



INTERFERENCE OF THE SUBSTRATE IN VEGETATIVE AND ROOT DEVELOPMENT IN LETTUCE CULTIVARS

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ABSTRACT

Lettuce is the most consumed leafy vegetable in Brazil, with great economic relevance in commerce and retail. Given the growing consumer demand for quality and safe food, the choice of material used in seedling production becomes fundamental, as it directly influences plant growth and root development. Thus, this work evaluated the effect of four cultivation compositions, formed by two pure commercial substrates and their respective mixtures with sand in a 1:1 ratio, on the performance of the cultivars Americana and Elba. The experiment was conducted in a completely randomized design, evaluating germination, plant height, fresh and dry weight of the aerial part, as well as length, area, volume, and diameter of the roots 30 days after sowing. The results indicated that the Bioplant substrate, without the addition of sand, provided higher values for height (up to 2.77 cm), fresh weight (0.77 g), and root diameter (5.14 mm). The Americana cultivar showed greater root system development, reaching 657.74 mm² in area and 86.19 mm³ in volume under this treatment. The incorporation of sand favored drainage and growth uniformity, benefiting some parameters of the Elba cultivar; however, it reduced performance when associated with the Amanfibra substrate. It is concluded that lettuce development is influenced by the interaction between cultivar and substrate composition used, with no single treatment being superior under all evaluated conditions.

KEYWORDS: Germination; Leafy vegetable; Seedling production.

INTERFERÊNCIA DO SUBSTRATO NO DESENVOLVIMENTO VEGETATIVO E RADICULAR EM CULTIVARES DE ALFACE

RESUMO

A alface (*Lactuca sativa* L.) é a hortaliça folhosa mais consumida no Brasil, com grande relevância econômica no comércio e varejo. Diante da crescente exigência do mercado consumidor por alimentos de qualidade e seguros, a escolha do material utilizado na produção de mudas torna-se fundamental, pois influencia diretamente o crescimento vegetal e o desenvolvimento radicular. Assim, este trabalho avaliou o efeito de quatro composições de cultivo, formadas por dois materiais comerciais puros e suas respectivas misturas com areia na proporção 1:1, sobre o desempenho das cultivares Americana e Elba. O experimento foi conduzido em delineamento inteiramente casualizado, avaliando-se germinação, altura das plantas, massa fresca e seca da parte aérea, além de comprimento, área, volume e diâmetro das raízes aos 30 dias após a semeadura. Os resultados indicaram que o material Bioplant, sem adição de areia, proporcionou maiores valores de altura (até 2,77 cm), massa fresca (0,77 g) e diâmetro radicular (5,14 cm). A cultivar Americana apresentou maior desenvolvimento do sistema radicular, alcançando 657,74 mm² de área e 86,19 mm³ de volume nesse tratamento. A incorporação de areia favoreceu a drenagem e a uniformidade do crescimento, beneficiando alguns parâmetros da cultivar Elba; entretanto, reduziu o desempenho quando associada ao Amanfibra. Conclui-se que o desenvolvimento da alface é influenciado pela interação entre cultivar e composição utilizada, não havendo um único tratamento superior para todas as condições avaliadas.

PALAVRAS-CHAVE: Alface; Desenvolvimento radicular, Substrato;

INTRODUCTION

Lettuce (Asteraceae: *Lactuca sativa*) is currently the most consumed leafy vegetable in Brazil. This prominence is attributed to its various nutritional benefits, such as its high content of mineral salts and vitamins essential to the human diet, in addition to its low caloric value (COSTA *et al.*, 2023). Furthermore, the crop has considerable economic and social importance, as it generates billions of reais in the commerce and retail sectors (MOURA *et al.*, 2024). At the same time, increasing concern regarding food quality and safety has driven the national vegetable market, attracting growing investments from companies and research groups aimed at developing new cultivars to meet consumer demands (CÂNDIDO *et al.*, 2026).

In this production system, lettuce cultivation is influenced by several factors, such as seed quality, seedling quality, substrate, and tray type, which are essential for improving production efficiency (COUTO *et al.*, 2020). Seedling quality is indispensable to maximize field survival rates and crop productivity (FIORIN *et al.*, 2022).

Among the components of the production system, the substrate is a fundamental factor in seedling production due to its widespread use during this cultivation stage (CORREA *et al.*, 2023). Plant growth and development depend on the proper selection of this material, which must combine economic feasibility with favorable physical characteristics, such as good drainage, high water retention

capacity, adequate porosity, and sufficient consistency for plant support (ANACLETO; BUENO, 2021).

