T.R.

NİĞDE ÖMER HALİSDEMİR UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF AGRICULTURAL GENETIC ENGINEERING

RESPONSES OF THE STRAWBERRY CULTIVARS TO SEVERAL LYSOPHOSPHATIDYLETHANOLAMINE (LPE) TREATMENTS UNDER GREENHOUSE CONDITIONS

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September, 2021

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MASTER THESIS

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Supervisor

Professor. Dr. Sedat SERÇE

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The study titled "**Responses of the Strawberry Cultivars to several Lysophosphatidylethanolamine (LPE) Treatments Under Greenhouse Conditions**" and presented by **Musa Ali Aman** under the supervision of **Prof. Dr. Sedat SERÇE** has been accepted as a Master of Science thesis by the jury at the Department of Agricultural Genetic Engineering of Niğde Ömer Halisdemir University, Graduate School of Natural and Applied Sciences.

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This thesis has been found appropriate at the date of 15/09/2021 by the jury mentioned above who have been designated by the Board of Directors of Graduate School of Natural and Applied Sciences and has been confirmed with the resolution of the Board of Directors dated .... and numbered..............

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DIRECTOR

THESIS DECLARATION

I certify that the thesis has been written by me and that, to the best of my knowledge and belief. All information presented as part of this thesis is scientific and in accordance with the academic with the scientific rules. Any help I have received in preparing the thesis, and all sources used, have been acknowledged in the thesis.

Musa Ali AMAN

SUMMARY

RESPONSES OF THE STRAWBERRY CULTIVARS TO SEVERAL LYSOPHOSPHATIDYLETHANOLAMINE (LPE) TREATMENTS UNDER GREENHOUSE CONDITIONS

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Graduate School of Natural and Applied Sciences
Department of Agricultural Genetic Engineering

Supervisor : Prof. Dr. Sedat SERÇE

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For the sustainability of the strawberry culture, the most suitable inputs enabling high yield and quality characteristics are used. Lysophosphatidylethanolamine (LPE) is one of those inputs helping several horticultural crops elevating fruit quality characteristics and shelf life in apples, cherries, grapes persimmon and cut flowers. LPE has also been experimented in open-field strawberry production with inconclusive results. In this study, four short day cultivars (‘E-22’, ‘Sabrina’, ‘Calinda’, and ‘Fortuna’) with low chilling requirements were grown in a greenhouse and exposed to two LPE treatments (20 ppm) where LPE has been applied either week or two weeks interval basis along with an untreated control. From the beginning of 2021 to end of May 2021, the fruits were harvested at their maturity and several quality characteristics. The results demonstrated that LPE application did not affect the quality characteristics on these short day cultivars when they were grown on a controlled scheme. However, the effects of harvest date, cultivar and their interactions were found to be significant for both characteristics. It was concluded that LPE effect on strawberry culture under greenhouse conditions aiming for early production are complex.

Keywords: *Precocity, lysophosphatidylethanolamine, quality, short day, strawberry*

ÖZET

ÇİLEK ÇEŞİTLERİNİN SERA KOŞULLARINDA ÇEŞİTLİ LİZOFOSFATİDİLETANOLAMİN (LPE) UYGULAMALARINA YANITLARI

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Çilek yetiştiriciliğinin sürdürülebilirliği için yüksek verim ve kalite özellikleri sağlayan en uygun girdiler kullanılmaktadır. Lizofosfatidiletanolamin (LPE), elma, kiraz, üzüm, tranzon hurması ve kesme çiçekler gibi çeşitli bahçe bitkileri ürünlerinde meyve kalite özelliklerini ve raf ömrünü artırmaya yardımcı uygulamalardan biridir. LPE, açık alan çilek üretiminde denenmiş ancak etkisi tam olarak anlaşılamamıştır. Bu çalışmada, düşük soğutma gereksinimlerine sahip kısa gün çeşitleri ('E-22', 'Sabrina', 'Calinda', ve 'Fortuna') bir serada yetiştirilmiş ve LPE'nin bir kontrol ile birlikte haftalık veya iki haftalık bazda uygulandığı iki LPE (20 ppm) işlemine maruz bırakılmıştır. 2021 yılının başlangıcından Mayıs 2021 sonuna kadar meyveler, derim olumuna geldiklerinde derilmiş ve çeşitli kalite özelliklerinde belirlenmiştir. Sonuçlar, kontrollü bir ortamda yetiştirildiklerinde LPE uygulamasının bu kısa çeşitlerin kalite özelliklerini etkilemediğini göstermiştir. Bununla birlikte, derim tarihi, çeşit ve interaksiyonlarının etkileri hemen tüm kalite özellikleri için de önemli bulunmuştur. Erken üretime yönelik sera koşullarında çilek kültürü üzerine LPE etkisinin karmaşık olduğu sonucuna varılmıştır.

