DIPLOMA THESIS

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BUDAPEST

IMPACT OF DISTANCE FROM HEDGE ON THE NUTRITIONAL QUALITY PARAMETER OF TOMATO

Departement of Agroecology and Organic Farming

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1. INTRODUCTION

Vegetable production plays a crucial role in agriculture, supplying vital nutrients for human nutrition and fostering economic development. In 2020, the worldwide vegetable output amounted to an impressive 1.1 billion metric tons. Asia emerged as the primary contributor, representing 60% of the total, trailed by Europe (20%), Africa (11%), and North America (9%) (Food and Agriculture Organization of the United Nations, 2022). Worldwide agricultural and natural ecosystems are at risk from the effects of climate change. Rising temperatures have altered the frequency of precipitation, leading to extended drought and excessive rainfall in various regions this condition affects agricultural crops including tomato crop production (Pascual et al., 2022).

Tomatoes (*Solanum lycopersicum* L) rank as the second most consumed vegetable globally, following potatoes (Ilić et al., 2014). It belongs to the Nightshade family (Solanaceae) which originated in the Andean region (Saavedra et al., 2017). There's debate over domestication in Peru or Mexico, with Mexico likely as the origin and Peru as the centre of diversity. Originally small berries, larger fruit sizes evolved through domestication and plant breeding (D. Melomey et al., 2019). Tomato cultivation is practiced employing a range of methods, encompassing both closed and open types, adapted to diverse conditions. Tomato quality is assessed through phytochemical parameters (β-carotene lycopene, lutein), internal quality parameters (firmness, colour, sugar, acidity), and nutritional parameters (vitamin C, potassium). Tomatoes cultivated organically exhibit notable distinctions compared to those from conventional systems. Organic tomatoes boast higher carotenoid levels, increased mineral content (P, K, Mg, Ca), significantly lower levels of heavy metals (Pb, Zn, Cu, Ni), about 30-40% fewer nitrates, and the absence of pesticide residues (Ilić et al., 2014). Many processed food items, including salads, soups, pastes, and sauces, including tomatoes' minerals content, vitamins, essential amino acids, fibre, protein, essential amino acids, carotenoids, monounsaturated fatty acids, and phytosterols are among the common nutrients found in tomatoes, according to reports (Ali et al., 2021a). These nutrients carry out several bodily tasks, such as preventing constipation, lowering high blood pressure, promoting blood circulation, maintaining bodily fluids and lipid profiles, detoxifying bodily toxins, and preserving strength and bone structure (Ramesh, Paul, and Pandey, 2021).In addition, tomatoes are a great source of nutrients and bioactive substances called secondary metabolites, the concentrations of which have been correlated to a reduction in the hazard of chronic degenerative disorders in humans, including cancer, cardiovascular disease (CVD), and neurological disorders.

Agroforestry systems offer a viable solution to address the ecological issue and maintain crop productivity at the same time (Mukhlis, Syamsu Rizaludin and Hidayah, 2022). Hedgerows a type of Agroforestry systems that border grasslands and arable fields are among the earliest and most traditional types of agroforestry systems (Van Den Berge et al., 2021). Hedgerows were originally planned for aesthetic and ecological reasons, but they were also used as property boundaries, fences, and a local supply of fruit, wood, and firewood (Garratt et al., 2017). With so many trees, bushes, and other perennial plants, as well as pests and diseases, crop management will be challenging in this rapidly changing environment. Post-harvest management and organic farming may also have an impact on the tomato fruit's quality (Kissoudis et al., 2015).

2. OBJECTIVES

The primary objective of this research is to assess the impact of Hedgerow conditions on the quality profile parameters of the Roma VF tomato genotype, focusing on final yields under hedgerow systems. Specifically, the study will compare the performance of Roma tomatoes grown at different distances from the hedgerow, analysing fruit quality on both the windy and protected sides. Investigating these factors in the organic farming setting contributes to sustainable farming practices by providing insight into the most effective approaches for the quality profile of tomatoes grown on both sides of the hedge within organic farm environments and make assure to maintain the nutritional composition of the tomatoes.

2.1. The specific objectives of the study:

1. Investigate any variations in quality between tomatoes grown on the windy side versus the protected side of the hedge within the organic farm system.
2. Assess the nutritional composition including levels of vitamin C, antioxidants, polyphenols, and organic acids in the tomatoes.
3. Explore potential impacts of environmental factors, such as agroforestry conditions, on the quality characteristics of the Roma VF variety tomatoes at different distances from and on different sides of the hedge.

3. LITERATURE REVIEW

3.1. Tomato's Origin and History, and Its Journey in Europe.

The ancient progenitor of tomatoes, *Solanum pimpinellifolium*, first emerged in the Andean region of South America, which includes the current time Peru, Ecuador, Bolivia, and Chile (Peralta & Spooner, 2006). Tomatoes, part of the Solanaceae family (Nightshades), are among over 3,000 species in this plant group. Within the Lycopersicon clade are the domesticated tomato (*Solanum lycopersicum L*) and 12 closely related wild relatives. The divergence within the tomato clade occurred around 7.8 to 2.7 million years ago, spanning from *S. lycopersicum* L to *S. pennellii* (Bauchet and Causse, 2012) Tomatoes are likely domesticated in Mexico or Peru; with evidence suggesting Mexico as the primary site for domestication. Peru is recognised as the centre for the wild tomato relative*. Solanum lycopersicum* L var. cerasiforme is seen as a cultivated precursor, common in Central America. Recent genetic studies show that 'cerasiforme' plants mix wild cultivated tomatoes. (Pavan et al., 2009). Between the 14th and 16th centuries, the native inhabitants of Mexico engaged in tomato cultivation as part of the milpa polyculture system. The rich, swampy soils in the area played a key role in the evolution of chinampas (Saavedra et al., 2017). Historical records enable tracing the introduction of tomatoes to the Old World after contact with Europe.

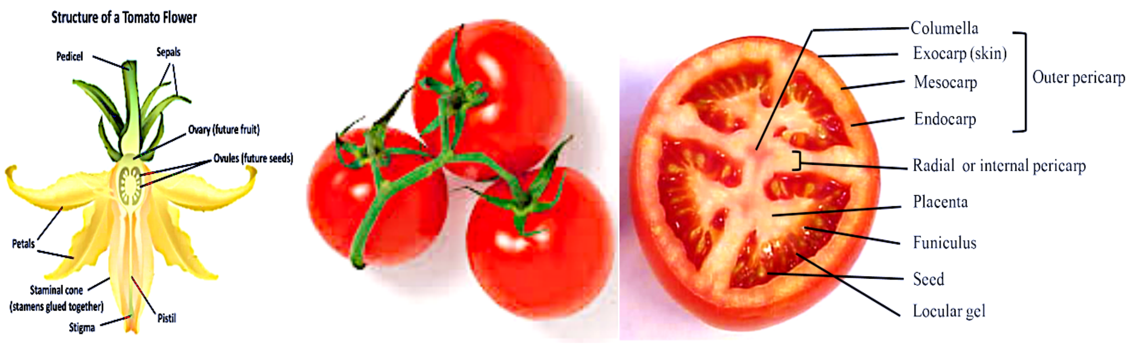
In the 16th century, Spanish navigators introduced tomato seeds to Europe. Friars then sent these seeds to fellow monks, marking the tomato's initial arrival in Andalusia via the Canary Islands. The Spanish and Italians were pioneers in embracing this "exotic" fruit (OECD, 2017). The tomato wasn't consumed until the 17th century due to fears of alkaloid presence. It was first described in Europe in 1543 by Oellinger and in 1544 by Matthiolus, who depicted it as a flat and segmented fruit (Donoso, Martínez and Salazar, 2022). Tomatoes gained culinary acceptance in Southern Europe in the 16th and 17th centuries (Peralta and Spooner, 2006). Recognizing the tomato's compatibility with a warm Mediterranean climate, the Spanish government encouraged its cultivation in Europe and distant colonies. The first variety introduced, probably yellow, was referred to as "pomid' oro" in Spain and Italy. Italy took the lead in embracing and growing tomatoes beyond South America (Mehta, 2017). Tomato, originally from the tropics, is now a global crop flourishing in diverse temperate regions due to widespread cultivation and adaptation (Alhaithloul, Galal and Seufi, 2021).

3.2. Characteristics and Morphology of the Tomato Plant

The tomato plant is naturally a perennial herbaceous by its characteristics (Kaul, 1991). At its genetic core, the tomato is fundamentally a diploid with chromosome number (2n=24) (Peralta and Spooner, 2006). Tomatoes exhibit specific adaptations to diverse climatic conditions, with maturity ranging from 60 to over 95 days. Through advanced genetic engineering techniques, the latest hybrids have been developed, enabling the production of mature fruits within just 45 days (J.Benton Jones, 1999 C.E.). Tomato is a plant that is not dependent on specific day lengths for its flowering and fruiting—a characteristic known as day-neutrality (Xu et al., 2021). Tomatoes thrive best in daily air temperatures ranging from 21 to 24 °C, with a preferred range of 22 to 28 °C, varying with the developmental stage (Ayankojo & Morgan, 2020).

Tomato plants are classified as determinate and indeterminate varieties (Ohta and Ikeda, 2015). the system of root for tomato plants exhibits variability manifesting either as a tap root system or a fibrous root system depending on its cultivation method (McCance and Drysdale, 1975; Sharma et al., 2021). Tomato plants exhibit a taproot system when grown from seeds, while cuttings result in a fibrous root system, accompanied by the formation of adventitious roots (de Lint and Klapwijk, 1986; Guan et al., 2019). The stems, soft and herbaceous, reach heights of 1–3 m and bear pinnate leaves measuring 10–25 cm Leaf arrangement Spiral phyllotaxy (González et al., 2011; Martinez et al., 2016). Both stems and leaves are adorned with glandular and non-glandular hairs known as trichomes, serving as protective features against pests (González et al., 2011; Zhang et al., 2020). The inflorescences are in cyme form, hosting 2–12 yellow flowers (1–2 cm in diameter) with five pointed lobes on the corolla (González et al., 2011).

Tomatoes undergo self-pollination since their flowers are "perfect," housing both male and female reproductive organs within a single blossom (Quinet and Kinet, no date; Hiraguri et al., 2023). Over the past five decades, breeding has markedly altered the tomato plant and its fruit characteristics (J.Benton Jones, 199AD). The outer skin is now fleshy with a thin pericarp layer, and seeds are connected to the placenta (Van De Poel et al., 2014; OECD, 2017). These small, flat seeds are embedded in the placenta. The fruit's colour originates from cells within the fleshy tissue, and tomatoes can exhibit either bilocular or multilocular features (OECD, 2017).



(a) Flower *(b) whole fruit* *(c) cross section of fruit*

Figure 1: Part of tomato flower and fruit (Ramesh, Paul and Pandey, 2021b)

3.3. The Taxonomy of Tomato Plants

Tomatoes are classified as the Solanaceae family, also known as the nightshade family. this extensive group boasts over 3,000 species, including some of our most recognizable cultivated plants like potatoes, peppers, eggplants, and even tobacco. within the family, tomatoes belong to the genus Solanum, a diverse group exceeding 1,500 species. But the story gets more specific: cultivated tomatoes (*Solanum lycopersicum* L) are part of a smaller group within Solanum called the tomato clade (section *Lycopersicum* L) (Bauchet and Causse, 2012). This clade includes 12 wild tomato relatives, all hailing from western South America. the history of tomato classification is quite interesting. Initially named *Solanum lycopersicum* L by Linnaeus in 1753, the tomato was later assigned its genus, Lycopersicon esculentum, by Miller in 1768 (OECD, 2017). While widely used, this classification clashed with naming rules. The modern genetic analysis reinforces Linnaeus's original placement making *Solanum lycopersicum* L the accepted scientific name it's important to note that you might encounter both *Solanum lycopersicum* L and *Lycopersicon esculentum* in your research, depending on the source and date of publication (J.Benton Jones, 199 C.E.). 12 wild relatives *Solanum chmiewelskii, Solanum Chinese, Solanum habrochaitse, Solanum neorickii, Solanum juglandifolium, Solanum lycopersicodes, Solanum sitiens, Solanum cornellomuelleri, Solanum arcanum, Solanum galapagense, Solanum ochranthum, Solanum pennilli (Peralta et al., 2006).*

3.4 The scientific classification of tomatoes is as follows:

Kingdom: Plantae
Subkingdom: Tracheobionta
Division: Magnoliophyte
Class: Magnoliophyte
Order: Solanines
Family: Solanines
Genus: Solanum
Species: Solanum lycopersicum L

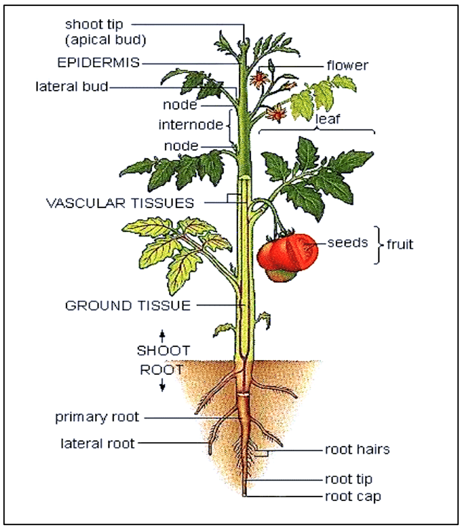


Figure 2: Tomato plant structure (Sajyan, Sassine and Germanos, 2019)

3.5. The World Production of Tomato

The global tomato production reaches approximately 190 million metric tons annually. Based on the latest data from the Food and Agriculture Organization of the United Nations (FAO),2021 here is a list of the top 10 tomato-producing countries along with their respective production quantities in tonnes per year.

Table 1: World-wide production of tomato in various country 2022, (FAO)

Country	Production
China	67.5M Tonnes
India	21.1M Tonnes
Turkey	13M Tonnes
USA	10.4M Tonnes
Italy	6.6M Tonnes
Egypt	6.2M Tonnes
Spain	4.7M Tonnes
Mexico	4.5M Tonnes
Brazil	3.6M Tonnes
Nigeria	3.5M Tonnes

3.6. Economic Importance of Tomato Production

Tomato (*Solanum lycopersicum. L.*) stands as a prominent climacteric fruit, securing the second position in worldwide fruit distribution, boasting an annual production of about 182 million tons. Food and Agriculture Organization of the United Nations (FAO), 2021. China leads in production, followed by India, Turkey and the USA. Globally consumed, tomatoes appear in various forms, including sauce, soup, juice, canned products, ketchup, and a variety of culinary delights. Euromonitor estimates the global processed tomato market reached nearly €157 billion in 2023 (Euromonitor, 2023). Over the past five decades, tomatoes, belonging to the Solanaceae family, have become a leading horticultural crop, with global production surpassing 180 million tonnes in 2019 (Panno *et al.*, 2021; Khalid *et al.*, 2024) in terms of quantity, the global market for "processed tomatoes" has expanded from 31 million tonnes in 2017 to surpass 34.2 million tonnes by 2023. According to Euromonitor's projections, this market is anticipated to reach approximately 37.2 million tonnes by 2027 (François-Xavier Branthôme, 2024). The tomato value chain employs millions of people worldwide, from farmers and agricultural workers to processors, distributors, and retailers. Estimates suggest over 10 million jobs are directly or indirectly related to tomato production and trade (International Labour Organisation, 2014). Tomatoes are versatile crops grown globally in open fields or greenhouses, harvested manually or mechanically. Beyond profitability, they contribute significantly to local economies. Commercially, tomatoes vary in colour, size, and shape (OECD, 2017).

