Scientific Papers. Series B, Horticulture. Vol. LXVIII, No. 2, 2024
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

STUDY ON THE EFFECT OF NUTRIENT CONCENTRATION ON QUALITY PARAMETERS FOR LETTUCE GROWN ON VARIOUS SUBSTRATE TYPES

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Abstract

The study was carried out in the research greenhouse, within the Horticultural Products Quality Research Center in 2021. On the mattresses filled with perlite, 2 varieties of lettuce were grown, oak leaf type, Kineta type, and Lollo Bionda type, variety Lugano. The nutrient solution was administered in 3 EC concentrations, respectively 1.5 mS, 2.5 mS and 3.5 mS. Three pH levels were used for each EC type. Differences were found between the experimental variants regarding the reaction of the varieties to these treatments. The aim of the study was to see the influence of nutrient solution concentration on some production and quality parameters of lettuce grown on perlite substrate.

Key words: *lettuce, soilless, perlite, conductivity*.

INTRODUCTION

Lettuce (*Lactuca sativa*) is an annual plant from the Asteraceae family, native to temperate regions of Europe and Western Asia. Its cultivation began in ancient Egypt, from where it spread to ancient Greece and Rome, becoming an essential part of the Mediterranean diet (Indrio and Motta, 2000; Janick, 2002). According to De Vries (1997), the species evolved from a wild plant to one of the most widely cultivated vegetables in the world. The spread of lettuce has been influenced by cultural, geographic, and agricultural factors (Doležalová et al., 2003; Lebeda et al., 2003; Chan et al., 2023). Numerous studies have investigated the direct impact of temperature on the metabolism and development of lettuce plants. For instance, recent studies by Velez-Ramirez et al. (2020) and Rana et al. (2019) have examined the physiological adaptations of lettuce plants to elevated temperatures. The optimal temperature for leaf growth and head formation is 16°C, while the formation of floral stems requires temperatures between 20 and 22°C. Under conditions of drought and insufficient light, the leaves become etiolated, heads fail to form properly, and those that do develop are of poor quality, being very loose (Ciofu et al., 2003; Drăghici, 2015; Drăghici and Jerca, 2022). Studies conducted by Park et al. (2021), Bantis et al. (2020), López-Gálvez et al. (2020), and Rivero et al. (2003) provide a detailed perspective on how temperature influences the growth and development of lettuce.

MATERIALS AND METHODS

The present study was carried out at the Faculty of Horticulture from USAMV Bucharest research greenhouses at the Research Centre for quality control of horticultural products.
The biological material used in the experiment consisted of two lettuce varieties: Kineta and Lugano. The experiment assessed plant growth in terms of height, diameter, number of leaves, plant mass and nitrate content.
The experimental design utilized a split-plot approach, consisting of 9 main plots and 27 subplots. In each pH and EC level, 3 plants were planted (Table 1).

Table 1. Experimental variants

Cultivars	EC-ul (µS/cm²)	pH		
Kineta	EC 1.5	5	6	7
	EC 2.5	5	6	7
	EC 3.5	5	6	7
Lugano	EC 1.5	5	6	7
	EC 2.5	5	6	7
	EC 3.5	5	6	7

RESULTS AND DISCUSSIONS

In Figure 1 it is observed that Kineta Variety at EC 1.5: pH 5 results in the tallest plants at 18.83 cm. As pH increases to 6, the plant height slightly decreases to 18.03 cm. At pH 7, the height significantly drops to 11.23 cm, indicating a negative effect on growth at higher pH values.
Regarding EC 2.5, at pH 5 results in a height of 19.00 cm, the highest observed in this category. At pH 6, the plant height decreases to 16.53 cm, and pH 7 sees a further decrease to 12.60 cm.
And at EC 3.5, at pH 5, height is 18.50 cm, showing stability at lower pH levels. At pH 6 results in the maximum plant height observed, 19.03 cm, and the height at pH 7 falls significantly to 10.50 cm. In general, for Kineta, lower pH levels (5 and 6) are more favorable for plant height, particularly at EC 2.5 and EC 3.5. Higher pH (7) consistently results in decreased growth.
For Lugano Variety EC 1.5, at pH 5 results in a plant height of 15.00 cm. At pH 6, the height is 15.13 cm, remaining relatively stable, and pH 7 results in a significant decrease to 10.13 cm.
It is observed that EC 2.5, at pH 5 produces a height of 13.53 cm. at pH 6, the height decreases to 12.07 cm, and pH 7 shows further reduction to 10.47 cm.
Regarding EC 3.5, at pH 5, the plant height is 14.33 cm. At pH 6, the height increases to 15.13 cm, and pH 7 results in the smallest plants at 10.37 cm. Similarly to Kineta, we can conclude that the Lugano variety follows the same trend, where lower pH values are linked to increased plant height. EC 1.5 and EC 3.5 at pH 6 seem to provide optimal conditions for growth, while higher pH (7) significantly reduces growth.
Impact of pH: Both plant varieties demonstrate reduced height at a pH of 7. The best growth seems to occur at lower pH levels (5 or 6), depending on the EC level.
Impact of EC: The data suggests that an EC level of 2.5 or 3.5, combined with a pH of 6, results in optimal plant growth for both varieties. EC 1.5 shows moderate growth but not as favorable as the higher EC levels (Figure 1).