In addition to physical characteristics, the growing medium must provide adequate conditions from germination to early development, influencing parameters such as leaf number, fresh biomass accumulation, and root system formation. For this purpose, it is essential that the medium presents suitable physical, chemical, biological, and sanitary qualities, ensuring the production of vigorous seedlings (LOBATO *et al.*, 2024).

Despite the widespread use of different substrates in lettuce seedling production, studies have demonstrated that plant responses may vary according to the substrate used and the cultivar (OTÁSIA *et al.*, 2026). Furthermore, most studies focus on the evaluation of shoot characteristics, with less emphasis on integrated root development. Therefore, further studies are still needed to simultaneously evaluate the vegetative and root performance of different cultivars under distinct cultivation conditions.

Given this, the objective of this study was to determine whether the substrate affects vegetative and root development in lettuce cultivars.

MATERIALS AND METHODS

The experiment was conducted in the seedling nursery located in the experimental area of the Federal University of Viçosa – Rio Paranaíba Campus (19°12'48.9" S, 46°13'57" W), in the municipality of Rio Paranaíba, Minas Gerais, Brazil. The climate of the region is classified as cwa according to the Köppen-Geiger classification, characterized by rainy summers and dry winters. The experiment was established in a completely randomized design arranged in a 2 × 4 factorial scheme (two cultivars and four substrates).

The cultivars used were Elba lettuce from TOPSeed, with 85% germination and 99% purity, and Great Lakes 659 lettuce (Americana) from TOPSeed, with 85% germination and 99% purity. The substrates tested were coconut fiber from Bioplant and Golden Mix from Amafibra. The other two treatments consisted of mixtures of each substrate with sand at a 1:1 ratio. Polystyrene trays with 72 cells (121.12 cm³ volume) were used for all treatments. Sowing was performed manually using a marker to establish a seed depth of 1.0 cm. Irrigation was carried out daily using 2 L of water for all treatments.

The evaluated parameters were germination percentage, number of true leaves, plant height, fresh and dry weight of shoots and roots, and morphological parameters of the root system. Germination was evaluated in the fourth week after sowing through the direct counting of emerged seedlings. Germination percentage was calculated according to Labouriau and Valadares (1976) using Equation 1:

$$G = (N/A) \cdot 100 \quad (1)$$

Where:

G = germination;

N = total number of germinated seeds;

A = total number of seeds placed for germination.

The number of leaves, plant height, and fresh weight were determined 30 days after sowing using three plants per plot, with two replications. Central plants were

selected to avoid significant border effects. Plant height was measured in centimeters using a ruler, from the base of the plant to the last fully expanded leaf. Fresh weight of shoots and roots was determined using an analytical balance (Splabor/BL-3200H).

After weighing, the samples were placed in plastic bags and stored under refrigeration until processing. Subsequently, they were washed under running water using sieves with mesh sizes smaller than 1.0 mm. The roots were stained with 1% gentian violet for 5 min and placed on paper towels to remove excess dye. Then, three corresponding plants per replication were separated, and the roots were arranged on a glass plate. The scanner (Hp ScanJet) was closed, and the entire set was scanned in grayscale at a resolution of 180 dpi.

The scanned images were individually processed using the Safira software developed by Embrapa (JORGE; RODRIGUES, 2008), with the threshold limit defined according to the approximation of the real image. Based on the results obtained from the software, the physiological parameters related to root system morphology were estimated: total root length (TL), in $\text{cm}\cdot\text{cm}^{-3}$; total root volume (TV), in $\text{mm}^3\cdot\text{cm}^{-3}$; total root area (TA), in $\text{mm}^2\cdot\text{cm}^{-3}$; and mean root diameter (MD), in mm. Subsequently, the samples were placed in paper bags and dried in a forced-air circulation oven (Lucadema) at 70 °C for 72 h until constant weight was achieved. Dry matter was then determined using an analytical balance (Splabor/AUY-220).

The obtained data were subjected to the Cochran and Lilliefors tests to verify whether they met the assumptions of homogeneity of variances and normality of errors, respectively, according to the statistical methodology adopted by SANTANA et al. (2024) and SILVA *et al.* (2022). Subsequently, the data were subjected to analysis of variance using the F test. Only significant effects were analyzed subsequently, and treatment means were compared using Tukey's test at a 5% probability level. Statistical analyses were performed using SAEG software, version 9.1 (SAEG, 2007).