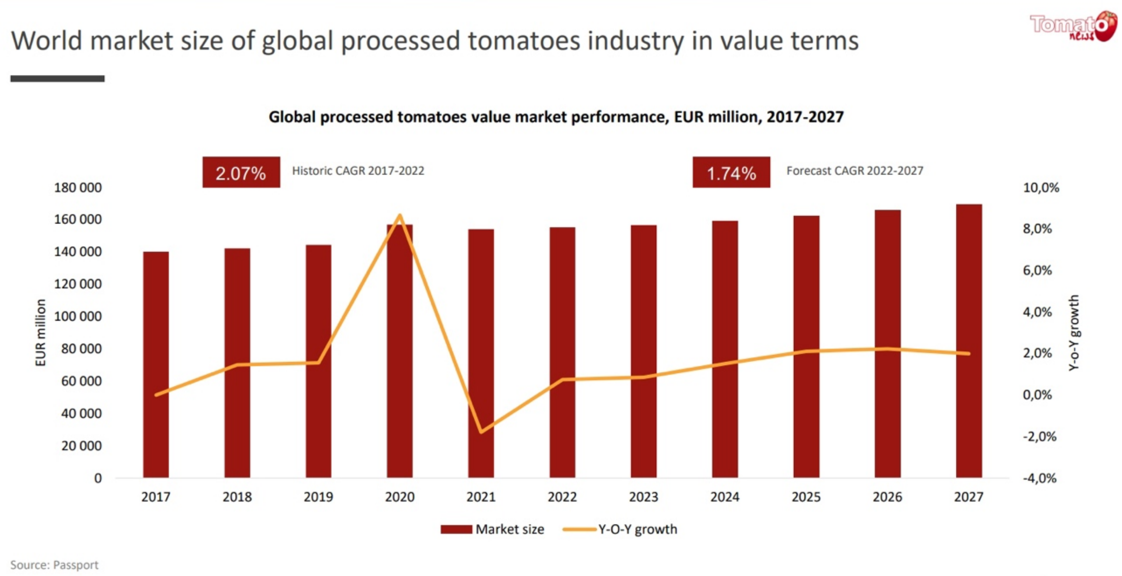


Figure 3: Global processed tomatoes industry in value terms (Euromonitor, 2023).

3.7. The Ecological Requirements

Tomato plants (*Solanum lycopersicum L*) have specific ecological requirements that contribute to their optimal growth and productivity. Here are some key factors to consider, supported by references.

Temperature: The temperature range conducive to optimal growth and abundant fruit yield is ideally between 20°C to 25°C during the daytime and 18°C to 25°C at night- time. Specific temperature requirements for different stages include germination between 15°C to 30°C, vegetative growth at 20°C to 24°C, night-time fruit set at 14°C to 20°C, daytime fruit set at 20°C to 24°C, and red colour development at 20°C to 24°C (Shamshiri et al., 2018; Tokić et al., 2023).

Relative Humidity: The recommended relative humidity for the entire growth cycle of tomatoes falls within the range of 50% to 70%. Research indicates that optimal pollination in tomatoes occurs when the relative humidity is approximately 60%. It's worth emphasizing that as temperatures rise, there is a correlated need for increased humidity, a relationship attributed to the transpiration process in plants (Harel et al., 2014; Shamshiri et al., 2018).

Soil: Loamy soil outperformed other soil types in terms of elevated seed germination rates, superior vegetative growth parameters (including height, leaf number, and fresh/dry weight), and a more abundant mineral content. Consequently, the results highlight loamy soil as the most optimal choice for cultivating tomatoes. Soil should be slightly acidic (Fagwalawa LD, Yahaya SM and Fatima YU, 2015; Zucco *et al.*, 2015).

Soil PH: Most plant species generally thrive in a pH range of 5.5 to 6.5 for near-maximum growth. Nevertheless, there are notable variations in the capacity of different species to flourish beyond this pH range (Islam, Edwards, and Asher, 1980). Root diameter development in tomato plants showed an increase at soil pH 7, contrasting with a decrease at both pH 5 and pH 9. This highlights pH 7 as the optimal condition for enhancing the root size of tomato plants (Astija, 2020). Soil pH impacts not just tomato growth and production but also plays a role in influencing sugar metabolism (Astija et al., 2022).

3.8. Alternative Tomato Production System.

3.8.1. Open Field Tomato Cultivation

Tomato productivity in open field conditions faces significant environmental challenges, with organic farming presenting a particularly difficult route to high yields (Ayankojo & Morgan, 2020). While conventional methods can achieve high output, their reliance on chemical fertilizers, synthetic pesticides, and biocides poses a serious threat to ecosystem health, human well-being, and resource sustainability. These practices contribute to various environmental issues, including nitrate leaching, groundwater pollution, freshwater contamination, soil acidification, water eutrophication, loss of biodiversity and habitat, and soil degradation (Zhou et al., 2023). The use of fertilizers and pesticides can also affect the quality profile of tomatoes and contribute to pollution."

3.8.2. High Technology Greenhouse Production System

High technology greenhouse production system, initially developed in the Netherlands, presents an opportunity to enhance sustainable food production by offering features such as humidity control, supplementary lighting, and thermal screening (Maureira et al., 2022). These innovative systems enable growers to fine-tune internal climate conditions to support optimal crop growth, ensuring both high-quality yields and increased quantity. By protecting from adverse weather conditions and excessive radiation, while also maintaining ideal temperature levels, these greenhouses create an environment conducive to maximizing crop development (Bazgaou et al., 2021). Growing tomatoes in greenhouses is mostly motivated by economic factors (Zhou et al., 2023). However, the visual difference between artificial growing conditions and those using natural sunlight can lead consumers to mistakenly believe that tomatoes are grown using artificial technologies. This, in turn, can raise concerns about the nutritional value of the final product and the potential for increased chemical use (Martínez-Blanco et al., 2011).

3.8.3. Tomato Organic Farm Production

Organic farming represents a traditional and eco-friendly approach to agriculture, utilizing organic fertilizers derived from crop residues, animal manure, human waste, and other natural materials. Its primary goal is to promote sustainability by encouraging natural pest control methods and reducing environmental pollution caused by industrial pesticides and antibiotics (Wu et al., 2019). Through the breakdown and mineralization of organic substances in these fertilizers, nitrogen and phosphorus become readily available to plants, enhancing tomato plant nutrient uptake via the soil microbiome, and resulting in improved fruit development and nutritional quality. Techniques such as crop rotation and intercropping further bolster soil fertility and nutrient balance, facilitating sustained tomato production with minimal adverse environmental impacts (Pieper & Barrett, 2009). According to the FAO, organic standards prohibit the use of growth hormones, insecticides, stimulants, preservatives, irradiation during post-harvest handling, and the use of materials or products derived from genetically modified organisms, Organic-certified products are recognized for their higher nutrient content compared to conventionally farmed products (Vélez-Terreros et al., 2021). Additionally, factors like post-harvest practices and organic farming methods may influence the quality of tomato fruits (Kissoudis et al., 2015).

3.8.4. Argo-Ecological Hedge Grow System.

Hedgerows bordering grasslands and arable fields represent one of the oldest and most traditional forms of agroforestry systems (Van Den Berge et al., 2021). Initially established for aesthetic and ecological purposes, hedgerows also served practical functions such as delineating property boundaries, acting as fences, and providing local sources of fruit, wood, and firewood (Garratt et al., 2017). Agroforestry, with its integration of trees, bushes, and perennial plants, offers a promising solution to address ecological concerns while maintaining crop productivity (Mukhlis et al., 2022). However, managing crops in such diverse environments, with the presence of pests and diseases, presents significant challenges.

During the research carried out in the hedgerow, numerous species were observed, including *Euonymus europaeus* (European spindle), *Prunus spinosa* (sloe), *Sambucus nigra* (Black elder), *Corylus avellana* (Hazelnut), *Rosa canina* (Meadow rose), *Ligustrum vulgare* (Common privet), *Cronus mas* (Cornelian cherry), *Cronus sanguine* (European dogwood), *Acer campestris* (Field maple), *Malus sylvestris* (Crab apple), and *Pyrus piaster* (Wild pear). The selection of these species was based on their frequency in the area surrounding the Soroksár research and experimental station. They were distributed evenly and placed in rows with a 1.5 x 1.5-meter gap between each one. Three rows are made up of shrubs placed on either side of the trees and trees in the middle (Mustafa, Magdolna Szalai and Csambalik, 2023).

3.9. The variety of Roma VF

The Roma VF tomato, often known as the "plum tomato," was chosen for this research due to its superior qualitative parameter (rock et al., 2010). The Roma VF genotype, originating from the Joseph Harris seed company was developed by crossing the original Roma variety with the California Red Top VR 9 (Nipa et al., 2020). Roma produced the maximum yield among all cultivars, and it is most suitable for agroclimatic conditions (Zhu *et al.,* 2018a). One significant tomato variety around the world is the Roma group they are more prominent for their rectangular shape, bright red colour, sweet flavour, and large pulp production (Zhu *et al.,* 2018b). Roma tomatoes are a hybrid variety developed around 1955 and are believed to be a cross of the Pan American tomato with San Marzano, a paste tomato that was thought to have been brought into the United States by Italian immigrants. Roma tomato is a paste tomato and generally has a thicker fruit wall, fewer seeds, and a denser grainier flesh. Roma tomatoes tend to be oblong in shape and heavy for their size (A. Oguntola, Ologundudu and Oladele, 2019). Roma VF's name came because of its resistant power on Verticillium and fusarium wilt hence it's called Roma VF. Roma tomatoes are grown in the United States, Mexico, Australia, and Great Britain. The vines are determinate which means that the fruit ripens at one time rather than continually through the season, while Roma tomato is an open-pollinated variety rather than a hybrid. The variety has a maturity period of 75 days and is resistant to verticillium and fusarium wilts and grows to a height of 120cm with red and pink coloured fruit with an average weight of 113g. Roma variety can be in red and yellow colour. Roma variety is also a popular variety for home canning because of its highly acidic nature (A. Oguntola, Ologundudu and Oladele, 2019). Despite well-established growth, yield, and fruit characteristics in various parts of the world, these attributes have not been thoroughly examined under the agroecological conditions of many countries. (Sind, 2009).

Figure 4: Roma VF variety, (HTTP 1,2024)

3.10. Factors Determining Fruit Quality

Fruit quality is a decisive factor in the production of tomatoes. some of the parameters set determining the quality of a tomato product are the concentration of soluble solids (°BRIX), acidity(pH), vitamin C levels, and protein content. Thus,100 g of fresh tomato provides over 46%, 8%, and 3.4% of the daily requirements of vitamin A (900 IU), vitamin C (82.5 mg), and potassium (3500 mg). Tomato fruit quality is a panoramic concept. So, the overall quality of fruit results from how these different external conditions interact and affect each other. The way different individual characteristics combine to form the overall quality of tomato fruits is a complicated concept (Flores et al., 2010). External aspects such as appearance, texture, taste, and size are frequently emphasized by classification systems as essential components of sensory quality. Fruit quality is commonly classified into four categories: nutritional aspects phenolic compounds (phenolic acids and flavonoids), carotenoids (lycopene,α and β carotene) vitamins (ascorbic acid and vitamin A) and glycoalkaloids (tomatine), taste attributes (like sugar content, organic acids, and consistency), and external traits (like size, consistency, shape, and colour) that affect storage (Wang et al., 2015).

3.11. The internal quality of tomatoes

Aromatics and Flavours of Tomato Fruit: Aromas and soluble solids these chemical compounds are directly related flavour of tomatoes (Fernández-Ruiz et al., 2004). Taste, smell, and texture all work together to greatly impact tomato flavour. Although the mechanisms behind tomato flavour have been studied, little is known about the variations in taste perception. The complex quality of aroma is essential. Interactions between non-volatile ingredients like sugars, acids, and amino acids are not the exclusive source of tomatoes' unique sweet-sour flavour. Instead, it results from a complicated mixture of substances that are both volatile and non-volatile This aroma is due to the presence of volatile compounds, such as terpenes and alcohols, that are naturally produced by the tomato (Erika et al., 2022). Each cultivar possesses its unique flavour profile, influenced by both volatile and non-volatile organic components. Organic tomatoes, in particular, are renowned for their superior flavour compared to other tomato varieties, owing to their distinct composition of organic compounds. (Feng et al., 2020). Fruit flavour is significantly influenced by the number of organic acids it contains. (Li et al., 2022).

Sugar and Organic Acid Dynamics in Tomato Fruits: The sugar and organic acid levels in tomatoes vary significantly based on the stage of growth and ripening (Agius et al., 2018) and both elements influence the flavour of tomato. Fruits often have a higher total sugar content throughout the ripening process – roughly 4%. Initially, glucose makes up most green, unripe fruits, with fructose being slightly more common to mature after ripening. There is a developmental stage in the presence of organic acids all phases 0 fruit growth are dominated by citric acid, yet unripe green tomatoes may contain a significant level of malic acid (Li, Lu and Li, 2022)

Textural Attributes of Tomato Fruit: The fruit texture significantly influences consumers' perceptions of tomato fruit quality. To many characteristics contribute to fruit texture, primarily sensory attributes like flesh firmness, mealiness, meltiness, juiciness, and crispness. Significant changes in texture emerge during fruit ripening, primarily linked to softening, which significantly impacts post-harvest performance including transportation, storage, shelf life, and resistance to pathogens (Chaïb et al., 2007).

3.12. External Quality

Size and form dynamics of tomato fruits: Fruit size and shape are important quality qualities that affect customer choices. They are mostly determined by hereditary causes; however, breeding efforts have resulted in significant variation. Fruit size varies because of intricate relationships between genetics, environment, and management techniques, whereas fruit form is mostly determined by genetic composition and is only slightly impacted by environmental influences. The increase in fruit volume is ascribed to the development of pericarp tissue, which includes cell formation (which normally stops 10–25 days after anthesis) and subsequent cell growth and expansion. Potentially restricting this process is epidermal extensibility. The fruit size cannot be increased in temperatures above 35°C. Research reveals a considerable association between the number of cells and the ultimate fruit size, despite the emphasis on growth, highlighting the complex mechanisms controlling fruit size. (Bertin and Génard, 2018).

Tomato Fruit skin colour impact: The outer appearance, or skin, of a tomato, significantly influences customer attraction, with colour being a key qualitative factor in how fleshy fruits are evaluated by consumers. Tomato fruits come in a variety of colours, ranging from green and yellow to orange and red. Colorimeters are utilized to measure L*, a*, and b* values. The L* value represents the ratio of white to black colour values, the a* value represents the ratio of red to green colour, and the b* value represents the ratio of yellow to blue colour (Saad, Ibrahim and El-Bialee, 2016). These colours are mostly determined by the concentrations of carotenoids, such as lycopene and β-carotene, as well as chlorine. Increased levels of lycopene and β-carotene, respectively, give birth to red and orange colours. Although chlorophylls are present in green fruits, they usually decompose as the fruit ages. Many of the genetic loci that control tomato fruit hue encode enzymes necessary for the synthesis of carotenoid pigments or the factors that control them (Bertin and Génard, 2018).

3.13. Nutrient Composition of Tomato

Nutritional perspective tomato fruit, is a good source of diet, Because of the well-balanced combination of minerals, and lipids, sugar, antioxidants, which includes vitamins C and E, lycopene, beta-carotene, lutein, and flavonoids, as well as amino acids, has low proteins, fatty acids, rich in water and fat content with some carbohydrates, it is a great source of health-promoting substances (OECD, 2017). Additionally, tomatoes are high in trace elements like Fe, Mn, Zn, and Cu and rich in macronutrients like K P, Mg, and Ca. According to nutritional research, eating a diet rich in fruits and vegetables, especially tomatoes, can help. The quantity and quality of phytochemicals detected in tomato fruits are known to depend greatly on genotype and environmental conditions (Ali et al., 2021b).