Anahtar Kelimler: *Erkencilik, lizofosfatidiletanolamin, kalite, kısa gün, çilek*

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SYMBOLS AND ABBREVIATIONS

Symbols	**Descriptions**
%	Percentage
°C	degree Celsius
g	gram
Kg	kilogram
L	Liter
mg	milligram
mm	millimeter
pH	power of hydrogen proton
ppm	part per million
µg	microgram
µmol	micromole

Abbreviations	**Description**
FW	Fresh weight
GAE	Gallic acid equivalent
GLM	Generalized linear model
LP	Lysophosphatidyl
LPE	Lysophosphatidylethanolamine
LSD	Least Significance Difference
PE	Phosphatidylethanolamine
PLA	Phospholipase A2
PLD	Phospholipase D
SAS	Statistical Analysis System
SSC	Soluble solids content
TA	Titratable acidity
TEAC	Trolox equivalent antioxidant capacity
TSS	Total soluble solid

CHAPTER I

INTRODUCTION

The increase in human population has raised many problems as customers around the World want fresh vegetables and fruits with high quality, extended shelf life and nutritional value. This upsurging demand of agricultural products questions the scientists and industry to create methods that can expand the storage time while maintaining quality of produce (Weis and Weis, 2007). Preserving vegetables and fruits for a longer time and increasing their yield have been a point of discussion for few decades now (Poulton et al., 2010). An environmentally friendly tactic to resolve this issue is application of edible films and coverings of agricultural products (Ashraf et al., 2021).

Among many other fruits, strawberry belongs to the genus *Fragaria,* a genus of over 20 species of blossoming plants in the rose family (Rosaceae) (Hummer et al., 2009). Cultivated varieties of strawberries are extensively grown all over the World while they are indigenous to the temperate regions of the Northern Hemisphere. Strawberries are full of vitamin C and are commonly referred as “dessert fruit” (Martinez Leoncio, 1995).

Turkey is the fifth largest strawberry producing country in the whole World, producing 415,150 tons per year. The main strawberry cultivating areas in Turkey are the Mediterranean (52.1%), Egean (24.7%), and Marmara (14.6%). Mersin has achieved 35% of the total production followed by Aydın, Antalya, Bursa and Konya among the cities (Kafkas, 2017). Due to high degree of finiteness and contamination caused by several pathogens, strawberry fruits have a very short shelf-life and senescence period. This inefficient quality and decay cause the wastage of a high number of fruits globally. To raise the production, improve export avenues and availability of strawberries at local market is the basic aim (Kuchi et al., 2019).

It has been known that lipids perform crucial roles in the cellularlevel. They are known to perform many roles in the management of various cellular functions (Cowan, 2006). Phosphatidylethanolamine (PE) is a membrane phospholipid that has two fatty acids acyl chains and an ethanolamine head group. Phospholipids are found in biological membranes but their concentration changes when plants are exposed to freezing (Lee et al., 1997; Scherer, 2002).

Modulation of plant physiology has been the basis of various horticultural techniques (Arteca, 1996). Plant growth regulators are used to enhance the growth and development of plants. Plant growth regulators like Lysophosphatidylethanolamine (LPE) have been used in pre and postharvest applications to accomplish a variety of goals. These regulators can enhance the growth and development of several harvests. They have been shown to improve the quality of cranberry fruit and reduce the stress resistance of plants. LPE is a plant growth regulator that can improve the quality of cranberry and many other fruit species (Özgen and Palta, 1999).