RESULTS AND DISCUSSION

For lettuce seedling production, it is essential to use a substrate that provides adequate conditions for germination and seedling establishment, ensuring satisfactory levels of moisture, aeration, and water retention. In addition, physical characteristics such as porosity, total volume, and water storage capacity directly influence germination performance and early plant development (PINTO JUNIOR *et al.*, 2024). In this context, the choice of substrate and its composition plays a determining role in the quality of the seedlings produced.

Germination percentages were high for both evaluated cultivars. For the Elba cultivar, 100% germination was observed in the treatments containing substrate and sand mixtures at a 1:1 ratio, whereas the Amafibra and Bioplant substrates showed germination rates of 91.66% and 93.75%, respectively. For the Americana cultivar, the highest percentages were observed in the Amafibra + sand and Bioplant treatments, both with 100% germination, while the Amafibra substrate alone showed 97.91% germination and the Bioplant + sand mixture resulted in 95.83%.

The highest values for plant height were observed in the Bioplant (2.77 cm) and Bioplant + sand (2.50 cm) treatments, differing statistically from the other treatments. For fresh weight, the highest results were also obtained with the Bioplant (0.73 g) and Bioplant + sand (0.77 g) substrates, whereas the lowest values were recorded for Amafibra (0.28 g) and Amafibra + sand (0.24 g). A similar pattern was

observed for dry weight, with the highest values obtained in the Bioplant and Bioplant + sand treatments. Regarding root diameter, the Bioplant + sand mixture provided the highest mean value (5.14 cm), followed by the Bioplant (3.22 cm) and Amafibra + sand (3.46 cm) treatments, whereas the lowest value was observed in the Amafibra substrate (2.28 cm), indicating a positive effect of sand addition on root system development (Table 1).

TABLE 1. Mean values \pm standard error for plant height (cm), fresh weight (g), dry weight (g), and root diameter (cm).

Substrate	Evaluated characteristics ¹			
	Height	Fresh weight	Dry weight	Diameter
Amafibra	1.62 \pm 0.40B	0.28 \pm 0.06B	0.02 \pm 0.01B	2.28 \pm 0.62B
Amafibra + Sand	1.18 \pm 0.29B	0.24 \pm 0.04B	0.02 \pm 0.00B	3.46 \pm 0.54AB
Bioplant	2.77 \pm 0.54 ^a	0.73 \pm 0.12A	0.03 \pm 0.01A	3.22 \pm 0.51AB
Bioplant + Sand	2.50 \pm 0.16 ^a	0.77 \pm 0.06A	0.03 \pm 0.00A	5.14 \pm 1.21A

¹Means followed by the same letter within a column do not differ statistically according to Tukey's test at the 5% probability level.

Similar results were observed in a study that reported greater fresh and dry matter production in lettuce cultivated in commercial substrates (SANTOS *et al.*, 2023). Likewise, Silva *et al.* (2019) reported greater shoot development in pepper and bell pepper seedlings produced in commercial substrates. Plant height is considered one of the main parameters for evaluating seedling quality (COSTA *et al.*, 2023).

The lower performance observed in the treatments based on coconut fiber may be related to the low nutrient content of this material, which generally requires nutritional supplementation through fertilization or fertigation to promote adequate plant growth (HAYATA *et al.*, 2023).

The interaction between cultivars and substrates showed a significant influence on plant development. For plant height, the Americana cultivar presented higher mean values than Elba in the Amafibra (2.23 cm) and Bioplant (3.53 cm) substrates, whereas the Elba cultivar showed mean values of 1.00 cm and 2.00 cm, respectively. In the Amafibra + sand treatment, the Americana cultivar showed a mean height of 1.56 cm, while Elba presented 0.80 cm. The only treatment in which no significant difference was observed between cultivars was Bioplant + sand.

For dry weight, the highest values were also observed for the Americana cultivar, especially in the Bioplant substrate (0.039 g), compared with Elba (0.021 g). In the Amafibra substrate, Americana presented a mean value of 0.027 g, whereas Elba showed 0.014 g. In the treatments containing sand, the values were more similar between cultivars (Table 2). These results suggest that sand addition contributed to greater uniformity in growth conditions.

