notably, the superior germination rates observed for the brown seeds are critical for establishing a robust crop stand, which is foundational for achieving optimal productivity. Effective germination leads to healthy seedlings that directly influence subsequent growth and yield, as supported by Tadesse et al. [3]. Additionally, the increased flowering and maturation rates in the brown seed variant enhance its adaptability to specific climatic conditions, suggesting strong potential for increased seed yield. These reproductive advantages can be attributed to the plant's efficient resource allocation, a trait that significantly enhances its overall performance. The growth patterns observed in the brown seed variant align well with previous studies that documented significant variability in agronomic traits among different genotypes of *L. sativum* [3]. This genetic diversity is essential for enhancing crop performance and adaptability to varying environmental conditions. Our results suggest that the brown seed variant not only thrives under optimal growth conditions but also likely possesses innate genetic predispositions that allow it to perform well under suboptimal conditions.

4.6. Brown Seed Variant: Superior Leaf and Reproductive Traits for Increased Yield and Adaptability

The brown seed variant of *L. sativum* demonstrates significant advantages in both leaf and reproductive traits, which are crucial for the overall fitness and productivity of the plant. Notably, this variant exhibits larger leaf areas that enhance its photosynthetic capacity, allowing it to capture more light and efficiently utilize available resources for growth. Coupled with increased flower production, these traits contribute to greater reproductive success and ultimately result in higher seed yields. The performance of the brown seed variant aligns well with earlier findings that identified leaf and reproductive traits as principal discriminatory characteristics within the studied germplasm [3]. Its superior leaf characteristics more likely supports higher biomass accumulation. Additionally, the number of flowers produced by the brown seed variant correlates directly with seed yield, suggesting that this genotype may offer enhanced economic returns for farmers.

4.7. Brown Seed Variant: Enhanced Yield and Seed Quality for Improved Agricultural Outcomes

The findings of our study reveal that the brown seed variant of *L. sativum* significantly outperforms the light blue variant in terms of both yield and seed quality (physical inspection). Most notably, the brown seed variant not only produces a higher quantity of seeds (personal observation) but also yields seeds of superior quality, which is essential for ensuring optimal germination potential and the health of subsequent crops [40]. High seed quality is crucial for successful cultivation, as it directly influences the germination rates and overall vigour of the plants. The enhanced yield and quality associated with the brown seed variant not only reflect better agronomic performance but also indicate greater benefits for cultivation practices aimed at maximizing output and quality. This positions the brown seed variant as a preferable choice for farmers, particularly in regions where both yield and quality are paramount. The correlation between seed quality and yield potential suggests that adopting the brown seed variant could lead to improved economic viability for farmers, especially in ecosystems where environmental pressures pose challenges to crop success.

4.8. Understanding Genotype–Environment Interactions for Optimizing Lepidium sativum Production—Future Research Directions

The interaction between genotype and environment plays a critical role in determining the phenotypic characteristics of plants. Our findings corroborate the understanding that both genetic makeup and environmental conditions significantly influence agronomic traits, including those related to grain characteristics. Specifically, the effects of genotype, environment, and genotype by environmental interactions have been shown to impact crucial grain properties, such as endosperm hardness, which can directly affect processing and commercialization [41]. Genotypes exhibiting contrasting growth habits demonstrate distinct phenotypic characteristics. As these plants develop, the environmental conditions can either exacerbate or mitigate the expression of these traits, leading to varying responses among genotypes. Miri et al. [42] highlighted the importance of correlation coefficients in understanding these interactions, where linkage and pleiotropism can significantly define the relationships among traits. Thus, the intricate relationships between growth habits and environmental conditions underscore the necessity of examining correlations within specific environmental contexts. The growth characteristics of plants, particularly the transition from vegetative to reproductive stages, are notably influenced by genotype. For instance, once a plant reaches a certain height, the main stem undergoes thickening, facilitated by the presence of a terminal bud linked to racemic inflorescence [42]. In contrast, genotypes with indeterminate growth habits exhibit unique behaviours; they continue to elongate throughout their flowering stages, often doubling in height after the first flowers appear. This indeterminate growth pattern allows for the simultaneous development of both vegetative and reproductive structures, maximizing the plant's reproductive potential under favourable conditions. Moreover, the findings by Va'zquez-Carrillo et al. [43] emphasize that grain hardness and colour are particularly susceptible to genotype by environmental interactions. Such variability not only affects the intrinsic quality traits of the grains but also imposes significant implications for processors, breeding programmes, and the commercial viability of different genotypes. Understanding how various environments impact the quality traits among genotypes is crucial for developing strategies that can enhance grain quality and consistency.

Ultimately, the implications of our findings extend beyond individual plant performances; they influence the broader framework of breeding programmes. By recognizing the intricate interplay between genotype and environment in shaping agronomic traits, breeders can make more informed decisions aimed at enhancing the resilience and quality of crops. This knowledge is essential for adapting grain production to varying environmental conditions, thereby sustaining agricultural productivity and ensuring economic viability within the context of a changing climate. Future research should focus on elucidating the mechanisms underlying these genotype–environment interactions to develop cultivars that are optimized for specific environmental conditions and market demands.

5. Conclusions

This study highlights the significance of seed colour variants in *L. sativum*, a notable medicinal plant in the Brassicaceae family, particularly within the context of climates such as Ataye in the Amhara Regional State of Ethiopia. Our findings reveal that the brown seed variant exhibits superior agronomic traits compared to the light blue variant, making it more suitable for cultivation in these environmental conditions. The brown seeds demonstrated enhanced performance in nearly all agronomic parameters assessed, with the exception of the number of secondary branches per plant and internode length. The results suggest that the agronomic performances associated with the brown seed colour confer advantages that promote better growth and resilience in various climates. As such, the brown seed variant holds particular promise for local farmers and communities aiming to cultivate *L. sativum* for its medicinal properties and agronomic benefits. In light of these findings, we advocate for the continued exploration of the genetic basis for seed colour variation in relation to environmental adaptability. Further research could enhance our understanding of the mechanisms at play and promote the development of more resilient crop varieties.

Author Contributions: K.T., S.M. and F.D. planned and designed the research; K.T. and F.D. performed experiments; S.M. interpreted the data; S.M. wrote the manuscript; all authors revised the final manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by Debre Berhan University (Ethiopia) and The Ministry of Education (Ethiopia) to K.T., Georg Förster Postdoctoral Research Grant (Alexander von Humboldt Stiftung) to S.M.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: We thank Katja Tielbörger and Sabine Zachgo for hosting S.M.; Alexander von Humboldt Foundation for a postdoctoral award to S.M.; Klaus Mummenhoff for critical discussion.

Conflicts of Interest: The authors declare no conflicts of interest.

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