

Nutritional quality parameters of tomato genotypes in a hedgerow system

MOHAMMED MUSTAFA^{1,2,3*} , ZITA MAGDOLNA SZALAI¹ and LÁSZLÓ CSAMBALIK^{1*} 

¹ Department of Agroecology and Organic Farming, Institute of Rural Development and Sustainable Production, Hungarian University of Agriculture and Life Sciences (MATE), 29-43 Villányi út, H-1117, Budapest, Hungary

² Doctoral School of Horticulture Science, Hungarian University of Agriculture and Life Sciences (MATE), 29-43 Villányi út, H-1117, Budapest, Hungary

³ Agriculture Research Corporation (ARC), Wad Madani 126, Horticultural Research Center, Khartoum, Sudan

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is grown worldwide in open fields and greenhouses in a range of climate conditions. Hedgerows are a type of agroforestry systems that monitors ecological and influence microclimate conditions. An experiment was conducted at the Soroksár experimental field of the Hungarian University of Agriculture and Life Sciences in 2022 to investigate the influence of hedgerow technology on tomato plant leaves, N, P, K, chlorophyll, and carotene mineral levels from different distances, Exposed sides W1-3m, W2-9m and W3-15m and Protected sides NP1-3m, NP2-9m and NP3-15m, meters from the hedgerow trees.

The results investigate potassium and carotene, as well as chlorophyll b levels, are less differed among the protected and exposed side of the hedgerows trees, while the others were impacted to a certain extent; nitrogen and chlorophyll content was generally higher on the exposed side regardless of variety, while in the case of phosphorus adverse effects were observed. Distance from the hedge showed similar patterns for all traits. The results will help to better understand the impact of alternate technologies on tomato production in open-field conditions.

KEYWORDS

hedgerow, abiotic stress, productivity, tomato

* Corresponding authors. E-mail: kurapicaomer@gmail.com, csambalik.laszlo.orban@uni-mate.hu

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a highly significant cultivated species belonging to the Solanaceae family, and it is the most-produced vegetable worldwide (Roccotiello et al., 2022).

Nutrients such as N, P, K, Ca, Mg, and S are essential for normal tomato growth and reproduction, while micronutrients such as Fe, Cu, Zn, Mn, B, Mo, and Cl are only needed in trace concentrations (Sainju et al., 2003). Nitrogen (N), with phosphorus (P) and potassium (K), is one of the most important macronutrients required by plants for existence (Soares et al., 2021). However, salinity conditions reduce tomato plants' capacity to reduce and assimilate N by inhibiting the synthesis and activities of assimilation enzymes (Chen et al., 2018; Debouba et al., 2007). NPK deficiency causes a slew of physiological, biochemical, and metabolic problems associated with NPK activity in plant metabolism, such as stunted growth, decreased pigment content and quantum efficiency of the photosystem, and high levels of lipid (Tewari et al., 2007). In addition, plant growth and fruit ripening rate and yield are improved by enhancing leaf chlorophyll content, improving plant growth and productivity (Baglieri et al., 2014). Other element concentrations in the leaf indicate that manganese excess and shortage were the main factors affecting growth inhibition and chlorophyll production (Polder et al., 2004; Shenker et al., 2004).

Hedgerows and other agroforestry methods can benefit sustainable agriculture systems by planting trees, shrubs, forbs, and grasses (Brandle et al., 2004). Windbreak trees may modify the microclimate, lessen wind erosion, and protect crops from direct wind. These factors may enhance crop development, plant morphology, phenology, and physiology, productivity (Nair et al., 2010, 2021; Nerlich et al., 2013). A recent study investigated the low light intensity in tomato plants, such as those grown under tree stands or interculture, which disrupts metabolism, leading to reduced photosynthesis and carbohydrate synthesis (Sulistyowati et al., 2016). This results in low growth rates and productivity, with a 26.6% decrease in yield per plant compared to full-light conditions. The aim of this study is to investigate the influence of hedgerow technology microclimate conditions on three tomato plants genotypes 'Szentlőrinc-káta', 'Roma VF' and 'Ace 55' on the nutritional traits such as N, P, K, and chlorophyll and carotene levels, as well as to compare the performance of the cultivation system on protected and exposed sides of hedgerows. It also aims to answer whether incorporating these systems can improve tomato productivity, increase nutrient use efficiency, and enhance environmental services by increasing the net complementarity of the system in organic farming conditions.