The first evidence of the influences of LPE on an agricultural service was introduced in 1989. The use of LPE was shown to boost the efficacy of ethephon on cranberry fruit. Various plant species and crop organs have been treated with LPE to improve their shelf-life and quality. The claimed horticultural benefits include an accelerated color development and the extension of shelf life for certain crops. The claimed benefits of these plants include delayed leaf senescence, enhanced shelf life, and color development (Hong et al., 2007). However, these effects are conflicting and are not supported by sufficient evidence (Farag and Palta, 1993a; Hong et al., 2009a and b; Özgen et al., 2005). A plant growth regulator might affect the development of the plant's organs, which are responsible for its ripening.

Earlier experiments revealed that LPE, a biologically arising phospholipid, can delaysenescence that enclosed and distant leaves and harvests of tomato (Farag and Palta, 1993b). The tomatoes treated with LPE showed a longer shelf life whether they were collected at the breaker, pink, or red phases of ripeness (Farag and Palta, 1993c). It is discovered that these treatments played an important role in reduction of leave senescence, cut flowers and fruits (Kaur and Palta, 1997; Özgen et al., 2005). It was observed that LPE increased the marketable yield of green pepper and prolonged the shelf life of the fruit. It also inhibited the production of ethylene and maintained the fruit's shelf life.

LPE has been used to alter different physiological processes in plants and it was therefore of concern to study the consequence of this lysophospholipid on fruit characteristic of table grapes. LPE has been reported to improve the food quality and storage life in various fruits. LPE is considered as a natural substance and does not cause any residual problems in agricultural applications. LPE is commercially derived from egg and soy lecithin. It is possible to make important contribution to horticulture products to generate successful results. Previous studies showed that LPE spray at various concentration enhance the fruit color and shelf life of crop species. It has a positive effect on fruit ripening and protects membrane degradation as well.

The fruit quality characteristics contribute to farm income and are most significant for sustainability. Consequently, in the current study the special effects of foliar utilized LPE on quality factors, comprising soluble solids content, titratable acidity, firmness, and strawberry size were observed. The objective of this planned investigation was to examine the impact of LPE on strawberry cultivars in green house conditions.

CHAPTER II

REVIEW OF LITERATURE

2.1 A brief history of the strawberry

The strawberry, *Fragaria*, belongs to rose (Rosaceae) family and is a very well-known berry fruit in whole World (Skrovankova et al., 2015). There are generally about twenty *Fragaria* species identified from the investigations of about 500 accessions of wild samples collected around the world and of specimens from the main relevant herbaria that are distinguishable in flavor, size and texture. However, they possess the same unique characteristics i.e., heart-shape, red flesh, and seeded coat (Hawkes et al., 2012). Strawberries are usually not considered as true fruits because they carry their seeds on the outside of the fruit. Strawberries are available in large commercial cultivars and researchers found a great variation due to diversity in date of fruit ripening, resistance against diseases, firmness, freezing quality berry mass, form and flavor. They come in several ploidy levels from diploid to decaploid species (Hummer et al., 2011). Furthermore, strawberry is rich source of a number of nutritional and anti-nutritional bioactive composites, which are involved in a variety of health-promoting and disease preventative factors (Afrin et al., 2016). Berries containwide-rangeof nutritive compounds such as sugars, carotenoids, essential oils, minerals and vitamins, as well as phytochemical compounds such as flavonoids, phenolic acids, anthocyanins stilbenes, phenolics, and tannins (Nile et al., 2014). In addition, strawberries can improve the immune system and reduce obesity-related disorders and reduce the probability of heart disease from polyphenolic and antioxidant contents (Minh et al., 2019).

2.2 The distribution of strawberry species

Strawberry species are spread across majority of habitats around the Northern continents of the World with a few endemic ones found in the tropics (Jellen et al., 2011). The diploid *Fragaria vesca* is the only species found in both Eurasia and America and are differentiated into four regional subspecies. However, all the others are located either in a single continent or specific areas within them. Central Asia and Far East are the two centers of diversity for the diploid strawberry species (Rousseau et al., 2009). The tetraploid species are found in the East and Southeast Asia and the only hexaploid species is in Europe. The most cultivated species, octoploids are mainly distributed in South and North America with one cultivar which is endemic to the Far East (Hummer et al., 2011). In addition, the highly average size of suitable area for tetraploid wild strawberry was lesser than diploid species and the future climate scenarios, as well as the average size of the highly suitable area of tetraploid species showed a tendency to shrink while it displayed a tendency to expand for diploid species (Yang et al., 2020).