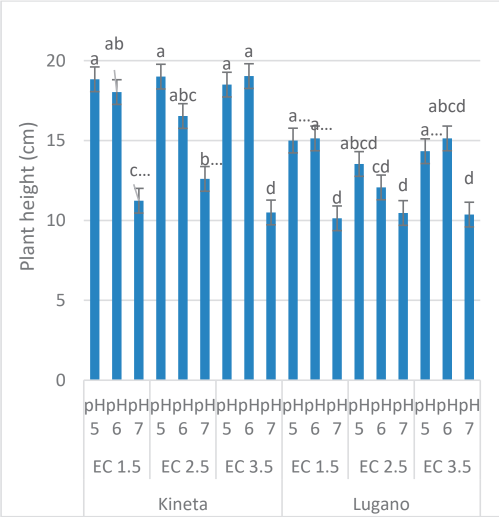

Figure 1. Influence of EC and pH on the height of lettuce plants

Regarding the Effect of EC on plants diameter can be observed higher EC values generally seem to reduce the measured diameter. For example: at pH 5: Diameters decrease from 32.63 (EC 1.5) to 30.03 (EC 3.5). At pH 6: Diameters reduce from 31.60 (EC 1.5) to 21.97 (EC 3.5). At pH 7: Diameters decrease consistently from 18.83 (EC 1.5) to 15.33 (EC 3.5). This suggests that increasing electrical conductivity negatively influences the diameter. In biological or agricultural contexts, this could imply that higher salt or nutrient concentrations may restrict growth or reduce the size of certain organisms or plants.
The analyzed effect of pH on plant diameter suggests that increasing pH (from acidic to neutral) tends to decrease the diameter. At an EC of 1.5, the diameter decreases from 32.63 at pH 5 to 18.83 at pH 7. At EC 2.5, diameter decreases from 32.87 at pH 5 to 22.30 at pH 7 and at EC 3.5: Diameter decreases from 30.03 at pH 5 to 18.07 at pH 7.

This suggests that higher pH may be less conducive to growth compared to more acidic conditions, particularly at lower EC values.

Combined Effect of EC and pH: it is observed that the largest diameters are generally at lower EC and acidic pH (around 5), indicating that organisms or materials being studied might thrive under slightly acidic conditions with lower electrical conductivity. Conversely, smaller diameters occur at higher EC values and neutral pH levels, suggesting stress or restriction of growth under these conditions.

Both higher electrical conductivity and higher pH negatively influence the diameter, likely due to the combined effects of increased salinity and reduced acidity. This pattern may reflect stress responses in biological systems, such as plants, where nutrient uptake or growth could be hindered by excessive salt concentrations or less acidic conditions (Figure 2).

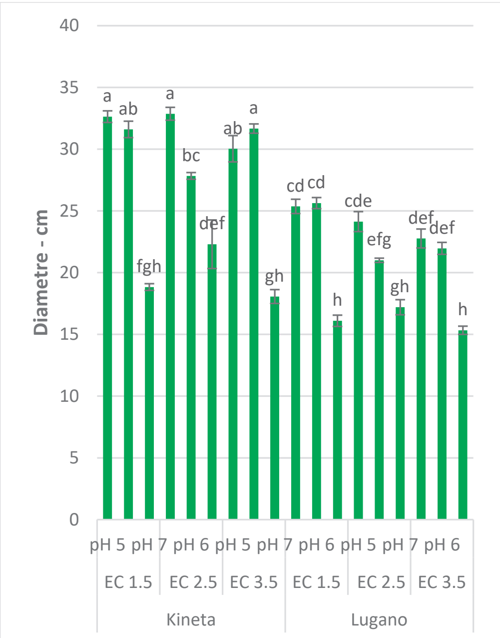

Figure 2. Plant diameter of lettuce varieties Lugano and Kineta depending on EC and pH

In Figure 3, the data shows the influence of electrical conductivity (EC) and pH on the number of leaves produced by two varieties, Kineta and Lugano.