MATERIALS AND METHODS

Experiment design and plant material

The experiment was conducted from May to September 2022 at the Soroksár experimental research farm, located at the Hungarian University of Agriculture and Life Sciences Organic Farming Unit. To mitigate the adverse effects of wind, a hedgerow was planted in 1999 and 2000 using local woody plant species, which were determined by their occurrence in the region of the research and the experiment was implemented in 3 rows: in the middle line trees, and the two sides bushes were planted distance of the species 1.5×1.5 m in row and between the rows (Szalai, 2010). The experiment was designed on two sides of hedgerow oriented to NW-SE.



Plots posed by distance (R1, R2, R3, R4, and R5) each distance was three meters apart, with R1 being the closest and R5 the farthest from the hedgerows. The experimental design employed was a random block design (RBD), consisting of five replicates of tree genotypes on both sides resulting in 2×15 plots. Each plot had 8 plants in two rows, the rows were in the right angle to the hedgerow. There were 120 plants on each side, and 240 plants on the overall experiment on both sides of the hedgerow strip, accounting for both windy and protected sides. 'Roma', 'Ace 55', and 'Szentlőrincákáta' tomato genotypes were used with 3 replicates and 5 plots in 2 rows on both sides from the strip in various distances per meter from the exposed sides (W1-3m, W2-9m and W3-15m) and protected sides (NP1-3m, NP3-9m and NP3-15m) from the hedgerow trees. The spacing between plants and rows was 60×60 and 70 cm between the plots and replications for a density of 3.5 plants per m^2 . The soil was covered with woven plastic fiber; plants were supported with bamboo poles.

Measurement parameter

The leaves of tomato plants were carefully selected based on their health and maturity. Four samples were collected on 10 September 2022 from each variety per plot, with 4 samples \times 3 species \times 5 plots \times 3 replications \times 2 sides, then transported to the university laboratory at the Department of Vegetable and Mushroom Growing to measure (Chlorophyll, NPK and Carotene).

Chlorophyll A and B and carotene spectrophotometric analyses

Sample preparation involved crushing the samples in a grinder and extractions were performed using pre-refrigerated acetone. The results were expressed as mg of chlorophyll A and B and carotene per (g) of fresh tissue and determined using the formula outlined by (Ling et al., 2011). The absorption readings were taken at 480, 644, and 663 nm.

NPK content determination of tomato plant leaves

Nitrogen (N): The Kjeldahl formula (1) (AOAC, 1995) was used to assess the total nitrogen (N) content of a sample, including the concentration of the sulfuric acid standard titration solution, the volume of the standard acid solution consumed by the sample, the sample cluster M, and the volume of liquid A to be tested during distillation.

$$w_1 = \frac{(V_2 - V_0) \times C \times 0.0140}{M \times \left(\frac{V_1}{V}\right)} \times 100 \quad (1)$$

Phosphorus (P): Molybdenum-antimony anti-absorption spectrophotometry formula 2 (Liu et al., 2015) was used to evaluate the concentration of phosphorus in tomato plant leaves. The total P content was calculated using formula $P = (C \times V_1 \times V_2) / (V \times m)$. Tomato plant leaves were extracted and placed in a solution containing ammonium molybdate and sulfuric acid. Data were analyzed based on calibration.