2.3 Lysophosphatidylethanolamine (LPE) and its uses

Lysophosphatidylethanolamine also known as LPE, is a chemical compound coming from the partial of phosphatidylethanolamine. In every fatty acid group, they must be obtained the process of enzymatic reaction (AKM et al., 2017). LPE is used in agriculture to modulate the plant development, to impacts the color, sugar content, plant health, and storability (increasing these factors without side effects) (Hong., 2012) (Table 2.1). It is present as phospholipid in the cell membrane. LPE extracted from egg yolk lecithin (≤1.5%), soybean lecithin (≤0.2%) are common sources of lecithin among many other sources (Cui et al., 2012). LPE plays a role in cell-mediated cell signaling and activation of other enzymes, speeds up ripening, prolongs the shelf life of the tomato fruit, retard senescence in attached and detach leaves and fruits. Moreover, LPE restrained the activity of phospholipase D, a membrane degrading enzyme, whose activity increases during senescence (Selvy et al., 2011). More recent research indicates that LPE improve color development, enhance the cranberries shelf life, increase the level of soluble solids content, titratable acidity, firmness, and even the size of 'Thompson's Seedless' grapes (Wan and Singh, 2011). Furthermore, the result shows that the LPE impact on the fruit ripening was possesses the ability to guard against senescence and delaying the fruits and leaves senescence as well as mitigating stress of ethylene-induces in processes. In addition, study conducted on tomatoes, peppers, grapes, cranberry, and oranges using LPE and it increase the color, sugar content of the fruits and their shelf life (AKM et al., 2017).

2.4 Phospholipids and their relevance

Phospholipids are members of a huge group of fatlike, phosphorus-containing substances that play vital roles in the structure and metabolism of living cells (Timperley et al., 2015). All biological membranes consist of phospholipids as an important part of their make-up due to the principal role they play in processes like signal transduction, cytoskeletal rearrangement, and membrane trafficking (Buchanan et al., 2015). Moreover, they serve as co-factors for enzymes localized in membranes responsible for signal cascading by enhance protein-lipid and protein-protein interactions (Balogi et al., 2019). Furthermore, the material used can impact the chemical properties of these membranes and effect on phospholipids that can cause an increase or decrease in ion flux, membrane transport, vesicle formation, and endocytosis or exocytosis (Degreif et al., 2019). In addition, the unsaturated membrane phospholipids are prone to oxidation, they can produce a complicated mixture of peroxy and hydroxyl species both enzymatically and even reactive oxygen species. In five to nine series of atom carbon length, they can spontaneously decompose to reduce the oxidized level, combined the aldehyde, including carboxyl,hydroxyl species while many of these exhibits have strong biological activities (Dushianthan and Postle, 2021).

2.5 Lysophosphatidylethanolamine as a plant bioregulator

A plant bioregulator is an agrochemical applied as an aqueous spray to plant surfaces which is then absorbed by the plant tissues and transported to a reaction site to achieve a desired result (Rostami et al., 2019). LPE is naturally occurring phospholipid produced as a result of series processes (production reaction of phospholipase A_2 (PLA_2) including hydrolysis of the phosphatidylethanolamine (PE)) which is commercially used as a bioregulator because it possesses the potential to affect the fruit ripening and delay senescence in many plant species (Ahmed et al., 2019). A study conducted by (Cowan et al., 2006) with the aim of elaborating the effect and used of several plant tissues to the LPE on plant development and its mode of action in terms to LPE and analyzing the response and potential target of enzymes to the LPE applied on plant. Moreover, LPE stimulated the delayed of dark-induced leaf senescence in many broad beans, enhanced the fruit set in tomatoes, and elongation growth and development of oat coleoptiles, as well as promoted the cytokinin-induced of cotyledon expansion of radish (Cowan et al., 2005). Later, it was also noticed that radish cotyledons treated with LPE were more tolerant to oxidative stress induced by high temperature. Plant physiology revealed that plant hormones and growth regulators impact growth and development by initiating series of biochemical and molecular events that alter the expression of genetic material (Cowan et al., 2006).