For **Kineta**, the number of leaves tends to decrease with increasing pH at all EC levels, with the highest leaf count at EC 2.5 and pH 5 (41.33 leaves). The lowest leaf count occurs at EC 3.5 and pH 7 (13.67 leaves), indicating a negative interaction between high pH and EC.

For **Lugano**, leaf production is generally lower compared to Kineta. Similarly, the number of leaves decreases as pH increases, but the effect of EC is less pronounced. The highest leaf count occurs at EC 3.5 and pH 6 (25.33 leaves), suggesting a slight tolerance to higher EC compared to Kineta.

Overall, both varieties show reduced leaf numbers at higher pH, with Kineta responding more significantly to variations in EC and pH.

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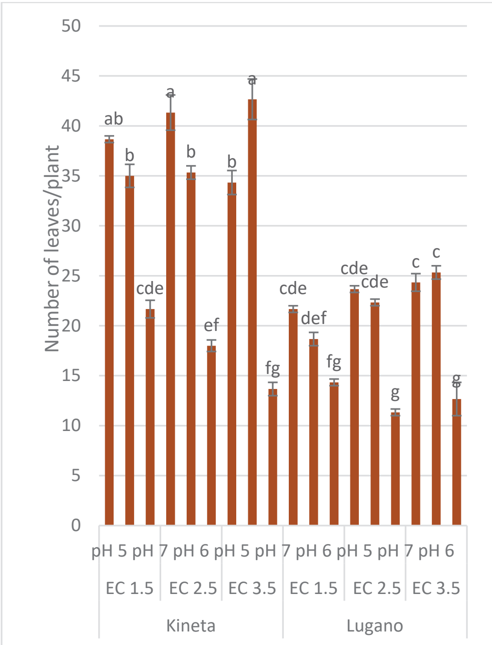

Figure 3. The influence of EC and pH values on the number of leaves per plant in the Lugano and Kineta lettuce varieties

In Figure 4, for Kineta, plant mass generally increases with EC, particularly at higher pH levels. At EC 3.5 and pH 7, the highest plant mass (150.03 g) is recorded. Plant mass production decreases slightly at lower pH values, indicating Kineta may tolerate higher EC and pH levels for optimal growth. For Lugano, the highest plant mass is observed at EC 3.5 and pH 6 (185.17 g), but there is a significant drop at pH 7 (60.00 g). Lugano shows greater sensitivity to high pH levels, particularly at EC 3.5. Kineta shows consistent plant mass production across varying pH and EC levels, with slightly higher plant mass at higher EC and pH levels. Lugano performs best at EC 3.5 and pH 6 but exhibits a sharp decline in plant mass at pH 7. This suggests that Lugano is more sensitive to extreme pH, particularly at higher EC.

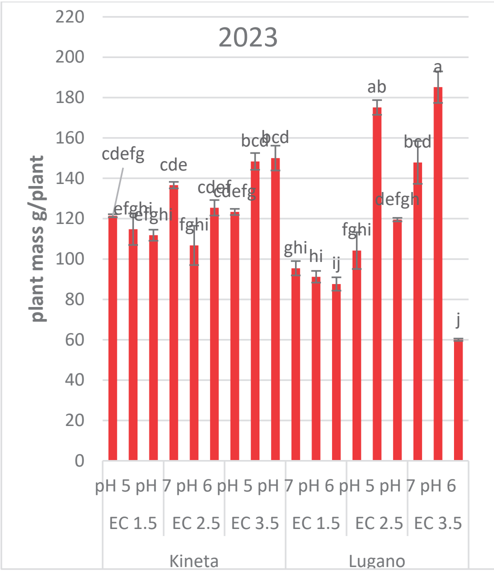

Figure 4. Mass of plants in lettuce varieties Lugano and Kineta depending on EC and pH

The data presented in Figures 5 and 6 show the effect of electrical conductivity (EC) and pH on the behavior of Kineta and Lugano on nitrate content. At lower EC (1.5), both show relatively moderate values, with Kineta decreasing as pH increases, and Lugano being higher at pH 5 and gradually decreasing. As EC rises to 2.5 and 3.5, Kineta's values generally increase at low pH but decrease at higher pH. Lugano follows a similar pattern, with higher values at lower pH but sharply reduced performance at higher pH (notably at EC 3.5 and pH 7). Overall, both EC and pH interact strongly to affect the values recorded for both Kineta and Lugano.