Table 3: Nutrient composition of tomato (Ali et al., 2021a).

Parameters	Values	Ranges	Units
Energy	34.67	75.00	(kcal/100 g)
Lipid	4.96	5.39	(g/100 g
Carbohydrates	5.96	8.00	(g/100 g)
Total sugar	50.60	56.45	(g/100 g)
pH	3.83	4.08	-
Acidity	0.48	0.55	(%)
Reducing sugar	35.84	41.21	(%)
Fructose	2.8	3.42	(%)
Glucose	2.45	3.18	(%)
Sucrose	0.02	0.02	(%)
Total fibber	11.44	19.36	(g/100 g)

3.13.1. Carotenoids

Carotenoids are well-known that natural organic substances that significantly reduce the chance of contracting several illnesses, such as diabetes, gastrointestinal issues, and cardiovascular conditions. Additionally, carotenoids have been linked to the demonstration of anticancer activities, particularly against malignancies of the stomach, lung, and prostate (Ali et al., 2021b). Lycopene, α-carotene, β-carotene, γ-carotene, δ-carotene, phytoene, phytofluene, neurosporene, and lutein are the primary carotenoids found in tomatoes Martí et al. (2016) carotenoids are fat soluble pigments. Lycopene (7.8–18.1 mg/100 g FW), α-carotene (0–0.002 mg/100 g FW), β-carotene (0.1–1.2 mg/100 g FW), γ-carotene (0.05–0.3 mg/100 g FW), δ-carotene (0–0.2 mg/100 g FW), and phytoene (1.0–2.9 mg/100 g FW) in tomatoes were examined in the research and their respective ranges were noted. Because lutein is concentrated more when the fruit achieves complete maturity, lutein is conspicuously lacking in unripe tomatoes. Lutein is detected in ripe tomatoes. (Chaudhary et al., 2018). HPLC is the most accurate technique for the objective detection and quantification of carotenoids. Accordingly, HPLC techniques have been used to accurately identify lycopene in fresh, canned, or juice samples. Nonetheless, colorimetric, and spectrophotometric techniques are also often employed to measure lycopene. The approach chosen and the precision of the outcomes greatly depend on the skilled labour, time, and accuracy required.

3.13. 2. Lycopene

Lycopene is a significant biological compound that has drawn a lot of attention due to its potential to prevent chronic illnesses including atherosclerosis, skin cancer, prostate cancer and cardiovascular disease According to Wang et al. (2016), (MK and BK, 2020), eating lycopene consistently lowers the chance of developing prostate cancer. One of the primary antioxidants present in both fresh and processed tomatoes is lycopene. When lycopene is exposed to harsh processing techniques like drying and sterilizing, it remains very stable. (Giovanelli et al., 2016). The most affordable raw material that provides a significant amount of the pigment lycopene is the tomato Approximately 80–90% of the carotenoids found in popular tomato varieties are lycopene. The distinctive deep-red colour of ripe tomatoes is caused by lycopene and this colour is an important indicator of tomato freshness. (Bobinaitė et al., 2021 a) The biological properties of red-coloured carotenoid lycopene, such as its antibacterial, photoprotective, anti-hypercholesterolemic, antioxidant, and cardioprotective properties, make its use as a nutraceutical attractive. (Carvalho and others, 2021). One of the main carotenoid pigments in diets, lycopene, is essential for protecting cells from oxidative damage to proteins, lipids, and DNA. (Górecka and others, 2020). The molecular makeup of the carotenoid lycopene $C_{40}H_5$ (Carvalho et al., 2021).

3.13. 3. β carotene

β carotene plays a pivotal role in carotenoid biosynthesis, with their synthesis facilitated by two key enzymes lycopene ε-cyclase and lycopene β -cyclase they are essential for the synthesis of α -branch carotenoids by catalysing the cyclization of lycopene(Ma et al., 2011). Tomatoes owe their distinctive reddish-orange hue to β carotene, a chemical compound with significant nutritional importance. Beyond its visual appeal, β carotene plays a crucial role in supporting immune system function, maintaining healthy skin, and promoting visual health as a precursor to vitamin A (MK and BK, 2020). Renowned for their high concentration of β carotene, making them a valuable dietary source of this essential substance. however, it's important to note that the bioavailability of β carotene from tomatoes can be influenced by various cooking methods and the presence of lipids, which may enhance its absorption. β carotene is sensitive to heat treatments and tends to degrade more rapidly when exposed to oxygen and light, rendering it less stable compared to lycopene (Bobinaitė et al., 2021 b).

Table 4: Carotenoid contents in tomato. (Ali et al., 2021a)

	Concentrations	Range	Units
β-carotene	9942.16	10,206.90	µg/100 g
α-carotene	101.00	101.00	µg/100 g
Lycopene	8002.50	11,110.00	µg/100 g
Lutein + zeaxanthin	60.67	123.00	µg/100 g
Phytoene	668.33	1860.00	µg/100 g
Phytofluene	500.00	820.00	µg/100 g
All trans-lutein	5.00	6.00	mg/kg
All trans-β carotene	29.25	75.00	mg/kg
9-cis-β carotene	6.50	9.00	mg/kg

3.13. 4. Fruit Total Phenolic Compounds (TPC)

Phenolic compounds, which are part of plants' secondary metabolites, are characterized by their structure, featuring one or more hydroxyl groups attached to a benzene ring (Chaudhary et al., 2018). The quantity and composition of phenolic compounds in foods are influenced by factors such as genotype, storage condition, extraction procedures, and environmental factors (Luthria, Mukhopadhyay and Krizek, 2006). Ripe tomatoes are rich in phenolic compounds, which serve various biological functions. These compounds aid in defusing injuries and cuts caused by insects, attract pollinators, and act as pigments in plant tissues (Li et al., 2012) Furthermore, they are considered beneficial for human health due to their antioxidant properties, which help prevent human health due to their antioxidant properties, which help prevent chronic diseases and may reduce the rate of ageing (Ali et al., 2021b).. Tomatoes contain a wide array of phenolic compounds, with over 8000 identified from plant materials. The compounds are classified into different groups, including phenolic acids such as caffeic, chlorogenic, sinapic, p-coumaric, and ferulic acids, as well as flavonoids like quercetin, rutin, kaempferol, and naringenin. During maturation, chlorophyll content decreases in tomatoes while flavonoid accumulation increases (Jafari et al., 2017).

3.13. 5. Phenolic Acids

Phenolic acids play a crucial role in shaping the flavour, aroma, and overall sensory appeal of tomatoes. They contribute significantly to the taste profile of tomatoes while also aiding in their preservation by inhibiting the growth of spoilage–causing bacteria (Feng et al., 2020). These compounds can be classified into two main groups: cinnamic acid derivatives and benzoic acid derivatives, each distinguished by its fundamental carbon skeleton structure (Luthria, Mukhopadhyay and Krizek, 2006).

3.13. 6 Flavonoids

Flavonoids, which are secondary metabolites derived from plant polyphenols, constitute a diverse class of compounds present widely in terrestrial plants, across various plant parts like flowers, fruits, leaves, stems, and roots. certain flavonols like kaempferol and quercetin found in tomatoes exhibit higher antioxidant activity in humans compared to other tomato-derived flavonoids/flavanols (Kamiloglu *et al.*, 2014). Initially identified in Solanaceae spp., key flavonoids such as phloretin 3',5'-di-C-}-glucopyranoside and quercetin 3-O-(2"-O-}-apiofuranosyl-6"-O-R-rhamnopyranosyl-}-glucopyranoside) are found across tomato cultivars (Slimestad, Fossen and Verheul, 2008). Functionally, flavonoids act as specialized UV filters, safeguarding plants against a spectrum of stresses including UV radiation, reactive oxygen and nitrogen species, pathogens, parasites, and herbivores (Luthria, Mukhopadhyay and Krizek, 2006). The concentration of total flavonoids in tomatoes varies among cultivars, ranging from 4 to 26mg per 100 grams (Slimestad, Fossen and Verheul, 2008). Beyond their potential preventive health benefits, flavonoids exhibit diverse biological activities such as anti-inflammatory, anti-allergic, and antibacterial properties (Katırcı et al., 2020).

Table 5: constituents in tomato. (Ali et al., 2021a)

	Concentrations	Range	Units
Phenolic acids	25.500 ± 3.590	21.34–31.23	mg CIAE/g extract
Flavonoids	4.230 ± 1.280	3.06–6.36	mg QE/g extract
Anthocyanins	0.870 ± 0.470	0.23–1.36	mg ME/g extract

3.13. 7. Ascorbic Acids and Vitamin C

Tomato fruits have a high vitamin C concentration soon after they start to mature and a slow decline as they get bigger. However, the fruit's vitamin C content usually rises as it ripens from the mature green stage onward. The amount of vitamin C in tomato flesh increases as it ripens; at the overripe stage, it even reaches higher levels (Ntagkas et al., 2016) Vitamin C is One of the most prevalent water-soluble antioxidant molecules also known as ascorbic acid (As A). Ascorbic acid (As A) is a multifunctional phytonutrient that is vital for plant development Several vital physiological functions, including the elimination of reactive oxygen species, growth regulation, cell metabolism, cell division, wall expansion, and the production of other metabolites, are directly impacted by vitamin C and human nutrition (Mellidou et al., 2021a). As a major source of ascorbic acid and relatively low amounts of dehydroascorbic acid, tomatoes are an important source of vitamin C for humans. However, the variety is a significant factor in ascorbic acid determination. Depending on the cultivar and growing environment, red tomatoes normally contain 23 mg of ascorbic acid per 100 grams of fresh produce. Ascorbic acid production and accumulation in tomatoes have been linked to the fruit's maturation stage. When compared to fresh tomatoes, torn tomatoes can reduce ascorbic acid levels in storage conditions by up to 50%. Under conditions of an adjusted environment, vitamin C may be stored in fresh tomatoes. as well as drops in the temperature (Sablani and others, 2005). Changes in vitamin content, the loss of components with aromatic aromas, and textural properties (Li et al., 2022). As A levels in leaves and fruits are mostly regulated by light. As A is produced locally in tomato fruit and may also be imported from ripe leaves.

Table 6: Vitamin contents in tomato. (Ali et al., 2021a)

Vitamins	Concentrations	Range	Units
Vitamin A	614.44	267.33–833.00	mg/100 g
Vitamin E	15.08	16.13	mg/100 g
Vitamin K	98.28	98.28	mg/100 g
Vitamin C	36.16	85.00	mg/100 g
Thiamine	0.66	0.98	mg/100 g
Riboflavin	0.48	0.81	mg/100 g
Niacin	9.68	9.68	mg/100 g
Pantothenic Acid	4.93	5.34	mg/100 g
Vitamin B_6	1.51	1.72	mg/100 g
Biotin	68.97	68.97	mg/100 g
Folate	14.00	15.00	mg/100 g

3.14. Factor Affecting Quality

Open-field crops are subjected to a variety of adverse environmental factors that might affect plant development and production, both biotic and abiotic stress. Environmental challenges such as drought and salinity, categorized as abiotic stresses, stand as primary factors constraining the global productivity of major crops (Mellidou et al., 2021b)Similar to other plant species, tomato plants suffer from a wide range of environmental stress factors, with the most important being drought, salt, and high temperature/high light. Due to increases in global warming, the average temperature is rising, and precipitation is falling due to the continuing climate change, which is being exacerbated by the increase in atmospheric CO2 concentration (Peters et al. 2011), notably in areas with moderate climates. The level of abiotic stress can affect responses to mixes of biotic and abiotic stress, hence the outcome of the interaction may. The ISO-standardized process known as life cycle assessment (LCA) is used to examine how environmentally friendly product systems are (Gentil et al., 2020). Hedge tree shade on plants holds moisture of soil to help to grow but affects the antioxidants in tomatoes and reduces the synthesis of the pigment, and ascorbic acid accumulation in tomatoes. it is a potent antioxidant that can neutralize free radicals and protect cells from oxidative damage. According to (Shimeles et al., 2017a) vitamin C content is lower near the hedgerow.

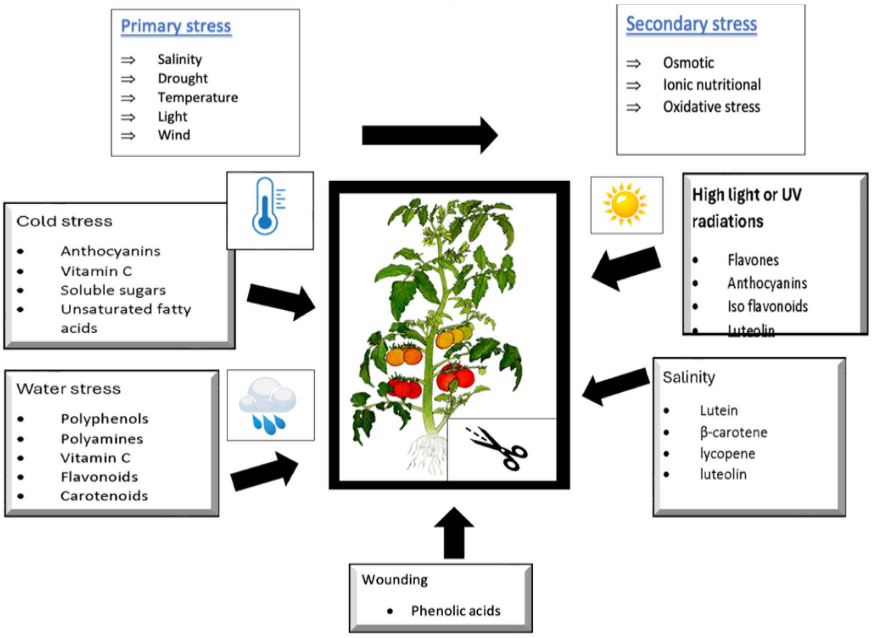


Figure 5: Factors that influence the nutritional content of tomatoes (Toscano et al., 2019).

4. MATERIALS AND METHODS

4.1 Materials

4.1.1. Study Area

The research study took place between April to September 2023 in the Soroksar Experimental Research Farm Organic unit of the Hungarian University of Agriculture and Life Sciences (MATE). The location in Túri István út. 2, which is situated around 20.2km northeast of Budapest at 47°23'34.6"N latitude and 19°08'53.7"E longitude. Its altitude varies between 99 and 110 meters above sea level. The main experimental site was set up near the geographical coordinates N 47°24'40", E 19°7'48". It encompasses around 11 hectares of officially classified ecological land, characterized by several soil types. In addition, a hedge consisting of indigenous woody plant species was planted in two phases, initially in 1999 and subsequently in 2000, so substantially improving the environmental circumstances of the experiment. The Soroksár Experimental Research Farm offers a complete and environmentally certified infrastructure for conducting agricultural and life sciences research in a controlled environment (Szalai, 2010)

Figure 6: Hedge in the Research and Experiment field of the Organic Unit in Soroksár Research and Experiment Station of Szent Istvan University (Google Map 2024).