2.6 The impact of Lysophosphatidylethanolamine in horticultural crops

The first evidence important of LPE is the influences on a horticultural species which was established during that time, when LPE was stated to improve ethylene manufacture and expand the efficacy in terms of ethephon (2-chloroethyl) phosphonic acid especially on cranberry fruit in 1989. Subsequent studies have been done ever since (Amaro et al., 2012). Applied LPE affects expansion, development, and postharvest durability of horticultural crops. Investigations of these effects have been carried out in a range of plant organs in about a dozen of horticultural species which revealed some horticultural benefit such as prolonged shelf-life in cranberry and tomato, enhanced color development, stimulated ripening of grape, delayed leaf senescence and prolonged vase life of cut flowers (Farag et al., 2016). Species, however, vary to a large extent in their response to LPE treatments, due to thedifferences in developmental stages, and organ types (Amaro and Almeida, 2013).

Table 2. 1: Lysophosphatidylethanolamine (LPE) effects on horticultural commodities (Amaro and Almeida, 2013).

Horticultural commodity and organ	Application method	LPE concentration and other treatment conditions	Horticultural (1), physiological (2), and biochemical (3) effects	References
Apple fruit 'McIntosh'	Preharvest spray Postharvest vacuum infiltration	50–100 mg/L; ethanol (1–2%)	(2) Improved postharvest fruit firmness and color uniformity; increased fruit peel anthocyanin content; stimulated ethylene production; no effect on respiration rate	Farag and Palta (1991)
Arabidopsis thaliana	Foliage spray	100 mg/L	(1) Increased freezing tolerance	Rajashekar et al. (2006)
Banana fruit (excised peel)	Postharvest incubation	25, 50 or 100 mg/L	(2) Decreased ethylene production; delayed firmness loss; decreased ion and protein leakage	Workmaster and Palta (1996)
Banana fruit	Postharvest dip	500 mg/L	(1) Extended shelf-life; increased fruit diameter (2) Fresh weight loss unaffected; decreased ion electrolyte leakage	Ahmed and Palta (2010)
Banana fruit	Postharvest dip	Unknown	(1) Higher marketable fruits, delayed senescence (2) Stimulated ethylene production; lowered respiration rate; total soluble solids and electrolyte leakage; higher fruit firmness	Ahmed and Palta (2011a)
Carnation flowers	Vase solution	10 mg/L	(2) Delayed fresh weight loss and reduced ion leakage at an early stage of flower opening; no effect of LPE on older (stage VII) carnations	Kaur and Palta (1996)
Cranberry crop and fruit	Preharvest spray and postharvest dip	200 mg/L 50–100 mg/L	(1) Effects depended on field location	Özgen and Palta (1999)
Cranberry crop	Preharvest spray	100 or 200 mg/l; chlorothalonil (6 L/ha)	(1) Increased fruit set; prevention of chlorothalonil toxicity	Özgen and Palta (2003)
Cranberry 'Searles' crop	Preharvest spray	200 mg/l; Sylgard (0.05%); ethanol (5%)	(2) Increased anthocyanin content	Özgen et al. (2004)
Cranberry 'Searles' crop and fruit	Preharvest spray Postharvest vacuum infiltration or dip	50–100 mg/l; ethanol (1–2%)	(2) Increased fruit peel anthocyanin content; fruit color uniformity; improved fruit firmness	Farag and Palta (1991)
Cranberry 'Stevens' fruit	Postharvest dip	100 µM of LPE with different acyl chains	(2) Inhibition of ethylene production increased with acyl chain length and the unsaturation of LPE	Ryu et al. (1997)
Cantaloupe fruit (fresh-cut)	Vacuum infiltration	200 mg/L	(2) No effect on color, firmness, soluble solids content or ethylene production; negligible effect on respiration rate; lower production of aldehydes	Amaro et al. (2012)
Grape berry 'Thompson Seedless'	Preharvest foliar spray	10 mg/L	(2) Higher anthocyanin concentration; increased berries soluble solid content, firmness and size	Hong et al. (2009 and b)
Impatiens plant 'Super Elfin', 'Rose' and 'Dazzler'	Spray	50, 100 and 200 mg/L	(1) Higher number of open flowers; faster recovery from water-stress cycles	Snider et al. (2003)

Table 2. 1 *(Continuation)*: Lysophosphatidylethanolamine (LPE) effects on horticultural commodities (Amaro and Almeida, 2013).