$$w_2 = \frac{p \times V}{m} \times \frac{V_1}{V_2} \times 10^{-4} \quad (2)$$

Potassium (K): Flame atomic absorption spectrophotometry formula 3 (Sun et al., 2019) was used to determine the potassium content of a plant sample, expressed as a mass fraction



(w3) in g/100 g. The total K content was determined by applying the formula: $K = (V - V1) \times K / (V2 \times m) - (V0 \times K / V2)$.

$$w_3 = \frac{(p - p_0) \times V}{m} \times \frac{V1}{V2} \times 10^{-4} \quad (3)$$

Statistical methods

Mineral nutritional parameters, for chlorophyll and carotene content spectrophotometric analyses and NPK. The data of the experiment were analyzed ($n = 360$). The statistical methods that were used include. The normality of data was checked using Shapiro-Wilk's test while the homogeneity of variance through Levene's test. The analysis has proceeded to post hoc test for the comparison of the time effect using Tukey HSD. Two-way univariate ANOVA with factors t varieties and distances was used in analyzing the data for inner content. Levene's test was significant; the conduct of further test through the ratio of maximum variance and minimum variance suggested that the aforementioned assumption was not seriously violated. Post hoc test using Tukey LSD was conducted to determine the significantly different treatments.

RESULTS AND DISCUSSION

Nitrogen content of tomato leaves was measured across all treatments in both the Protected and Exposed sides of the hedge shown in Fig. 1. The 'Roma' variety had higher nitrogen content on the Exposed side W1-3m- W3-15m and all the varieties groups, but there is no significant difference on the Protected side. However, there was a significant interaction effect between two varieties in the nitrogen content on variety 'Ace 55' and 'Szentlőrincákata' on both sides at $P < 0.05$.

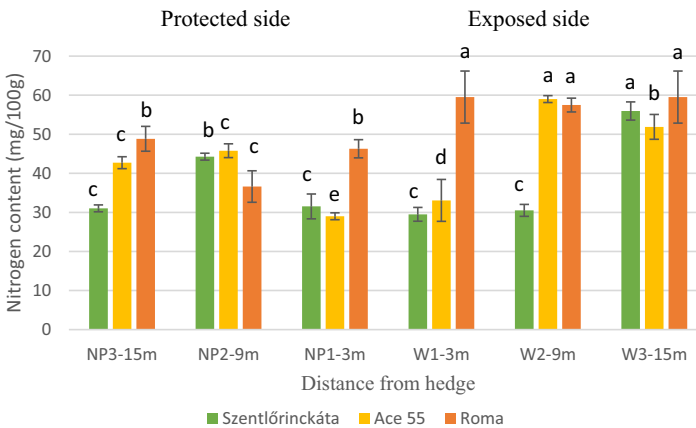


Fig. 1. Nitrogen content (mean + SD) of tomato plant leaves samples produced on the protected and the exposed side of a hedge, at various distances. Ascending numbers mean higher/distances. Differing letters mean significant difference ($P < 0.05$) among samples of the same variety



Regarding phosphorus, there was no significant difference between the two sides in Fig. 2. However, there was a significant difference in the phosphorus content among the variety groups