4.1.2. Plant Materials Used

Roma VF tomatoes	*(Solanum lycopersicon. L)*
Maturity	75 days
Type	Open-pollinated
Vine	Determinate
Plant height	1 metre (3.3 feet)
Fruit weight	112g
Leaf	Regular leaf
Resist	V, F(Verticillium and fusarium wilt)
Colour	Red(pink)
Shape	plum

Figure 7: Planting material (HTTP 2,2024)

4.1.3. Experiment Design

Various genotypes of tomato seeds for processing and fresh market were used in the complete experiment, including globally registered cultivars like Roma VF, ACE 55, and the Hungarian landrace Szentlőrinckáta. The plants were exposed to circumstances like those in an open field, with the planned hedgerow site providing a microclimate with both protected and windy sides. Considerations included soil type, irrigation systems, lighting, temperature, relative humidity, and fertilizer amount. A random complete block design (RCBD) was used as the experimental setup. This required moving the plants into a configuration made up of five diagonally arranged plots and five duplicates of each of the three types. As shown, two rows were created, one on each side of the hedgerow strip, with protected and windy sides. Every plot was made up of eight plants, one variety was represented by 5 plots x 2 sides = 80 plants. A density of 3.5 plants per m^2 was achieved by placing 60 x 60 cm between plants and rows and 70 cm between plots and replications. Among 3 different varieties, my research topic is only concentrated on Roma variety quality assessment.

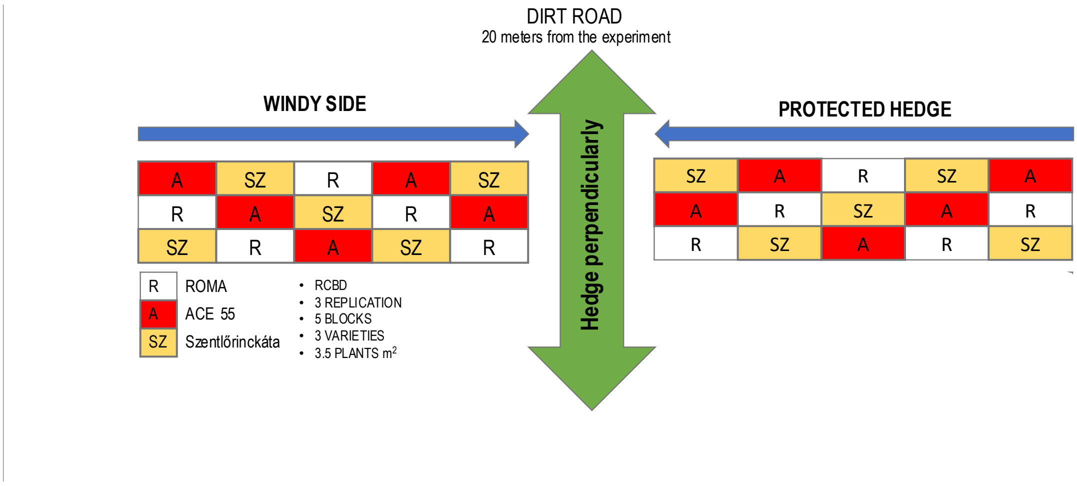


Figure 8: Random complete block design of the experiment setup.

4.2. Methods and Data Collection

4.2.1. Harvest and Tomato Fruit Sample

Ripen Roma tomatoes, cultivated organically, were harvested on August 16, 2023, separated by side and distance. The yield of each plot was separated into 1st, 2nd and waste categories and measured by a field scale. From each plot, an average of 1,5 kg of fruits were taken and transported to the laboratory for homogenizing.

4.2.2. Sample Preparation of Extracts

5-6 full ripe tomatoes from various distances were selected and washed in tap water; the tomatoes were cut into pieces using a kitchen knife. Subsequently, the tomato fragments were homogenized using a kitchen blender (Hungarian University of Agriculture and Life Sciences, Department of Agroecology and Organic Farming). The homogenates were frozen until further analysis.

(a) (b) (c)

Figure 9: Tomato sample preparation tomato, cut piece, paste, packed sample, frozen sample (own work)

4.2.3. Chemicals and Reagents

Folin-Ciocalteau, methanol, Sodium carbonate (Na_2CO_3), gallic acid, Sodium acetate (Na-acetate), acetic acid, pH 3.6, ferric chloride ($FeCl_3$), 2,4,6-Tripyridyl-s-Triazin (TPTZ) and distilled water was used through. phosphoric acid and methanol.

Figure 10: Preparation for the instrumental measurements (own work)

4.3. Data Collection and Measurements

4.3.1. Total Polyphenol Content (TPC)

Determination of total polyphenol content with Folin-Ciocalteu reagent, which was derived from (Singleton, V & Rossi) was used to determine the total phenolic contents, with some modification 50 mL Folin is blend diluted with 500 ml distilled water to get Folin solution. Methanol is diluted with distilled water (DW) in a ratio of 80:20 mL proportion 31.1g Sodium carbonate (Na_2CO_3) is diluted in 500 distilled water (DW) and 5.1 mg gallic acid is diluted with methanol and distilled water with a ratio of 80:20 mL. 1250μL of Folin solution and 200μmL MeOH: DW are added to the test tube and they are placed in a 50°C water bath for 5 minutes the absorbance of the blank sample will be measured at 750nm and by adding 50μmL of gallic acid and 10 mL of blended tomato juice is added and the total measurement of the sample always keep the final volume to 2500μmL and each measurement was performed in triplicate by using below equation of the calibration (Singleton and Rossi, 1965).

$$\text{TPC} = \frac{A}{tg\alpha} * \frac{V\ all}{V\ sample} * D$$

TPC - Total polyphenol content

A- Absorbance

tg α - the slope of the calibration line

V all- final volume =2500μmL

V sample – the volume of the sample

D – Dilution

Figure 11: The machine used in the instrumental measurements (spectrophotometer)

4.3.2. Ferric Reducing Antioxidant Power (FRAP)

Determination was conducted according to what was used to determine the antioxidant power. The FRAP reagent was obtained by blending (3.1g Na- acetate*$3H_2O$/16 ml acetic acid (1liter) pH 3.6) 300 mM Acetate buffer, ferric chloride ($FeCl_3$ *6 H_2O) with distilled water of 54mg/ 10ml, 2,4,6-tripyridyl-s-triazine solution at a 10:1:1 (v/v/v) ratio was heated to 37° C for 5 minutes in a water bath. A test tube was filled with 1500 μml of FRAP reagent, and a blank reading was recorded at 593 nm. 1500 μ ml of FRAP reagent and 50μL of prepared selected extracts and 50μL of distilled water were added into the cuvette. The second reading recorded at 983 nm was 5 minutes reaction time (Benzie and Strain, 1996). FRAP assay measures the antioxidant capacity of a sample by its ability to reduce ferric (Fe^{3+}) ions to ferrous (Fe^{2+}) ions in the presence of a reagent containing a ferric tripyridyl triazine complex.

$$Fe^{3+} - TPTZ <> Fe^{2+} - TPTZ$$

Colourless blue

The spectrophotometer is a scientific instrument that measures the method of light a substance absorbs at different wavelengths of phenolic compound

Figure 12: The machine used in the experiment (spectrophotometer)

4.3.3. Vitamin C measurement

According to the protocol of the laboratory, the vitamin C measurement was done as follows: using a Waters 2487 dual absorbance detector with a wavelength of 254 nm and an ATLANTIS dC18 column, 5 µm in size, the linear eluent flow consisting of A: methanol and B: 0.1 ml/l phosphoric acid, with a ratio of A to B as 15:85. The sampling frequency was set at 10 samples per second. The retention times for the standards were: ascorbic acid at 2.38 minutes, oxalic acid at 6.4 minutes, citric acid at 6.9 minutes, malic acid at 7.7 minutes, succinic acid at 8.8 minutes, and fumaric acid at 10.7 minutes (Abushita *et al.*, 1997). HPLC equipment: The WATERS (Milford MA 01757, USA) HPLC system had the following components: an absorbance detector (2487 Dual λ) a 1525 Binary HPLC pump, a column thermostat, a 717plus autosampler (set to 5 °C) and an in-line degasser and was controlled using EMPOWER™2 software.

4.4. Statistical Analysis Method

The assessment of nutrient content in Roma variety tomatoes involved two main considerations: the influence of different sides of the experimental design (protected vs windy) and the variation between two harvest dates. The measured variables included total polyphenols content (TPC), Ferric reducing antioxidant power (FRAP), and vitamin C content, which can be affected by environmental stresses such as heat, cold, salinity, and wind, especially under organic cultivation using the hedgerow system,

Spectrophotometric methods were employed to analyse the nutritional parameters. We have SPS software for data analysis. The normality of the data was assessed using Shapiro-Wilk's test, while Levene's test was utilized to ensure homogeneity of variance. Box's Test of Equality of Covariance Matrices was applied to validate the equality of covariance matrices.

The analysis proceeded with a post hoc test to examine the time effect using Tukey's Honestly Significant Difference (HSD) test. A two-way univariate ANOVA with factors for tomato varieties and distances was employed to analyse the inner content data. Based on the outcome of the Levene test, Games-Howell or Tukey post hoc tests were employed.

5. RESULTS

5.1.1 Total Phenolic Content (TPC) - First Harvest

Figure 13 illustrates the total phenolic content (TPC) of the Roma tomato variety across diverse treatment conditions. Phenolic compounds, pivotal as antioxidants synthesized by plants under stress, notably in windy high-temperature environments like the sheltered sides with a hedgerow stem, play a significant role. Upon the initial harvest, it was evident that the Roma variety exhibited higher TPC levels on the windy side, with values of 2967 mg/100g for W5, 2733 mg/100g for W1, 2667 mg/100g for W4, and 2633 mg/100g for P1. While a minor variation was observed in TPC levels on the windy side, TPC levels remained consistent across various observations at different distances along the protected side.

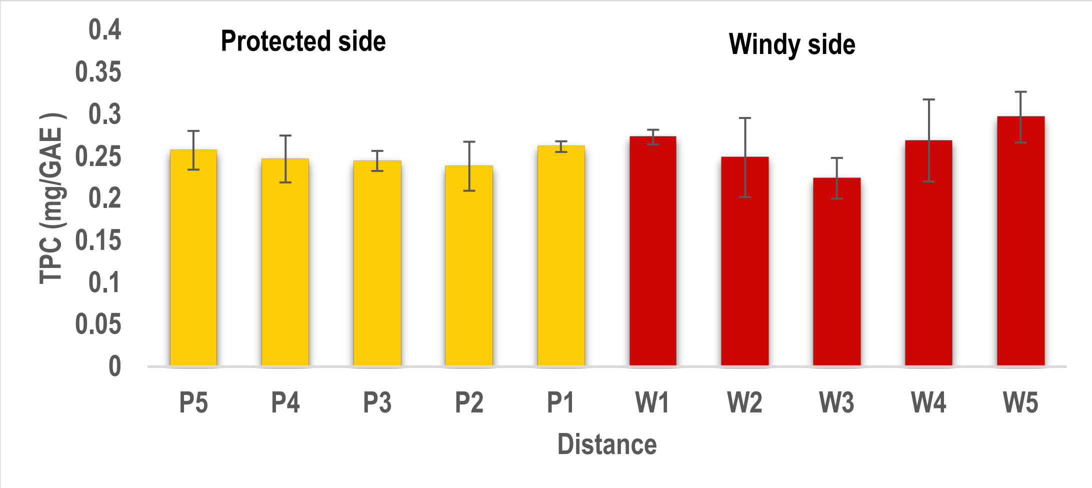


Figure 13: Total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, with the hedge in the middle of the graph.

5.1.2. Total Phenolic Content (TPC) - Second Harvest

The TPC of the Roma tomato variety under varied treatment conditions, as depicted in Figure 14, merits further examination. The Roma variety displayed higher TPC levels on the windy side, registering at 2767 mg/100g for W3, 2733 mg/100g for W2, 2633 mg/100g for P1, and 2533 mg/100g for W1. Remarkably, no significant difference was observed on the protected side, with only a slight variance noted on the windy side.

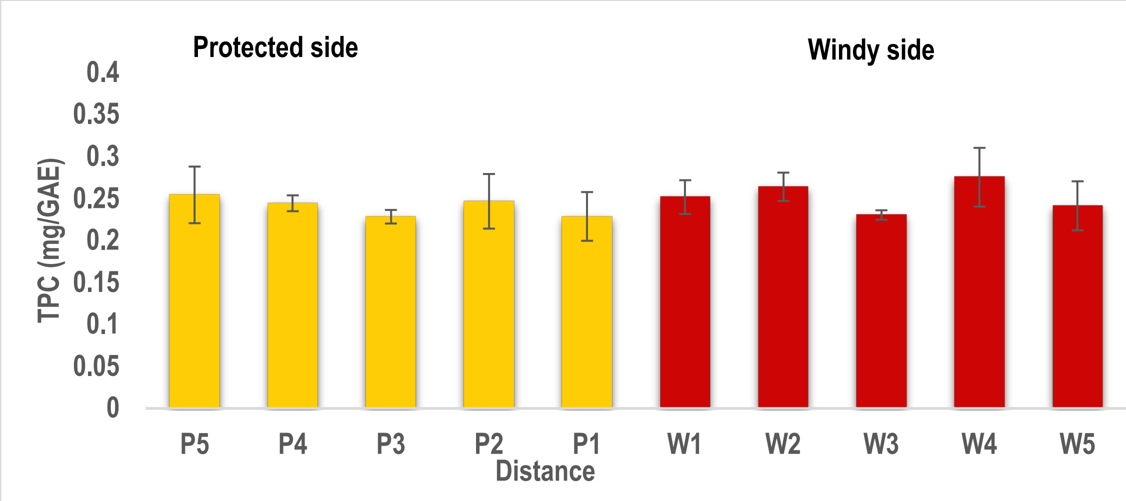


Figure 14: Total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the second harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, with the hedge in the middle of the graph.

5.2.1. The Ferric Reducing Antioxidant Power (FRAP) On Side, Distance and Date (Initial Harvest)

During the initial harvest, we assessed the ferric reducing antioxidant power (FRAP) of the Roma variety across various environmental conditions, with particular emphasis on comparing the antioxidant properties between the windy and protected sides within hedgerow systems. Significant differences were observed between the two sides, with substantial variance. On the windy side, the antioxidant content was notably higher, with W1 recording the highest value at 7033 mg/100g, followed by W2 at 6467 mg/100g, and P1 at 5633 mg/100g. Conversely, the lowest antioxidant content was also observed on the windy side, with W3 registering 3767 mg/100g. (P>0.005) In Figure 15, significant differences between the protected and windy sides are depicted, although there is some overlap, suggesting similarities between the antioxidant levels. Post hoc tests were conducted to further explore these differences.

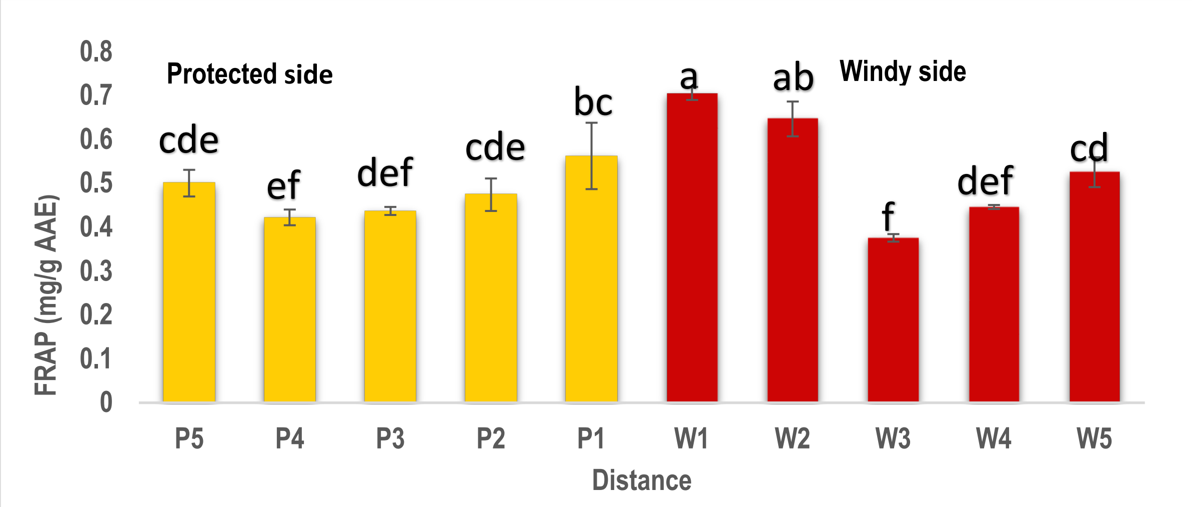


Figure 15: The Ferric reducing antioxidant power (FRAP) (mean ± SD) of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, the hedge in the middle of the graph. Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$). Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$).