At low EC (1.5), Kineta decreases consistently with increasing pH, indicating that at this conductivity level, higher pH reduces Kineta's values. The drop from pH 5 (1176 mg/kg) to pH 7 (453 mg/kg) is significant, showing a 61% decrease.

At EC 2.5, Kineta starts higher at low pH (1151 mg/kg at pH 5) and then increases with pH 6 (1351 mg/kg), showing a 17% increase. However, at pH 7, there's a steep drop to 396, reflecting a significant 70% decrease relative to pH 6. At the highest EC (3.5), Kineta performs best at low pH, with the highest value (1567 mg/kg) at pH 5. It slightly decreases to 1489 at pH 6, then stabilizes at 1512 mg/kg at pH 7, showing minimal fluctuation between pH 6 and 7. Thus, at high EC, pH has less of an inhibitory effect.

Lugano follows a similar trend at EC 1.5. It starts high at pH 5 (1454 mg/kg) and decreases with increasing pH. The drop from pH 5 to pH 7 is around 30%, suggesting that Lugano, like Kineta, is sensitive to higher pH at low EC levels. As EC increases to 2.5, Lugano exhibits its highest value at pH 6 (1627 mg/kg), indicating improved performance at a mid-range pH. However, at pH 7, Lugano sharply decreases to 1000, showing a 38% reduction from its peak at pH 6. At the highest EC (3.5), Lugano experiences a peak value of 2294 mg/kg at pH 5. However, as pH increases, the values decline, with a notable drop to 508 mg/kg at pH 7 (a 78% reduction from pH 5), indicating that Lugano is highly sensitive to higher pH at elevated EC levels.

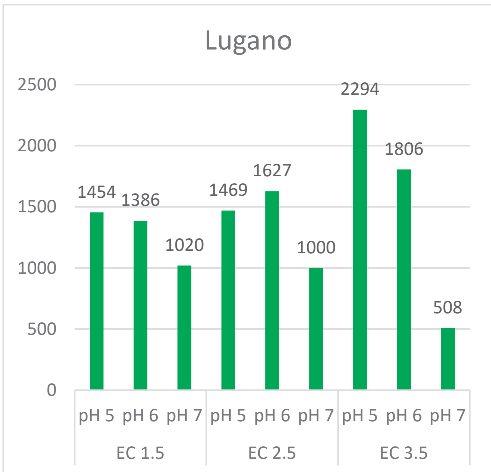

Figure 5. The nitrate content in the lettuce leaves of the Lugano variety

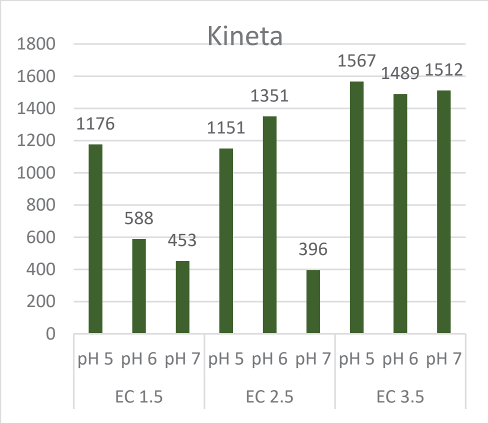

Figure 6. The nitrate content in the lettuce leaves of the Kineta variety

In the Table 2 below indicated the effect of variety on all four growth parameters is significant ($p < 0.001$ for plant height, diameter, and number of leaves; $p < 0.01$ for plant mass).

Kineta consistently outperforms Lugano in plant height (16.03 ± 0.72 cm vs. 12.91 ± 0.50 cm), plant diameter (27.31 ± 1.13 cm vs. 21.06 ± 0.75 cm), number of leaves (31.79 ± 1.99 vs. 19.37 ± 1.01), and plant mass (126.50 ± 3.20 g vs. 118.46 ± 8.0 g). These results suggest that Kineta is a more robust variety under the conditions tested.