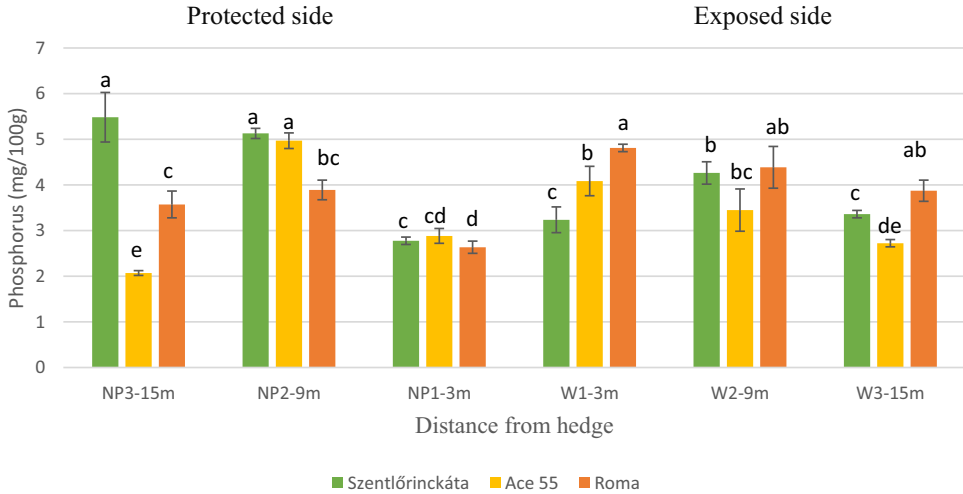


Fig. 2. Phosphorus content (mean +SD) of tomato plant leaves samples produced on the protected and the exposed side of a hedge, at various distances. Ascending numbers mean higher distances. Differing letters mean significant difference ($P < 0.05$) among samples of the same variety

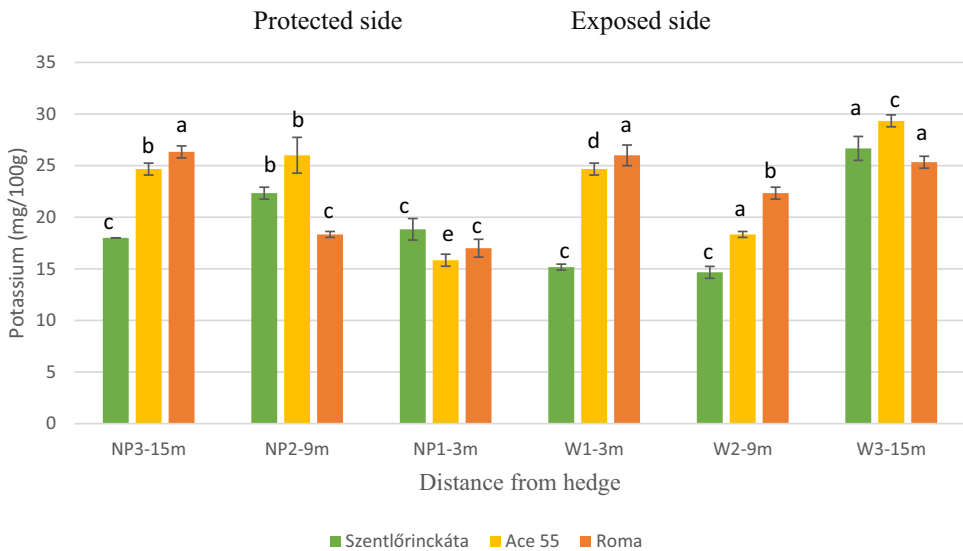


Fig. 3. Potassium content (mean +SD) of tomato plant leaves samples produced on the protected and the exposed side of a hedge, at various distances. Ascending numbers mean higher distances. Differing letters mean significant difference ($P < 0.05$) among samples of the same variety



and distances. The ‘Szentlőrincskáta’ variety had the highest phosphorus content in distance NP3-15m of the Protected side, and significantly different from all the treatments on both sides. The lowest phosphorus content in the varieties group was in the distance NP1-3m of the Protected at $P < 0.05$.

The ‘Ace 55’ variety on the Exposed side had the highest potassium content compared to other varieties and distances. Additionally, there was a significant difference in potassium content among both sides and distances Fig. 3. There was an interaction between the ‘Roma’