5.2.2. Ferric reducing antioxidant power (FRAP) - second harvest

During the second harvest, we evaluated the ferric reducing antioxidant power (FRAP) of Roma tomatoes under varying environmental conditions, particularly comparing windy and protected sides within hedgerow systems. Significant differences between the two sides can be observed, indicating notable variance. Interestingly, the antioxidant content was notably higher on the windy side, with W1 recording the highest value at 7733 mg/100g, followed by W2 at 7467 mg/100g, and W1 at 6633 mg/100g. Figure 16 illustrates these differences, clearly showing that the protected side exhibited the lowest antioxidant content. Conversely, the windy side showed less disparity among its subsets, with values overlapping.

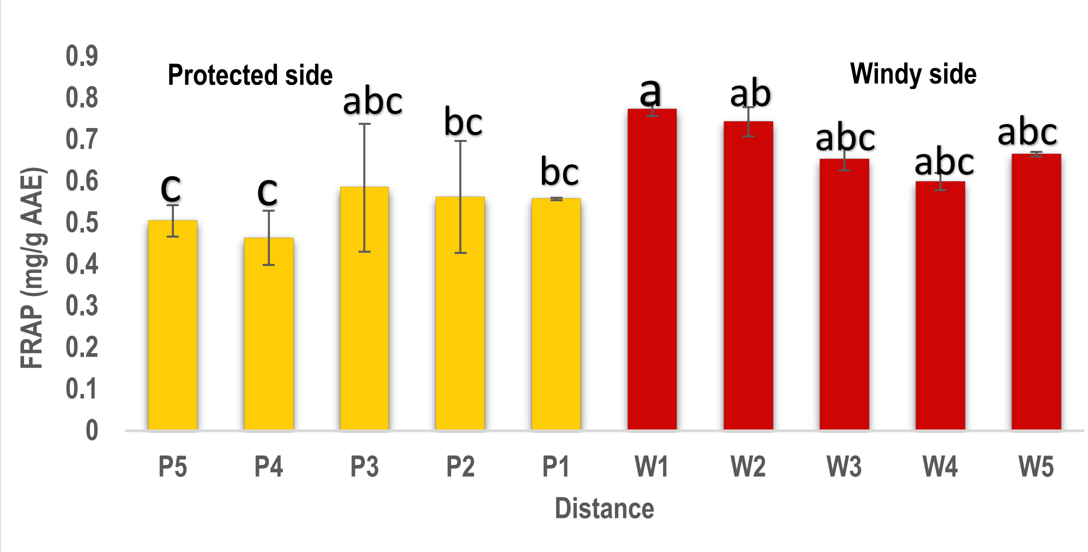


Figure 16: The Ferric reducing antioxidant power (FRAP) (mean ± SD) of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, with the hedge in the middle of the graph. Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$).

5.3. Acids content analysis

Through the analysis of acid content, we aimed to understand the impact of various acids on vitamin C content. Figure 17 illustrates the levels of citric acid, oxalic acid, succinic acid, malic acid, and fumaric acid. Interestingly, succinic acid exhibits higher content on both sides of cultivation, with the windy side showing the highest levels. However, there is minimal disparity between the two sides in terms of succinic acid content. On the other hand, the protected side displays significantly higher levels of vitamin C compared to the windy side, indicating a substantial difference.

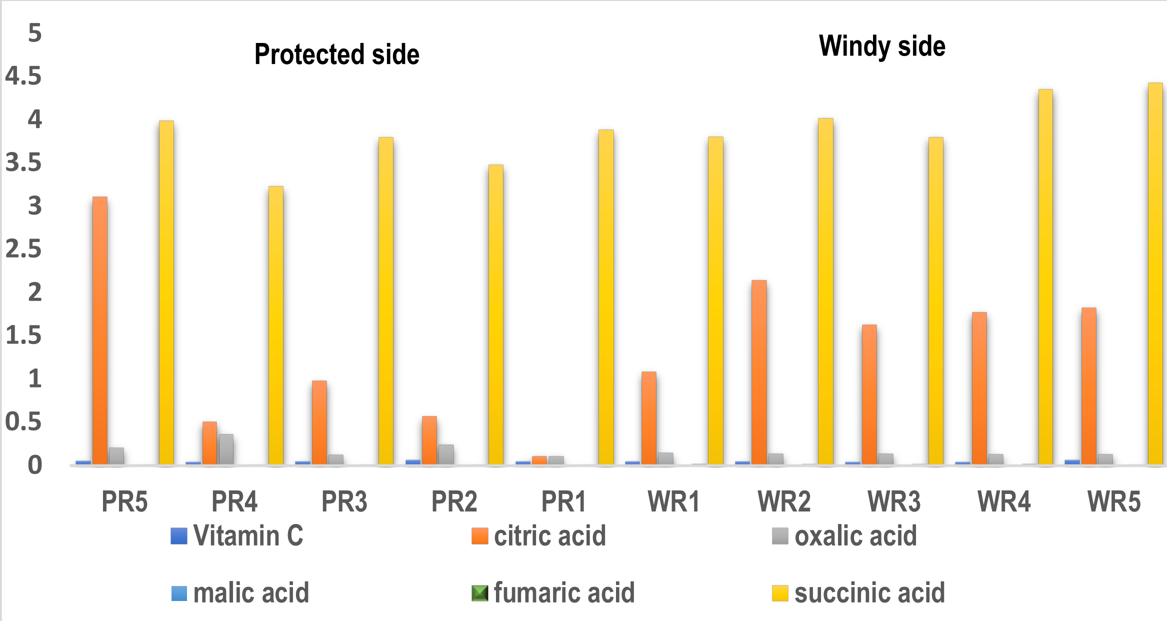


Figure 17: ACIDS of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, with the hedge in the middle of the graph.

5.4. Vitamin C

In the analysis of vitamin C content from Figure 18, both the side of cultivation and distance exhibit significant differences. Notably, the protected side displays considerably higher levels of vitamin C, showcasing a substantial disparity compared to the windy side. Conversely, the windy side shows lower values with only minor differences observed.

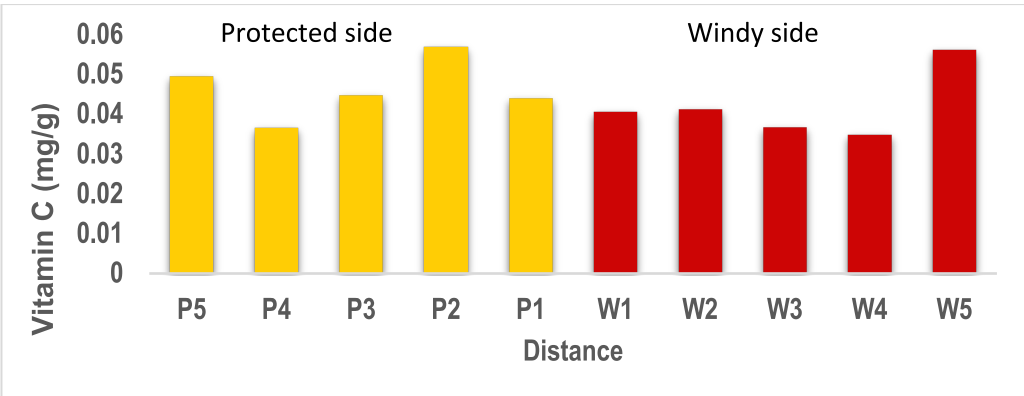


Figure 18: Vitamin C (mean) of the Roma tomato variety harvested from both the protected and windy sides of a hedgerow at the second harvest. Ascending numbers on the X-axis show greater distances from the hedge. The layout corresponds to the actual spatial design of the experiment, being the hedge in the middle of the graph.

5.5.1. Total Phenolic Content (TPC) - First Harvest Protected Side

At the first harvest on August 16th, 2023, the graph in Figure 19 shows the influence of the first harvest on the total phenolic content of tomatoes on the protected side. The horizontal axis represents the distance (P1, P2, P3, P4, P5) which is in ascending order (P1(0.5633mg/100g), P5(0.5000mg/100g), P2(4767mg/100g), P3(4200mg /100g), P4(4200mg/100g) and the vertical axis represent the TPC. There is no significant difference in TPC observed between the different distances on the protected side. The TPC values range from .0.05 to 0.15.

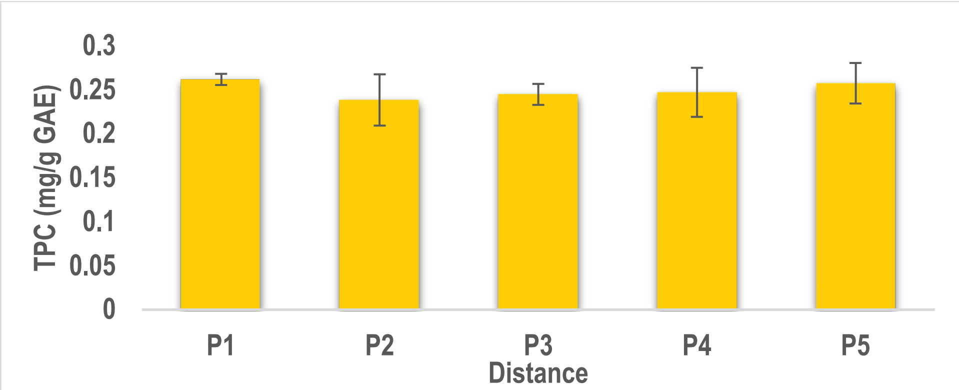


Figure 19: Impact of the distance from the hedge on the total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from the protected sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge.

5.5.2. Total Phenolic Content (TPC) - FIRST Harvest WINDY Side

The graph in Figure 20 shows the influence of the first harvest on the total phenolic content (TPC) of tomatoes on the windy side (W1, W2, W3, W4, and W5) Which is ascending order W5(0.2967), W1(0.2733), W4(0.2667), W2(0.2467), W3(0.2267).

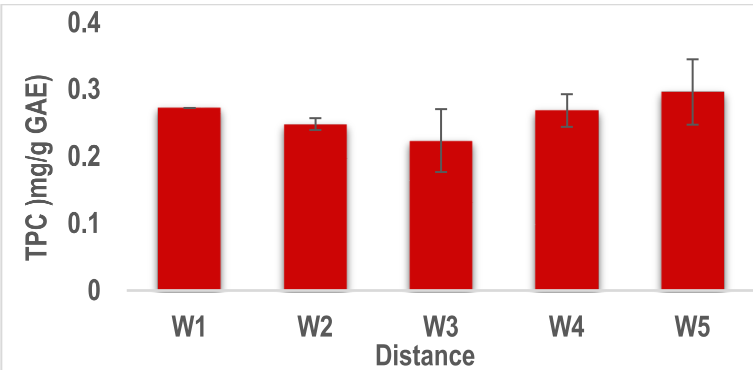


Figure 20: Impact of the distance from the hedge on the total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from the windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge.

5.5.3. Ferric Reducing Antioxidant Power (FRAP) – First Harvest Protected Side

The graph in Figure 21 displays the results of an ANOVA test followed by a posthoc Tukey's Honestly Significant Difference (HSD) test. This analysis compares the means of five distances (P1, P2, P3, P4, P5) at a significance level of 0.05. The distance values are as follows: P1 (0.5633), P5 (0.500), P2 (0.4767), P3 (0.4400), P4 (0.4200). The results indicate a significant difference among the distances.

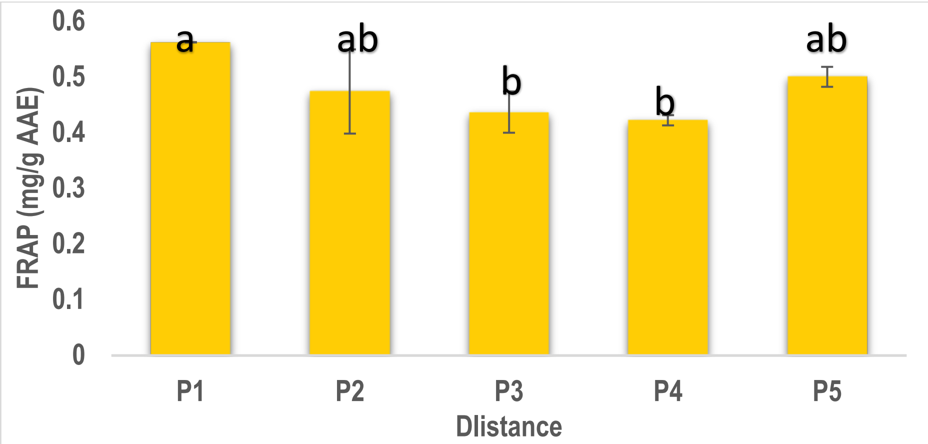


Figure 21: Impact of the distance from the hedge on the Ferric Reducing Antioxidant Power (FRAP) (mean ± SD) of the Roma tomato variety harvested from the protected sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$).

5.5.4. Ferric Reducing Antioxidant Power (FRAP) – First Harvest Windy Side

The graph in Figure 22 illustrates the impact of the first harvest of FRAP (ferric reducing antioxidant power) of tomatoes on the windy side (W1, W2, W3, W4, W5). Among these, W1 (0.7033) exhibits the highest values, followed by W2 (0.6467), W5 (0.5233), W4 (0.4467), and W3 (0.3767). There are significant differences observed between them

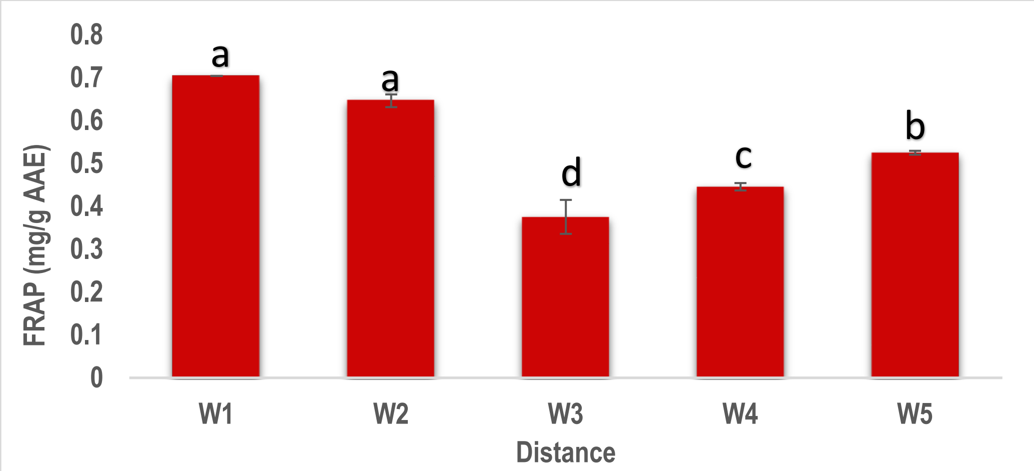


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Figure 22: Impact of the distance from the hedge on the Ferric Reducing Antioxidant Power (FRAP) (mean ± SD) of the Roma tomato variety harvested from the windy sides of a hedgerow at the first harvest. Ascending numbers on the X-axis show greater distances from the hedge. Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$).