Regarding electrical conductivity (EC) effects we can see that plant height and number of leaves show no significant effect of EC (ns), suggesting that EC variation from 1.5 to 3.5 does not influence these parameters. However, plant diameter ($p < 0.001$) and plant mass ($p < 0.001$) are significantly affected by EC. Higher EC (3.5) results in the largest plant mass (135.79 ± 9.55 g), while the lowest mass occurs at EC 1.5 (103.72 ± 3.41 g). A similar trend is observed for plant diameter, where EC 1.5 produces a significantly larger diameter than EC 3.5 (25.03 ± 1.48 cm vs. 23.31 ± 1.45 cm, respectively).

The pH also exerts a highly significant impact ($p < 0.001$) on all parameters. Plant height and plant diameter decrease significantly at pH 7, compared to pH 5 and 6, with the lowest values observed at pH 7 (10.88 ± 0.48 cm for height, 17.97 ± 0.63 cm for diameter).

Number of leaves also decreases at pH 7 (15.28 ± 0.90), compared to pH 5 and 6 (30.67 ± 1.91 and 29.89 ± 2.07 leaves, respectively).

The highest plant mass is observed at pH 6 (136.90 ± 8.81 g), while pH 7 results in significantly lower mass (109.06 ± 7.05 g), indicating that alkaline conditions (pH 7) adversely affect plant growth.

Regarding the interaction effects between variety × EC (V × EC), there was not significant different on for plant height, plant diameter, but significant for the number of leaves and plant mass at ($p < 0.01$, or $p < 0.001$). This suggests that the number of leaves and plant mass is influenced by variety differently at varying EC levels, while the other parameters remain unaffected by the interaction between these two factors.

The interaction between variety × pH (V × pH) was significant difference between variety and pH for plant height ($p < 0.05$), plant diameter ($p < 0.001$), number of leaves ($p < 0.001$), and plant mass ($p < 0.001$). These interactions indicate that the response of each variety to pH is different. For example, Kineta may tolerate extreme pH levels better than Lugano, leading to differential growth outcomes in terms of size, number of leaves, and biomass.

We observed that the interaction between EC × pH was significant difference for plant diameter ($p < 0.001$), number of leaves ($p < 0.001$), and plant mass ($p < 0.001$). The interaction between EC and pH levels highlights the complexity of these factors' combined effects on plant growth. Specifically, the optimum pH for maximizing diameter and mass may depend on the EC level, and vice versa.

We also can see three-way interaction between variety × EC × pH (V × EC × pH) for number of leaves ($p < 0.01$) and plant mass ($p < 0.001$), indicating that the number of leaves and plant mass are influenced by the combination of variety, EC, and pH. These interactions suggest that the response of plant growth to pH and EC is variety-dependent, and each combination of factors produces different growth outcomes.

CONCLUSIONS

The results indicate that variety, pH, and EC significantly affect plant growth parameters, with strong interactions between these factors. In particular: Kineta generally outperforms Lugano under all conditions. pH 7 negatively impacts plant growth, while pH 5 and 6 are

more conducive to better plant height, diameter, and mass. Higher EC levels tend to increase plant mass, with a significant decline in diameter as EC increases. The interaction effects reveal that the impact of EC and pH varies depending on the variety, emphasizing the need for optimizing these factors according to the plant variety for improved growth outcomes.
Kineta shows more variability in response to both pH and EC, especially at lower pH levels and higher EC.

Lugano exhibits more stable performance at low pH, particularly at higher EC, but suffers significant declines at pH 7, especially under high conductivity conditions. Both variables display their highest values at low pH (5), particularly at higher EC levels (3.5), while pH 7 consistently results in lower values, suggesting that high pH negatively affects both Kineta and Lugano, especially under higher EC conditions.

Table 2. Interaction between the analyzed parameters in the 2 varieties in the year 2023