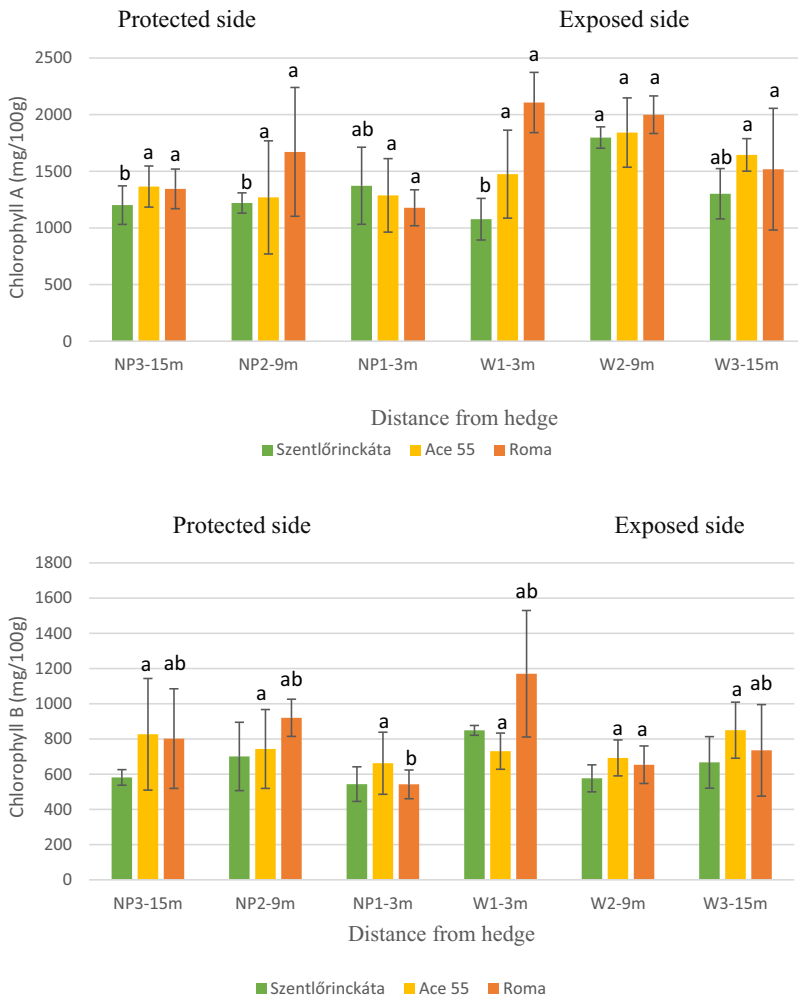


Fig. 4. Chlorophyll A and B content (mean +SD) of tomato plant leaves samples produced on the protected and the exposed side of a hedge, at various distances. Ascending numbers mean higher distances from the hedgerow in 3 m/measured plots distance. Differing letters mean significant difference ($P < 0.05$) among samples of the same variety



and ‘Ace 55’ varieties in distances W1-3m and W3-15m on the Exposed sides. Similarly, in distances NP2-9m and NP3-15m on the Protected sides, an interaction was observed. A significant decrease potassium content was observed in the Protected side distance NP1-3m at $P < 0.05$.

Chlorophyll is an important factor for plant growth due to its influence on photosynthetic ability, which is responsible for the green color of plants in the results shown in Fig. 4. Based on the analysis of chlorophyll A content, it can be observed that the trend increases from distances W1-3m to W2-9m, and the ‘Roma’ variety has the highest chlorophyll A value compared to the rest of the treatments and varieties on both sides. On the other hand, the ‘Szentlőrincskáta’ variety has the lowest chlorophyll content overall at $P < 0.05$. Chlorophyll B, based on the result analysis, the ‘Roma’ variety from the Exposed side and distance W1-3m has the highest significant difference compared to all the other treatment distances and variety groups. The trend is decreasing in chlorophyll B content in Protected sides at $P < 0.05$. This indicates that the ‘Roma’ and ‘Ace 55’ varieties across all treatment distances and sides. In the case of ‘Szentlőrincskáta’, no significant difference was found in terms of distance. However, the ‘Roma’ variety had the highest carotene content compared to the other varieties on both sides and in distance NP2-9m and W2-9m shown in Fig. 5. Moreover, a significant difference was observed in ‘Szentlőrincskáta’ variety in distance and varieties groups at $P < 0.05$. In the case of ‘Roma’ and ‘Ace 55’, distance had no significant effect on carotene content.