5.5.5. Total Phenolic Content (TPC) – Second Harvest Protected Side

The graph in Figure 23 shows the influence of the second harvest on the total phenolic content (TPC) of tomatoes on the protected side at various distances (P1, P2, P3, P4, P5). And P3 (0.5833) contains higher values and as follows P2(0.5667), P1(0.5567), P5 (0.5067), P4 (0.4633) are the lowest values and it does not have any significant differences.

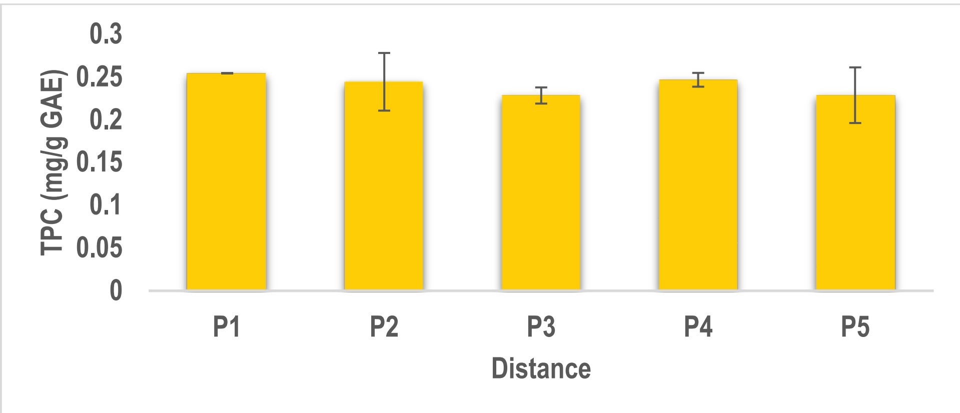

Figure 23: Impact of the distance from the hedge on the total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from the protected sides of a hedgerow at the second harvest. Ascending numbers on the X-axis show greater distances from the hedge.

5.5.6. Total Phenolic Content (TPC) - Second Harvest WINDY Side

This graph in Figure 24 shows the influence of the second harvest on the total phenolic content (TPC) of tomatoes on the windy side on various distances (W1, W2, W3, W4, W5) and W4(0.2767), W2(0.2633), W1(0.2500), W5(0.2433), W3(0.2300) is the lowest values. there is no significant difference.

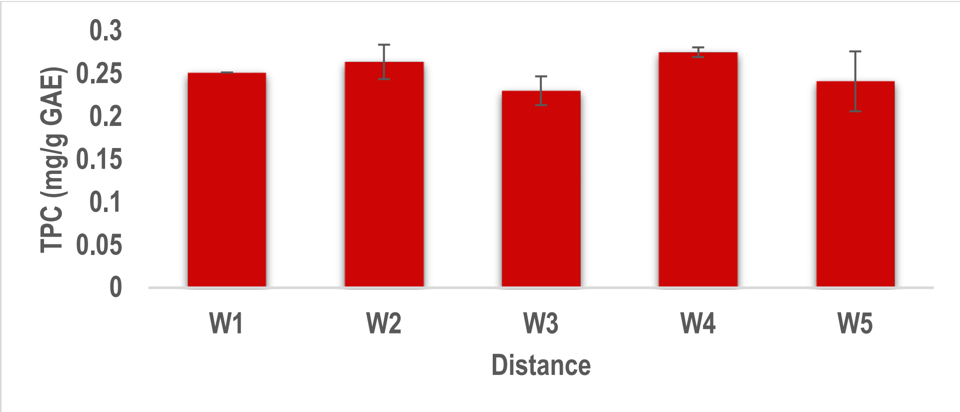

Figure 24: Impact of the distance from the hedge on the total phenolic content (TPC) (mean ± SD) of the Roma tomato variety harvested from the windy sides of a hedgerow at the second harvest. Ascending numbers on the X-axis show greater distances from the hedge.

5.5.7. Ferric Reducing Antioxidant Power (FRAP) – Second Harvest Protected Side

This graph in Figure 25 shows the influence of the second harvest on FRAP (ferric reducing ability of plasma) of the protected on various distances P1, P2, P3, P4, and P5. The highest values are observed in P1 (0.2533), P4 (0.2500), P2 (0.2467), P5 (0.2300), and P3 (0.2267), with no significant difference noted among the values as the lowest.

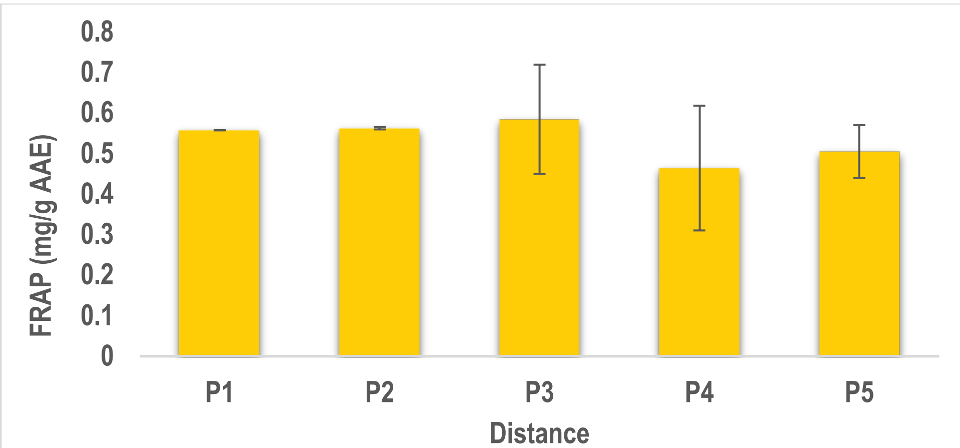

Figure 25: Impact of the distance from the hedge on the Ferric Reducing Antioxidant Power (FRAP) (mean ± SD) of the Roma tomato variety harvested from the protected sides of a hedgerow at the second harvest. Ascending numbers on the X-axis show greater distances from the hedge.

5.5.8. Ferric Reducing Antioxidant Power (FRAP) – Second Harvest WINDY Side.

This graph in Figure 26 shows the influence of the second harvest on FRAP (ferric reducing ability of plasma) of the windy on various distances W1, W2, W3, W4, W5. The highest values are found in W1 (0.7733), W2 (0.7467), W5 (0.6633), W3 (0.6533), and W4 (0.6033), with the lowest value showing a significant difference compared to the others.

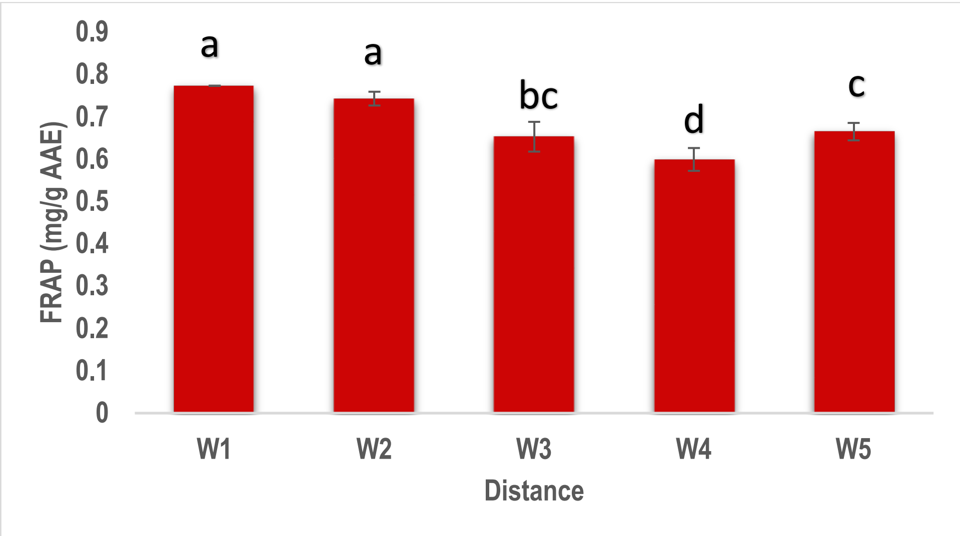

Figure 26: Impact of the distance from the hedge on the Ferric Reducing Antioxidant Power (FRAP) (mean ± SD) of the Roma tomato variety harvested from the windy sides of a hedgerow at the protected harvest. Ascending numbers on the X-axis show greater distances from the hedge. Different letters on columns show significant differences in terms of position (side + distance) ($p<0.05$).

5.6.1. Vitamin (C) Second Harvest Protected Side.

This graph in Figure 27 shows the influence of the second harvest on vitamin C of the windy on various distances P1, P2, P3, P4, and P5 the higher values lie P2(0.056), P5 (0.049), P3(0.044), P1 (0.043), P4 (0.0360) is the lowest values.

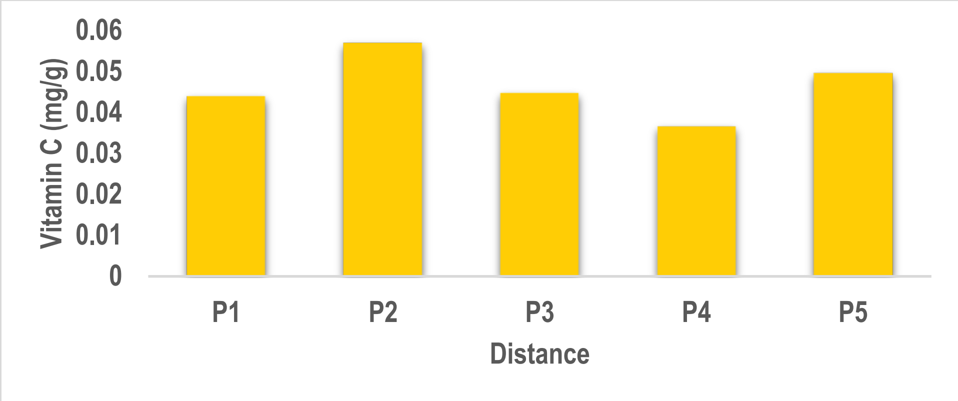

Figure 27: Impact of the distance from the hedge on the Vitamin C (mean) of the Roma tomato variety harvested from the protected sides.

5.6.2. Vitamin (C) Second Harvest WINDY Side.

This graph in Figure 28 shows the influence of the second harvest on vitamin C of the windy on various distances W1, W2, W3, W4, W5. The highest values are observed in P1 (0.2533), P4 (0.2500), P2 (0.2467), P5 (0.2300), and P3 (0.2267). Notably, there is no significant difference among these values, even at their lowest.

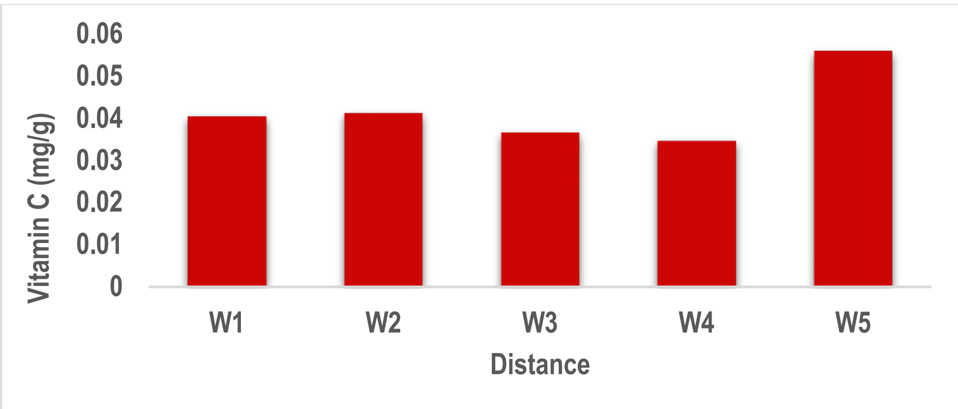

Figure 28: Impact of the distance from the hedge on the Vitamin C (mean) of the Roma tomato variety harvested from the protected side.

6. CONCLUSION (discussion of results)

The study reveals that environmental conditions did not significantly influence the total phenolic content (TPC) of tomatoes, irrespective of side, distance, or harvest date. In protected and windy environments, no significant difference in TPC was observed between the first and second harvests. While the total phenolic content (TPC) did not exhibit a significant difference overall, the windy side demonstrated higher phenolic substance values (0.2967 mg/g GAE) compared to the protected side, which displayed lower values (0.2267 mg/g GAE). Although previous studies have suggested an increase in TPC under high-temperature stress, attributing it to the protective role of phenolics against environmental stressors (Rivero et al., 2001), our study observed a decrease in TPC with increasing temperature during tomato production. This discrepancy may be attributed to the complex interplay of various environmental factors and genetic differences among tomato cultivars. (Kumar et al., 2015). Furthermore, our findings suggest that heat stress may influence the activity of phenylalanine ammonia-lyase, affecting the production of TPC (Tinyane, Sivakumar and Soundy, 2013). These results underscore the importance of considering multiple factors when assessing the nutritional qualities of tomatoes and highlight the need for further research to elucidate the underlying mechanisms.

The study found a significant difference in vitamin C content, influenced by fluctuating environmental conditions, particularly on the windy side, which is partially covered by shade from trees in the hedgerow. Higher temperatures were observed to decrease the vitamin C content in tomatoes, although an increase was reported during flowering and fruit setting (Dasgan et al., 2021). Tree shade retained soil moisture, aiding growth but negatively impacting tomato antioxidants and pigment synthesis, as well as ascorbic acid accumulation (Shimeles et al., 2017a).

In this study, antioxidants exhibit significant differences in the hedgerow cultivation system due to various abiotic stresses such as moisture levels, shading, high temperature, wounds, wind, and salinity stress (Vijitha and Mahendran, 2010). A higher concentration of ascorbic acid was observed under deficit moisture conditions, whereas lower concentrations were noted under adequate moisture conditions. This variance is attributed to the shading effect created by hedgerow, which helps retain moisture content in the environment (Kumar *et al.,* 2015). Lycopene is an antioxidant which influences the colour of fruit and is significantly influenced by early irrigation cut-offs. This can notably impart the antioxidant properties of the fruit (cual et. al., 2022).

The findings of this study reveal that there were no significant differences in the total phenolic contents, Ferric Reducing Antioxidant Power (FRAP), acid content analysis, and vitamin C levels between the first and second harvests of tomato plants grown in both windy and protected areas using hedgerows. This suggests that the environmental conditions, particularly wind exposure and hedgerow protection, may not have had a substantial impact on the nutritional profile of the tomatoes. These results challenge the common assumption regarding the influence of environmental factors, such as wind stress, on the accumulation of beneficial compounds in tomato fruits. However, the consistent levels of biochemical parameters across harvests hint at the potential influence of other factors, such as genetic characteristics and microclimate conditions, on tomato quality (Shimeles et al., 2017b). The resilience of tomato plants to varying wind conditions implies that hedgerow systems could be an effective strategy for protecting tomato crops without compromising their nutritional quality. Further research is needed to explore the long-term effects of wind exposure and hedgerow protection on tomato quality, as well as to elucidate the underlying physiological mechanisms contributing to these observations.

In conclusion, this study highlights the intricate relationship between environmental factors and tomato quality within the hedgerow system. While certain environmental factors positively influence tomato quality in hedgerow systems, others may have adverse effects. Understanding these interactions is crucial for optimizing cultivation practices to achieve the desired nutritional qualities in tomatoes.