Horticultural commodity and organ	Application method	LPE concentration and other treatment conditions	Horticultural (1), physiological (2), and biochemical (3) effects	References
Loquat tree	Prebloom spray	100 mg/L	(1) Increased fruit set; earliness for flowering and harvest date (2) Increased pollen viability rate; decreased pollen germination and pollen tube growth rates	Demirkeser et al. (2009)
Philodendron cordatum leaf (excised discs)	Incubation	50, 150, 200 and 250 µM	(3) No PAL or insoluble acid invertase inhibition; no effect on ABA induced increase in malonaldehyde or loss of chloroplast pigments	Hong et al. (2009 and b)
Potato tuber 'Russet Burbank'	Growing medium with LPE	50 or 100 mg/L	(1) Higher number of healthy leaves (2) Higher chlorophyll content; less auxiliary shoot formation	Özgen et al. (2005)
Potato shoot	Culture medium	400 mg/L	(1) Mitigation of calcium deficiency injury (2) Enhanced calcium uptake; promoted root growth	Ahmed and Palta (2011b)
Radish cotyledons	Incubation	2 mmol/L ; K-phosphate (2 mmol/L)	(3) No effect on soluble acid invertase activity, glucose and sucrose levels; increased PAL and insoluble acid invertase	Hong et al. (2009 a and b)
Radish cotyledons	Unknown		(3) Transient induction of acid invertase, phenylalanine ammonia lyase, endo þ-1,3(4)-glucanase and peroxidase Suppression of polyphenol oxidase and 3-hydroxy-3-methylglutaryl coenzyme A reductase activity	Cowan et al. (2006)
Red pepper crop	Preharvest spray	100, 200 or 400 mg/L; siloxane (0.1 mg/L); Ethephon (250 mg/L) 10 or 50 mg/L	(1) Mitigation of ethephon-induced foliage injury; increased ripened fruit yield (2) Enhanced ethylene production	Kang et al. (2003)
Red and green pepper crops	Preharvest spray		(1) High marketable yield than controls but similar to that of ethephon treated plants; reduced chilling injury	Hong et al. (2007)
Rose 'Lavande' and 'Sensation'	Vase solution	10% aqueous solution; 8-hydroxyquinoline citrate; sucrose	(1) Slower flower opening; increased vase life	Snider et al. (2003)
Snapdragon flowers	24-h pulse	25 mg/L	(1) Enhanced bud opening (2) Delayed weight loss; lower ethylene production; reduced ion leakage	Kaur and Palta (1997)
Horticultural commodity and organ	Application method	LPE concentration and other treatment conditions	Horticultural (1), physiological (2), and biochemical (3) effects	References
				Farag and Palta (1991)

Table 2. 1 (Continuation): Lysophosphatidylethanolamine (LPE) effects on horticultural commodities (Amaro and Almeida, 2013).