Discussion

The goal was to improve the performance of tomato plants and enhance their tolerance to susceptible abiotic factors in the face of climate change and varying environmental conditions on nutritional content and quality. The investigation of the influence of hedgerow technology

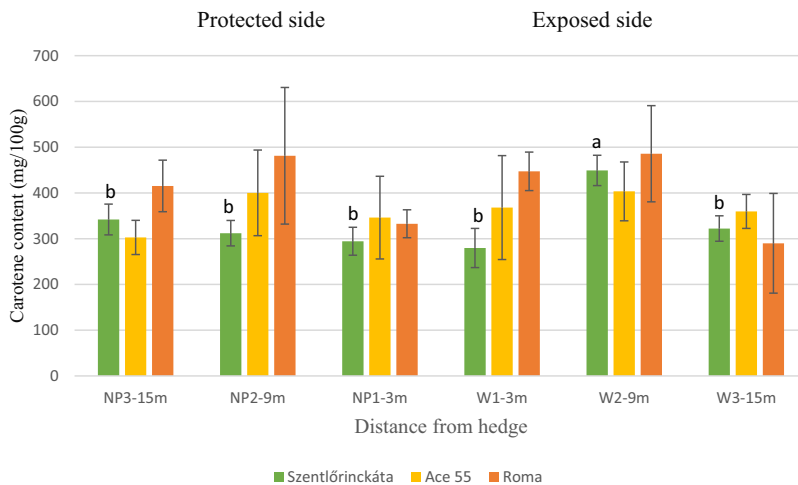


Fig. 5. Carotene content (mean +SD) of tomato plant leaves samples produced on the protected and the exposed side of a hedge, at various distances. Ascending numbers mean higher distances. Differing letters mean significant difference ($P < 0.05$) among samples of the same variety



microclimate conditions on three tomato plant genotypes showed variations in nitrogen, phosphorus, potassium, chlorophyll, and carotene content among the different varieties and distances. In terms of chlorophyll content, varieties had no significant effect, except for 'Szentlőrincákáta'. The Roma variety had higher nitrogen, potassium, and carotene content than the other varieties on both sides, while the 'Szentlőrincákáta' variety had the lowest chlorophyll content overall, similar to the finding of (Polder et al., 2004). There were significant differences among the varieties and distances in phosphorus and potassium content, as well as a significant interaction effect between the 'Szentlőrincákáta' and 'Ace 55' varieties in nitrogen content. The present results of phosphorus, potassium, chlorophyll, and carotene content underline the higher physiological activity of the plant leaves on the Protected side in our experiment. However, there was no significant difference observed between all varieties at both distances. In terms of the effects of distance, it was observed that overall, the exposed sides consistently promoted more plant chlorophyll content and morphology than the protected sides, which agrees with the findings of Vicente et al. (2015).

CONCLUSIONS

The investigation of the influence of hedgerow technology microclimate conditions on three tomato plant genotypes leaves nutritional content and quality, showed variations in nitrogen, phosphorus, potassium, chlorophyll, and carotene content among the different varieties and distances. The 'Roma' variety had higher nitrogen, potassium, and carotene content than the other varieties on both sides, while the 'Szentlőrincákáta' variety had the lowest chlorophyll content overall. There were significant differences among the varieties and distances in phosphorus and potassium content, as well as a significant interaction effect between the 'Szentlőrincákáta' and 'Ace 55' varieties in nitrogen content. The study findings indicate that the determination of nutritional content on tomato plant leaves was not affected by the distances, while 'Roma' showed significant differences among the genotype groups. The present results of phosphorus, potassium, chlorophyll, and carotene content underline the higher physiological activity of the plant leaves on the Protected side in our experiment.

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