	Plant height (cm)	Plant diameter (cm)	Number of leaves/plant	Plant mass (g/plant)
Variety (V)	***	***	***	**
Kineta	16.03 ± 0.72 a	27.31 ± 1.13 a	31.79 ± 1.99 a	126.50 ± 3.20 a
Lugano	12.91 ± 0.50 b	21.06 ± 0.75 b	19.37 ± 1.01 b	118.46 ± 8.0 b
EC	ns	***	ns	***
1,5	14.73 ± 0.85 a	25.03 ±1.48 a	25.0 ± 2.14 a	103.72 ± 3.41 b
2,5	14.03 ± 0.76 a	24.22 ± 1.26 ab	25.33 ± 2.48 a	127.93 ± 6.11 a
3,5	14.64 ± 0.93 a	23.31 ± 1.45 b	25.50 ± 2.62 a	135.79 ± 9.55 a
pH	***	***	***	***
5	16.53 ± 0.61 a	27.97 ± 1.01 a	30.67 ± 1.91 a	121.48 ± 4.78 bc
6	15.99 ± 0.66 a	26.62 ± 1.03 b	29.89 ± 2.07 a	136.90 ± 8.81 a
7	10.88 ± 0.48 b	17.97 ± 0.63 c	15.28 ± 0.90 b	109.06 ± 7.05 c
V x EC	ns	ns	**	***
V x pH	*	***	***	***
EC x pH	ns	***	***	***
V x EC x pH	ns	ns	**	***

Low pH (5) is more favorable for both Kineta and Lugano, especially at high EC.
High pH (7) tends to suppress values for both, with Lugano being more negatively affected at high EC and pH.
The interaction between EC and pH has a complex effect on both variables, with pH 6 sometimes improving performance at moderate EC (2.5), but consistently declining at pH 7.

REFERENCES

Bantis F, Karamanoli K, Papadimitriou K, Kanellis Ak, Hernández A, Goulas V. (2020). Optimizing lettuce growth under changing climate conditions: An update review." *Agronomy for Sustainable Development*, 40: 1-27.

Chan S., Jerca O. I., Arshad A., Drăghici E. M., (2023). Study regarding the influence of different sowing dates on the production of some brassica species cultivated in Nutrient Film Technique (NFT), *Scientific Papers. Series B, Horticulture. LXVII,*1:550-557.htps://horticulturejournal.usamv.ro/pdf/2023/issue_1/Art73.pdf.

De Vries, I. M. (1997). Origin and domestication of *Lactuca sativa* L. *Genetic Resources and Crop Evolution,* 44(2), 165-174.

Drăghici E. M., (2015). Culturi horticole fără sol, *Ed. Granada* ISBN 978-606-8254-74-6, 210 pg.

Drăghici E. M., Jerca I. O., (2022). *Culturi horticole fără sol*, Ed. Invel-Multimedia, ISBN 978-606-764-034-2, pg. 305.

Doležalová, I., Lebeda, A., Grube, R. (2003). Lettuce (Asteraceae; *Lactuca* spp.) germplasm collecting in the Czech Republic. *Genetic Resources and Crop Evolution*, 50(6): 605-617.

Indrio, F., Motta, V. (2000). Lettuce: History and Development. *Journal of Agricultural and Food Chemistry*, 48(5): 1695-1700.

Jones, J. B. Jr. (2019). Hydroponics: *A Practical Guide for the Soilless Grower*. CRC Press.

Janick, J. (2002). Ancient Egyptian agriculture and the origins of horticulture. In: *Horticultural Reviews*, Volume 28, edited by Jules Janick. John Wiley & Sons, Inc, pp. 191-247.

Lebeda, A., Doležalová, I.,Novotná, A. (2001). Wild *Lactuca* species, their genetic diversity and geographical distribution. In: *Lactuca Genetic Resources*, edited by A. Lebeda and E. Kristkova, Palacky University, Olomouc, pp. 107-128.

López-Gálvez F, López-Gálvez G, Del Mar Guerrero M, Almansa Ms, Allende A, Gil Mi. (2020). High relative humidity and temperature promote lettuce growth and light absorption capacity, *Journal of the Science of Food and Agriculture*, 100(8): 3140-3148.

Park S, Gutierrez Rm, Mumtaz M, Cho H. (2021). Effect of temperature on the growth and morphogenesis of *Lactuca sativa* L. seedlings. *Scientia Horticulturae*, 283: 109882.

Rana G, Kaur S, Suri S, Kang H. (2019). Effect of temperature on germination, growth, and photosynthesis of lettuce, *Journal of Plant Interactions*, 14(1): 82-89.

Rivero Rm, Ruiz Jm, Romero L (2003). Can grafting in tomato plants strengthen resistance to thermal stress? A study on the antioxidant systems. *Plant Growth Regulation,* 40(1): 65-77.

Velez-Ramirez Ai., Van Ieperen W., Vreugdenhil D., Millenaar Ff. (2020). Plasticity of growth and development of lettuce plants in response to changes in temperature. *Environmental and Experimental Botany*, 178: 104159.