7. Summary

Tomato, belonging to the Solanaceae family, ranks as the second most consumed vegetable, and holds global culinary significance, serving as essential ingredients in daily cuisine. Organically cultivated tomatoes exhibit notable diction, boasting higher carotenoid levels, increased mineral content, significantly lower levels of heavy metals, reduced nitrates, and the absence of pesticide residues, their nutrients, including minerals, vitamins, essential amino acids, fibre, and bioactive substance, contribute to various bodily functions, such as promoting cardiovascular health and reducing the risk of chronic degenerative disorders. Agroforestry practices, particularly hedgerow systems offer a holistic approach to tomato cultivation that enhances both environmental sustainability and product quality. The diverse plant composition and shading provided by hedgerows contribute to this enhancement in antioxidant content, particularly on the windward side and near the hedge. Additionally, the presence of trees and shrubs in the agroforestry system. Our research investigates the impact of hedgerow system cultivation on the quality profile of Roma VF genotype tomatoes, conducted at the Soroksar Experimental and Research Organic Farm, MATE. This innovative approach integrates the cultivation of forestry plants, shrubs, and trees alongside commercial crops, aiming to enhance antioxidant properties and overall health benefits.

Our study aims to scientifically evaluate key parameters such as Total Phenolic Content (TPC), Ferric Reducing Antioxidant Power (FRAP), and Vitamin C content in tomatoes. We focus on comparing tomatoes grown on the windy and protected sides within the hedgerow system. Through our analysis, we aimed to investigate variations in quality between these two sides and explore potential correlations between environmental factors, such as proximity to the hedge, and tomato quality characteristics.

Our findings reveal that while Total Phenolic Content remains consistent across conditions, significant disparities in Ferric Reducing Antioxidant Power are influenced by environmental factors, particularly proximity to the hedge and side of cultivation. Antioxidant content is notably higher on the windy side, particularly near the hedge, compared to the protected side. Furthermore, closer proximity to the hedge correlates with higher antioxidant values, with slight variations observed as the distance increases or decreases. Interestingly, during the second harvest of the protected side, no significant difference in distance is noted.

The Vitamin C profile of the Roma VF variety exhibits distinct patterns compared to other parameters. Higher vitamin C content is observed at longer distances from the hedge, particularly at distances P5 and W5 on both sides of the experiment. However, when examining distance P2, higher values are noted on the protected side, while on the windy side, the distance W5 shows higher values near the hedge. This suggests that the shade provided by the hedge influences Vitamin C content, resulting in lower levels observed due to shading.

Our research emphasizes the pivotal role of the hedgerow system in microclimate conditions and impacting the nutritional content of Roma VF genotype tomatoes. While the protected side demonstrates a more stable quality profile, the windy side shows significant fluctuations in various parameters. These insights shed light on sustainable farming practices and highlight the intricate relationships between environmental

factors and tomato quality within the agroforestry system. In conclusion, agroforestry, especially the hedgerow system, presents a comprehensive approach to tomato cultivation, fostering environmental sustainability and enhancing product quality. through the synergistic interaction among diverse plant species, agroforestry provides an environment conducive to producing high-quality tomatoes abundant in antioxidant and essential nutrients, showcasing its potential as a sustainable farming strategy for improving tomato quality while bolstering ecosystem health.

8. References

1. Oguntola, E., Ologundudu, F. and Oladele, I.S. (2019) 'Physiological Responses and Nutritional Composition of Two Tomato (Lycopersicum esculentum) Cultivars-Roma-VF and IFE-1', Journal of Biotechnology Research, (512), pp. 145–153. Available at: https://doi.org/10.32861/jbr.512.145.153.
2. Abushita, A.A. et al. (1997) Determination of a tomt ioxidant vitamins in Aoes, Food Chemistry.
3. Agius, C. et al. (2018) 'Quantification of sugars and organic acids in tomato fruits', MethodsX, 5, pp. 537–550. Available at: https://doi.org/10.1016/j.mex.2018.05.014.
4. Alhaithloul, H.A.S., Galal, F.H. and Seufi, A.M. (2021) 'Effect of extreme temperature changes on phenolic, flavonoid contents and antioxidant activity of tomato seedlings (Solanum lycopersicum L.)', PeerJ, 9, p. e11193. Available at: https://doi.org/10.7717/peerj.11193.
5. Ali, M.Y. et al. (2021a) 'Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: A review', Foods, 10(1). Available at: https://doi.org/10.3390/foods10010045.
6. Ali, M.Y. et al. (2021b) 'Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: A review', Foods, 10(1). Available at: https://doi.org/10.3390/foods10010045.
7. Astija et al. (2022) 'The effect of soil pH on a carbohydrate level of tomato fruits (Lycopersicum esculentum Mill.) from bobo and Sidera villages', GSC Advanced Research and Reviews, 12(1), pp. 001–004. Available at: https://doi.org/10.30574/gscarr.2022.12.1.0169.
8. Astija, A. (2020) Soil pH influences the development of tomato root organ (Solanum lycopersicum L.). Available at: https://www.researchgate.net/publication/348379989.
9. Ayankojo, I.T. and Morgan, K.T. (2020) 'Increasing air temperatures and its effects on growth and productivity of tomato in south Florida', Plants, 9(9), pp. 1–16. Available at: https://doi.org/10.3390/plants9091245.
10. Bauchet, G. and Causse, M. (2012) 'Genetic Diversity in Tomato (Solanum lycopersicum) and Its Wild Relatives', in Genetic Diversity in Plants. InTech. Available at: https://doi.org/10.5772/33073.
11. Bauchet, G., Causse, M.M. and Causse, M. (no date) Genetic diversity in tomato (Solanum lycopersicum) and its wild relatives 8 Genetic Diversity in Tomato (Solanum lycopersicum) and Its Wild Relatives. Available at: https://hal.inrae.fr/hal-02805788.
12. Benzie, I.F.F. and Strain, J.J. (1996) The Ferric Reducing Ability of Plasma (FRAP) as a Measure of '"Antioxidant Power"': The FRAP Assay, ANALYTICAL BIOCHEMISTRY.
13. Van Den Berge, S. et al. (2021) 'Soil carbon of hedgerows and "ghost" hedgerows', Agroforestry Systems, 95(6), pp. 1087–1103. Available at: https://doi.org/10.1007/s10457-021-00634-6.
14. Bertin, N. and Génard, M. (2018) 'Tomato quality as influenced by preharvest factors', Scientia Horticulturae. Elsevier B.V., pp. 264–276. Available at: https://doi.org/10.1016/j.scienta.2018.01.056.
15. Bobinaitė, R. et al. (no date a) Carotenoids, Ascorbic Acid and Physical Properties of Tomatoes.
16. Bobinaitė, R. et al. (no date b) Carotenoids, Ascorbic Acid and Physical Properties of Tomatoes.
17. Carvalho, G.C. et al. (2021) 'Lycopene: From tomato to its nutraceutical use and its association with nanotechnology', Trends in Food Science and Technology. Elsevier Ltd, pp. 447–458. Available at: https://doi.org/10.1016/j.tifs.2021.10.015.
18. Chaïb, J. et al. (2007) 'Physiological relationships among physical, sensory, and morphological attributes of texture in tomato fruits', Journal of Experimental Botany, 58(8), pp. 1915–1925. Available at: https://doi.org/10.1093/jxb/erm046.
19. Chaudhary, P. et al. (2018) 'Bioactivities of phytochemicals present in tomato', Journal of Food Science and Technology. Springer, pp. 2833–2849. Available at: https://doi.org/10.1007/s13197-018-3221-z.
20. Dasgan, H.Y. et al. (2021) 'Effects of High-Temperature Stress during Plant Cultivation on Tomato (Solanum lycopersicum L.) Fruit Nutrient Content', Journal of Food Quality, 2021. Available at: https://doi.org/10.1155/2021/7994417.

21. Donoso, A., Martínez, J.P. and Salazar, E. (2022) 'History of Tomato Cultivation in Chile: The Limachino Tomato Case', RIVAR, 9(27). Available at: https://doi.org/10.35588/rivar.v9i27.5673.
22. Erika, C. et al. (2022) 'Flavor and Other Quality Traits of Tomato Cultivars Bred for Diverse Production Systems as Revealed in Organic Low-Input Management', Frontiers in Nutrition, 9. Available at: https://doi.org/10.3389/fnut.2022.916642.
23. Euromonitor (2023) 'Euromonitor 2023 Global Market report on processed tomatoes '. Available at: https://www.tomatonews.com/en/euromonitor-2023-global-market-report-on-processed-tomatoes_2_2178.html (Accessed: 18 April 2024).
24. Fagwalawa LD, Yahaya SM and Fatima YU (2015) EFFECT OF SOIL TYPE ON THE GROWTH OF TOMATO. Available at: http://www.cibtech.org/cjbp.htm.
25. Fernández-Ruiz, V. et al. (2004) Internal Quality Characterization of Fresh Tomato Fruits, 339 HORTSCIENCE.
26. François-Xavier Branthôme (2024) Euromonitor 2023 Global Market Report on Processed Tomatoes, https://www.tomatonews.com/en/euromonitor-2023-global-market-report-on-processed-tomatoes_2_2178.html#:~:text=In%20terms%20of%20quantities%2C%20the,37.2%20million%20t%20in%202027.
27. Garratt, M.P.D. et al. (2017) 'The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context', Agriculture, Ecosystems and Environment, 247, pp. 363–370. Available at: https://doi.org/10.1016/j.agee.2017.06.048.
28. Gentil, C. et al. (2020) 'Coupling pesticide emission and toxicity characterization models for LCA: Application to open-field tomato production in Martinique', Journal of Cleaner Production, 277. Available at: https://doi.org/10.1016/j.jclepro.2020.124099.
29. Giovanelli, G. et al. (no date) THE ANTIOXIDANT ACTIVITY OF TOMATO. III. EFFECTS OF PROCESSING TECHNOLOGIES ON OXIDATIVE AND HEAT DAMAGE.
30. González, M., Cid, M.C. and Lobo, M.G. (2011) 'Usage of Tomato (Lycopersicum esculentum Mill.) Seeds in Health', in Nuts and Seeds in Health and Disease Prevention. Elsevier, pp. 1123–1132. Available at: https://doi.org/10.1016/B978-0-12-375688-6.10133-1.
31. Guan, L. et al. (2019) 'Auxin regulates adventitious root formation in tomato cuttings', BMC Plant Biology, 19(1). Available at: https://doi.org/10.1186/s12870-019-2002-9.
32. Harel, D. et al. (2014) 'The effect of mean daily temperature and relative humidity on pollen, fruit set and yield of tomato grown in commercial protected cultivation', Agronomy, 4(1), pp. 167–177. Available at: https://doi.org/10.3390/agronomy4010167.
33. Hiraguri, T. et al. (2023) 'Shape classification technology of pollinated tomato flowers for robotic implementation', Scientific Reports, 13(1). Available at: https://doi.org/10.1038/s41598-023-27971-z.
34. International Labour Organisation (2014) Report on value chain analysis: The tomato sector in Mafraq Governorate Jordan. Budapest.
35. Islam, A.K.M.S., Edwards, D.G. and Asher, C.J. (1980) 'pH optima for crop growth', Plant and Soil, 54(3), pp. 339–357. Available at: https://doi.org/10.1007/BF02181830.
36. Jafari, S.M. et al. (2017) 'Effects of thermal processing by nanofluids on vitamin C, total phenolics and total soluble solids of tomato juice', Journal of Food Science and Technology, 54(3), pp. 679–686. Available at: https://doi.org/10.1007/s13197-017-2505-z.
37. J.Benton Jones, Jr. (199AD) Tomato Plant Culture in the field, Greenhouse, and Home Garden. Second.
38. Kamiloglu, S. et al. (2014) 'Home processing of tomatoes (Solanum lycopersicum): Effects on in vitro bioaccessibility of total lycopene, phenolics, flavonoids, and antioxidant capacity', Journal of the Science of Food and Agriculture, 94(11), pp. 2225–2233. Available at: https://doi.org/10.1002/jsfa.6546.
39. Katırcı, N. et al. (2020) 'Differences in antioxidant activity, total phenolic and flavonoid contents of commercial and homemade tomato pastes', Journal of the Saudi Society of Agricultural Sciences, 19(4), pp. 249–254. Available at: https://doi.org/10.1016/j.jssas.2018.11.003.
40. Kaul, M.L.H. (1991) 'Reproductive Biology in Tomato', in, pp. 39–50. Available at: https://doi.org/10.1007/978-3-642-84275-7_4.

41. Khalid, S. et al. (2024) 'Factors responsible for spoilage, drawbacks of conventional packaging, and advanced packaging systems for tomatoes', Journal of Agriculture and Food Research, 15, p. 100962. Available at: https://doi.org/10.1016/j.jafr.2023.100962.
42. Kissoudis, C. et al. (2015) 'Combined biotic and abiotic stress resistance in tomato', Euphytica, 202(2), pp. 317–332. Available at: https://doi.org/10.1007/s10681-015-1363-x.
43. Kumar, P.S. et al. (2015) 'Influence of growth stage-specific water stress on the yield, physico-chemical quality and functional characteristics of tomato grown in shallow basaltic soils', Scientia Horticulturae, 197, pp. 261–271. Available at: https://doi.org/10.1016/j.scienta.2015.09.054.
44. Li, H. et al. (2012) 'Microwave-assisted extraction of phenolics with maximal antioxidant activities in tomatoes', Food Chemistry, 130(4), pp. 928–936. Available at: https://doi.org/10.1016/j.foodchem.2011.08.019.
45. Li, W., Lu, X. and Li, J. (2022) 'The effect of organic nutrient solution on flavor in ripe cherry tomato fruit—Transcriptome and metabolomic analyses', Environmental and Experimental Botany, 194. Available at: https://doi.org/10.1016/j.envexpbot.2021.104721.
46. de Lint, P.J.A.L. and Klapwijk, D. (1986) 'PHYSIOLOGY OF TOMATO ROOTS WITH RESPECT TO SUBSTRATE CULTURE', Acta Horticulturae, (190), pp. 467–470. Available at: https://doi.org/10.17660/ActaHortic.1986.190.53.
47. Luthria, D.L., Mukhopadhyay, S. and Krizek, D.T. (2006) 'Content of total phenolics and phenolic acids in tomato (Lycopersicon esculentum Mill.) fruits as influenced by cultivar and solar UV radiation', Journal of Food Composition and Analysis, 19(8), pp. 771–777. Available at: https://doi.org/10.1016/j.jfca.2006.04.005.
48. Ma, C. et al. (2011) 'Regulation of Carotenoid Content in Tomato by Silencing of Lycopene β/ε-Cyclase Genes', Plant Molecular Biology Reporter, 29(1), pp. 117–124. Available at: https://doi.org/10.1007/s11105-010-0211-3.
49. Martinez, C.C. et al. (2016) 'Left - Right leaf asymmetry in decussate and distichous phyllotactic systems', Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1710). Available at: https://doi.org/10.1098/rstb.2015.0412.
50. Martínez-Blanco, J. et al. (2011) 'Assessment of tomato Mediterranean production in open-field and standard multi-tunnel greenhouse, with compost or mineral fertilizers, from an agricultural and environmental standpoint', Journal of Cleaner Production, 19(9–10), pp. 985–997. Available at: https://doi.org/10.1016/j.jclepro.2010.11.018.
51. McCance, D.J. and Drysdale, R.B. (1975) 'Production of tomatine and rishitin in tomato plants inoculated with Fusarium oxysporum f. sp. lycopersici', Physiological Plant Pathology, 7(3), pp. 221–230. Available at: https://doi.org/10.1016/0048-4059(75)90027-2.
52. Mehta, R. (2017) 'History of Tomato (Poor Man's Apple)', IOSR Journal Of Humanities And Social Science (IOSR-JHSS, 22(8), pp. 31–34. Available at: https://doi.org/10.9790/0837-2208033134.
53. Mellidou, I. et al. (2021a) 'Regulation of vitamin c accumulation for improved tomato fruit quality and alleviation of abiotic stress', Genes, 12(5). Available at: https://doi.org/10.3390/genes12050694.
54. Mellidou, I. et al. (2021b) 'Regulation of vitamin c accumulation for improved tomato fruit quality and alleviation of abiotic stress', Genes, 12(5). Available at: https://doi.org/10.3390/genes12050694.
55. MK, A. and BK, S. (2020) 'Isolation and Quantification of Lycopene and Determination of Β-Carotene and Total Phenolic Contents from Tomato (Lycopersicum Esculentum) by using Various Methods', International Journal of Food Science, Nutrition and Dietetics, pp. 442–447. Available at: https://doi.org/10.19070/2326-3350-2000079.
56. Mukhlis, I., Syamsu Rizaludin, M. and Hidayah, I. (2022) 'Understanding Socio-Economic and Environmental Impacts of Agroforestry on Rural Communities', Forests, 13(4). Available at: https://doi.org/10.3390/f13040556.
57. Mustafa, M., Magdolna Szalai, Z. and Csambalik, L. (2023) 'Nutritional quality parameters of tomato genotypes in a hedgerow system', Progress in Agricultural Engineering Sciences, 19, pp. 113–122. Available at: https://doi.org/10.1556/446.2023.00091.
58. Nipa, S.N., Islam, M.S. and Islam, M.M. (2020) 'region of Bangladesh', International Journal of Natural and Social Sciences, 7(3), pp. 89–93. Available at: https://doi.org/10.5281/zenodo.4068186.