In contrast, Smiderle *et al.* (2001) did not observe an increase in the dry mass of lettuce seedlings following the inclusion of sand in the substrate. However, Santos *et al.* (2023) reported that the addition of this material significantly improved substrate physical properties, such as density and porosity, thereby enhancing oxygen and water availability and promoting more uniform root system development.

TABLE 2. Breakdown of the interaction between the Elba and Americana cultivars and the Amafibra and Bioplant substrates for plant height (cm) and dry weight (g).

Substrate	Evaluated characteristics ¹			
	Plant height		Dry weight	
	Elba	Americana	Elba	Americana
Amafibra	1±0.0.58Bb	2.233±0.153BCa	0.014±0.002Bb	0.027±0.004BCa
Amafibra + Sand	0.8±0.1Bb	1.567±0.233Ca	0.013±0.002Ba	0.019±0.002Ca
Bioplant	2±0.153Ab	3.533±0.348Aa	0.021±0.004Bb	0.039±0.003ABa
Bioplant + Sand	2,6±0.175Aa	2.4±0.153BCa	0.034±0.003Aa	0.035±0.001ABCa

¹Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ statistically according to Tukey's test at the 5% probability level

The interaction between cultivars and substrates also showed a significant effect on root area and root volume. The Americana cultivar presented greater root development, especially in the Bioplant substrate, in which the highest values of root area (657.74 mm²) and root volume (86.19 mm³) were observed, whereas the Elba cultivar showed values of 210.98 mm² and 25.23 mm³, respectively. In the Bioplant + sand treatment, the Americana cultivar also presented high values of root area (487.75 mm²) and root volume (70.28 mm³), which were higher than those observed for Elba, which presented 329.44 mm² and 37.15 mm³.

In the Amafibra substrate, the Americana cultivar presented a root area of 408.45 mm² and a volume of 53.56 mm³, whereas Elba showed 271.16 mm² and 34.37 mm³, respectively. However, in the Amafibra + sand treatment, a reduction in root development was observed for the Americana cultivar, with a root area of 223.85 mm² and a volume of 22.70 mm³, which were lower than the values observed for Elba, which presented 294.81 mm² and 39.86 mm³ (Table 3).

TABLE 3. Breakdown of the interaction between cultivars Elba and Americana and substrates Amafibra and Bioplant for the characteristics area (mm²) and root volume (mm³).

Substrate	Evaluated characteristics ¹			
	Area		Volume	
	Elba	Americana	Elba	Americana
Amafibra	271.16±20.00Aa	408.45±21.17ABa	34.37±5.88Aa	53.56±5.95ABa
Amafibra + Sand	294.81±66.40Aa	223.85±65.37Ba	39.86±13.28Aa	22.70±6.71Ba
Bioplant	210.98±56.10Ab	657.74±84.74ABa	25.23±5.50Ab	86.19±15.11ABa
Bioplant + Sand	329.44±36.59Aa	487.75±95.72ABa	37.15±1.96Ab	70.28±15.91ABa

¹Means followed by the same letter, uppercase in the column and lowercase in the row, do not differ statistically from each other by the Tukey test at 5% probability.

Despite the positive performance of Bioplant observed in this study, Lima *et al.* (2016) reported that high proportions of this component did not favor passion fruit seedling production, demonstrating that the response to the substrate may vary according to the species and genetic material used.

The results demonstrate that the addition of sand promoted distinct responses depending on the substrate composition. In the case of Bioplant, the presence of sand favored root development, probably due to improved drainage and aeration.

However, when associated with Amafibra, sand promoted a reduction in the performance of the Americana cultivar, indicating possible excess macroporosity and lower water retention. According to Cunha *et al.* (2022), changes in the physical properties of the substrate, such as density and porosity, directly influence the space available for root growth. Similar results were observed by Smiderle *et al.* (2001), who reported improved drainage and development of lettuce seedlings using sandy components associated with commercial substrates.

Thus, the results demonstrate that seedling development depends not only on the physical and chemical characteristics of the substrate but also on the interaction of these conditions with the genetic characteristics of the evaluated cultivars.

CONCLUSION

The substrates significantly influenced the vegetative and root development of lettuce, with responses varying according to the interaction between the cultivation material and the cultivar used. No single substrate was superior under all conditions: pure Bioplant favored the root system of the Americana cultivar, whereas sand addition benefited some parameters of the Elba cultivar.

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