59. Ntagkas, N. et al. (2016) 'Illuminating tomato fruit enhances fruit Vitamin C content', Acta Horticulturae, 1134, pp. 351–356. Available at: https://doi.org/10.17660/ActaHortic.2016.1134.46.
60. OECD (2017) 'Tomato (Solanum lycopersicum)', in Safety Assessment of Transgenic Organisms in the Environment. PARIS : OECD, pp. 69–104. Available at: https://doi.org/10.1787/9789264279728-6-en.
61. Ohta, K. and Ikeda, D. (2015) 'Differences in branch formation in indeterminate and determinate tomato types', Environmental Control in Biology, 53(4), pp. 189–198. Available at: https://doi.org/10.2525/ecb.53.189.
62. Panno, S. et al. (2021) 'A review of the most common and economically important diseases that undermine the cultivation of tomato crop in the mediterranean basin', Agronomy. MDPI. Available at: https://doi.org/10.3390/agronomy11112188.
63. Pascual, L.S. et al. (2022) 'Climate change-associated multifactorial stress combination: A present challenge for our ecosystems', Journal of Plant Physiology. Elsevier GmbH. Available at: https://doi.org/10.1016/j.jplph.2022.153764.
64. Pavan, S., Heusden, A.W. and Bai, Y. (2009) ' Solanum lycopersicum (Tomato) ', in eLS. Wiley. Available at: https://doi.org/10.1002/9780470015902.a0003686.
65. Peralta, I. and Spooner, D. (2006) 'History, Origin and Early Cultivation of Tomato (Solanaceae)', in Genetic Improvement of Solanaceous Crops Volume 2. Science Publishers, pp. 1–24. Available at: https://doi.org/10.1201/b10744-2.
66. Van De Poel, B. et al. (2014) Tissue specific analysis reveals a differential organization and regulation of both ethylene biosynthesis and E8 during climacteric ripening of tomato Van de Poel et al. Tissue specific analysis reveals a differential organization and regulation of both ethylene biosynthesis and E8 during climacteric ripening of tomato. Available at: http://www.biomedcentral.com/1471-2229/14/11.
67. Quinet, M. and Kinet, J.-M. (no date) Transition to Flowering and Morphogenesis of Reproductive Structures in Tomato.
68. Ramesh, K. V., Paul, V. and Pandey, R. (2021) 'Dynamics of mineral nutrients in tomato (Solanum lycopersicum L.) fruits during ripening: part I—on the plant', Plant Physiology Reports, 26(1), pp. 23–37. Available at: https://doi.org/10.1007/s40502-020-00546-0.
69. roCk, C. et al. (2010) *Corresponding author; phone: (352) 392-1991, State Hort. Soc.
70. Saad, A., Ibrahim, A. and El-Bialee, N. (2016) Internal quality assessment of tomato fruits using image color analysis. Available at: http://www.cigrjournal.org.
71. Saavedra, T.M., Figueroa, G.A. and Cauih, J.G.D. (2017) 'Origem e evolução da produção de tomate Lycopersicon esculentum no México', Ciencia Rural, 47(3). Available at: https://doi.org/10.1590/0103-8478cr20160526.
72. Sajyan, T., Sassine, Y. and Germanos, M. (no date) 'COMPARATIVE STUDY ON THE EFFECT OF DIFFERENT PRODUCTS (MONOPOTASSIUM-PHOSPHATE, ASPIRINE, LITHOVIT-STANDARD) AND METHODS OF APPLICATION (FOLIAR SPRAYING AND FERTIGATION) ON SALT'. Available at: https://doi.org/10.13140/RG.2.2.20771.17443.
73. Shamshiri, R.R. et al. (2018) 'Review of optimum temperature, humidity, and vapour pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato: a review', International Agrophysics, 32(2), pp. 287–302. Available at: https://doi.org/10.1515/intag-2017-0005.
74. Sharma, Manvi et al. (2021) 'Understanding the intricate web of phytohormone signalling in modulating root system architecture', International Journal of Molecular Sciences. MDPI. Available at: https://doi.org/10.3390/ijms22115508.
75. Shimeles, T. et al. (2017a) 'Review on factors affecting the quality and antioxidant properties of tomatoes', African Journal of Biotechnology, 16(32), pp. 1678–1687. Available at: https://doi.org/10.5897/ajb2017.16054.
76. Shimeles, T. et al. (2017b) 'Review on factors affecting the quality and antioxidant properties of tomatoes', African Journal of Biotechnology, 16(32), pp. 1678–1687. Available at: https://doi.org/10.5897/ajb2017.16054.

77. Singleton, V.L. and Rossi, J.A. (1965) 'Colorimetry of Total Phenolics with Phosphomolybdic-Phosphotungstic Acid Reagents', American Journal of Enology and Viticulture, 16(3), pp. 144–158. Available at: https://doi.org/10.5344/ajev.1965.16.3.144.
78. Slimestad, R., Fossen, T. and Verheul, M.J. (2008) 'The flavonoids of tomatoes', Journal of Agricultural and Food Chemistry, 56(7), pp. 2436–2441. Available at: https://doi.org/10.1021/jf073434n.
79. Tinyane, P.P., Sivakumar, D. and Soundy, P. (2013) 'Influence of photo-selective netting on fruit quality parameters and bioactive compounds in selected tomato cultivars', Scientia Horticulturae, 161, pp. 340–349. Available at: https://doi.org/10.1016/j.scienta.2013.06.024.
80. Tokić, M. et al. (2023) 'Growth and Molecular Responses of Tomato to Prolonged and Short-Term Heat Exposure', International Journal of Molecular Sciences, 24(5), p. 4456. Available at: https://doi.org/10.3390/ijms24054456.
81. Toscano, S. et al. (2019) 'Effect of Preharvest Abiotic Stresses on the Accumulation of Bioactive Compounds in Horticultural Produce', Frontiers in Plant Science. Frontiers Media S.A. Available at: https://doi.org/10.3389/fpls.2019.01212.
82. Vijitha, R. and Mahendran, S. (2010) EFFECT OF MOISTURE STRESS AT DIFFERENT GROWTH STAGES OF TOMATO PLANT (Lycopersicon esculentum Mill.) ON YIELD AND QUALITY OF FRUITS, J Sci.Univ.Kelaniya.
83. Xu, D. et al. (2021) 'Tomato SlCDF3 Delays Flowering Time by Regulating Different FT-Like Genes Under Long-Day and Short-Day Conditions', Frontiers in Plant Science, 12. Available at: https://doi.org/10.3389/fpls.2021.650068.
84. Zhang, Y. et al. (2020) 'The Roles of Different Types of Trichomes in Tomato Resistance to Cold, Drought, Whiteflies, and Botrytis', Agronomy, 10(3), p. 411. Available at: https://doi.org/10.3390/agronomy10030411.
85. Zhou, J. et al. (2023) 'Impacts of Environmental Factors and Nutrients Management on Tomato Grown under Controlled and Open Field Conditions'. Available at: https://doi.org/10.3390/agronomy.
86. Zhu, Y. et al. (2018a) 'Sensory and Flavor Characteristics of Tomato Juice from Garden Gem and Roma Tomatoes with Comparison to Commercial Tomato Juice', Journal of Food Science, 83(1), pp. 153–161. Available at: https://doi.org/10.1111/1750-3841.13980.
87. Zhu, Y. et al. (2018b) 'Sensory and Flavor Characteristics of Tomato Juice from Garden Gem and Roma Tomatoes with Comparison to Commercial Tomato Juice', Journal of Food Science, 83(1), pp. 153–161. Available at: https://doi.org/10.1111/1750-3841.13980.
88. Zucco, M.A. et al. (2015) 'Effect of soil type and vermicompost applications on tomato growth', International Journal of Recycling of Organic Waste in Agriculture, 4(2), pp. 135–141. Available at: https://doi.org/10.1007/s40093-015-0093-3.

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10. APPENDIX

10.1. European Union Regulation on Organic Farming (Crop Quality)

Organic farming rules entail upholding principles crafted to foster environmental protection, uphold Europe's biodiversity, and in still consumer confidence in organic products. these regulations span every aspect of production, processing, and distribution, from primary cultivation to final consumer supply. A key goal of organic production is minimal reliance on external inputs. To combat pests or plant diseases, only substances pre-proved by the European Commission may be used in organic agriculture.

Plant protection product usage must be significantly limited, with a preference for employing measures that prevent pest and weed damage without relying on such products, such as crop rotation. Monitoring the presence of pests and weeds is essential to determine if intervention is warranted both economically and ecologically. However, specific plant protection products may be utilized if alternative techniques prove inadequate and if these products have been authorized in compliance with Regulation (EC) No 1107/2009. Authorization is contingent upon alignment with the objectives and principles of organic production, even if subject to restrictive usage conditions.

In instances where plants cannot be adequately safeguarded from pests using available measures or when there is a confirmed threat to crops, only products and substances authorized for use in organic production under Articles 9 and 24 shall be employed, and solely to the extent necessary. operators are required to maintain records substantiating the necessity of utilizing such products. Regarding products and substances utilized in traps or dispensers other than pheromones, these devices must prevent the release of products and substances into the environment and prohibit contact with cultivated crops. Following use, all traps, including pheromone traps, must be collected and safely disposed of.

10.2. RESULTS

TPC first harvest

	position	N	Subset 1
Tukey HSD[b,c]	W3	3	0.2267
	P2	3	0.2400
	P3	3	0.2433
	W2	3	0.2467
	P4	3	0.2500
	P5	3	0.2567
	P1	3	0.2633
	W4	3	0.2667
	W1	3	0.2733
	W5	3	0.2967
	Sig.		0.147

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,001.
a. date = 1,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

FRAP first harvest.

	position	N	Subset 1	2	3	4	5	6
Tukey HSD[b,c]	W3	3	,3767					
	P4	3	,4200	,4200				
	P3	3	,4400	,4400	,4400			
	W4	3	,4467	,4467	,4467			

P2	3		,4767	,4767	,4767		
P5	3		,5000	,5000	,5000		
W5	3			,5233	,5233		
P1	3				,5633	,5633	
W2	3					,6467	,6467
W1	3						,7033
Sig.		,287	,155	,124	,099	,124	,554

Based on observed means.
The error term is Mean Square(Error) = 0,001.

a. date = 1,00

b. Use Harmonic Mean Sample Size = 3,000.

c. Alpha = 0,05.

TPC second harvest.

	position	N	Subset 1
Tukey HSD[b,c]	P3	3	0,2267
	P5	3	0,2300
	W3	3	0,2300
	W5	3	0,2433
	P2	3	0,2467
	P4	3	0,2500
	W1	3	0,2500
	P1	3	0,2533
	W2	3	0,2633
	W4	3	0,2767

Sig.		0,345

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,001.
a. date = 2,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

FRAP second harvest.

	position	N	Subset		
			1	2	3
Tukey HSD[b,c]	P4	3	0,4633		
	P5	3	0,5067		
	P1	3	0,5567	0,5567	
	P2	3	0,5667	0,5667	
	P3	3	0,5833	0,5833	0,5833
	W4	3	0,6033	0,6033	0,6033
	W3	3	0,6533	0,6533	0,6533
	W5	3	0,6633	0,6633	0,6633
	W2	3		0,7467	0,7467
	W1	3			0,7733
	Sig.		0,060	0,084	0,084

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,0005.
a. date = 2,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

TPC first harvest and protected side

	position	N	Subset
			1
Tukey HSD[b,c]	P2	3	0,2400
	P3	3	0,2433

	position	N	1
	P4	3	0,2500
	P5	3	0,2567
	P1	3	0,2633
	Sig.		0,695

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,000.
a. date = 1,00, side = 1,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

FRAP first harvest and protected side

	position	N	Subset 1	2
Tukey HSD[b,c]	P4	3	0,4200	
	P3	3	0,4400	
	P2	3	0,4767	0,4767
	P5	3	0,5000	0,5000
	P1	3		0,5633
	Sig.		0,178	0,132

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,002.
a. date = 1,00, side = 1,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.
d.

TPC first harvest and windy side

	position	N	Subset 1
Tukey HSD[b,c]	W3	3	0,2267
	W2	3	0,2467
	W4	3	0,2667
	W1	3	0,2733

	W5	3	0,2967
	Sig.		0,166

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 0,001.
a. date = 1,00, side = 2,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

FRAP first harvest and windy side.

	position	N	Subset			
			1	2	3	4
Tukey HSD[b,c]	W3	3	0,3767			
	W4	3		0,4467		
	W5	3			0,5233	
	W2	3				0,6467
	W1	3				0,7033
	Sig.		1,000	1,000	1,000	0,106

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) =0,001.
a. date = 1,00, side = 2,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05.

TPC second harvest and protected side.

	position	N	Subset
			1
Tukey HSD[b,c]	P3	3	0,2267
	P5	3	0,2300
	P2	3	0,2467
	P4	3	0,2500
	P1	3	0,2533

	Sig.		0,702

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) =,001.

a. date = 2,00, side = 1,00
b. Uses Harmonic Mean Sample Size = 3,000
c. Alpha = ,05.

FRAP second harvest and protected side.

	Position	N	Subset 1
Tukey HSD[b,c]	P4	3	0,4633
	P5	3	0,5067
	P1	3	0,5567
	P2	3	0,5667
	P3	3	0,5833
	Sig.		0,583

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,010.

a. date = 2,00, side = 1,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05

TPC second harvest and windy side.

	position	N	Subset 1
Tukey HSD[b,c]	W3	3	0,2300
	W5	3	0,2433
	W1	3	0,2500
	W2	3	0,2633
	W4	3	0,2767
	Sig.		0,211

Means for groups in homogeneous subsets are displayed.

Based on observed means.
The error term is Mean Square (Error) = 0,001.
a. date = 2,00, side = 2,00
b. Use Harmonic Mean Sample Size = 3,000.
c. Alpha = ,05

FRAP second harvest and windy side.

	position	N	Subset		
			1	2	3
Tukey HSD[b,c]	W4	3	0,6033		
	W3	3	0,6533	0,6533	
	W5	3		0,6633	
	W2	3			0,7467
	W1	3			0,7733
	Sig.		0,114	0,979	0,601

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 0,000.
a. date = 2,00, side = 2,00
b. uses Harmonic Mean Sample Size = 3,000
c. Alpha = ,05

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