Horticultural commodity and organ	Application method	LPE concentration and other treatment conditions	Horticultural (1), physiological (2), and biochemical (3) effects	References
Tomato leaves (excised) and fruit	Dip and immersion of fruit peduncle	50 mg/L	(1) (2) Leaves lower ethylene and CO_2 production rates and higher chlorophyll content; higher fruit	Farag and Palta (1993a)
Tomato 'H7155' crop and fruit	Preharvest spray Postharvest spray	100 mg/L	(2) (2) Lower ethylene and CO_2 production rates, higher fresh weight and chlorophyll content, and lower electrolyte leakage proportion of firm fruits	Farag and Palta (1993b)
Tomato fruit	Unknown	Unknown	(2) Reduced firmness loss (3) Polygalacturonase activity inhibition	
Tomato 'Mountain Spring' crop	Preharvest spray application	200 mg/L; ethephon (1000 mg/L)	(1) Reduced foliar injury by ethephon (3) Lower PLD activity	Hong et al. (2002)
Tomato fruit (mature-green)	Postharvest dip	50 and 100 mg/L; sodium hypochlorite (150 mg/L); citric acid (180 mg/L)	(2) Accelerated color development; enhanced ethylene production	
Tomato fruit	Postharvest dip	50 mg/L	(1) Stimulated ripening of MG4 fruits; moderate effect on MG1 and MG2 fruits (2) Improved fruit firmness	
Tomato pericarp (excised)	Incubation	Different LPE concentrations in buffer solutions	(2) Increased ethylene production, respiration rate and in green tissue; reduced ethylene production, respiration rate in light red tissue (3) Increased ACC oxidase activity in green tissues; reduced ACC oxidase activity in light red tissues	Hong et al. (2007)

2.7 Uses of Lysophosphatidylethanolamine in cranberry

LPE has been mentioned in many studies about its uses in many horticultural commodities. Economically LPE is made from the egg and soy lecithin and therefore, it is considered as organic substance. It can accelerate fruit ripening, while at the same time promote shelf life on cranberry fruit as well as its anthocyanin accumulation (Özgen et al., 2002). The LPE impact on fruit trait was more pronounced after a month of storage and these results they concluded that a preharvest application of LPE possesses the ability to improve anthocyanin production, fruit color and prolong shelf life (Özgen et al., 2002) In long period of storage there is moderately impact of anthocyanin production including the expression of structural of genes (Lo et al., 2005). Moreover, the fruit samples from cranberries counted and weighed to determine shelf life and the effect of LPE to the fruits (Ahmed, 2014). Furthermore, for the final harvest on cranberries the wet harvesting machines were used and along with the scheduled of harvest the commercial cold storage was ready for the fruit to stored (Kiaya, 2014). Most of the sample fruits were harvested two weeks after LPE application and at the final harvest period to ascertain the changes in fruit color. One or two months after cold storage, the cranberries counted and weighed to determine shelf life and the effect of LPE to the fruits (Özgen et al., 2002).

2.8 Uses of Lysophosphatidylethanolamine in sweet cherry

A study conducted by (Özgen et al., 2015) to determine the impact of LPE on phytochemical features of sweet cherry and anthocyanin accumulation that involved with the application of LPE (10 mg·L^{-1}) to a commercial orchard of sweet cherry cultivar '0900 Ziraat', within a couple of weeks before harvesting the fruits for a period of two treatment years (2011 and 2012). In both pomological and horticulture analysis on phytochemical characteristics of the fruit, the applications of LPE are accounted for better results during preharvest (Takeda, 2000). There was a 6% increase in soluble solid content and 17% also increased in fruit weight as average of the two experimental years. The phytochemical content and antioxidant capacity greatly improved (Özgen et al, 2015). The normal total phenolic substance of fruits treated LPE with for the two experimental years varied largely from the control as treated fruits had 703 µg gallic acid equivalent (GAE)/g fresh weight and the untreated control had 569 µg GAE/g FW.

In both years, LPE-treated fruits had a 27 % and 16 % increase in anthocyanin content than the monitor fruits. With the use of TEAC (Trolox equivalent antioxidant capacity) assay to measure the average antioxidant capacity of fruits over the two experimental years, 12.5 and 11.4 µmol TE/g FW was recorded in LPE-treated and untreated control fruits, respectively. The results indicated a potential rise in anthocyanin accumulation, improved fruit quality and enhancement of phytochemical characteristics in sweet cherries when LPE applied before harvest (Özgen et al., 2015).

2.9 Uses of Lysophosphatidylethanolamine in strawberry

To determine the LPE applications effect on pre-skin of strawberry in pomological and phytochemical quality characteristics during fruit storage, (Çeler et al., 2019) conducted a research study with ‘Camarosa’ a summer strawberry cultivar of the Hatay region of Turkey. The unravelling effect of LPE on plant yield, weight loss, flesh hardness, total soluble solid, titratable acid content, anthocyanin content, total phenolic and antioxidant capacity values is the main focused on the study. The results of the study disclosed that there’s no effect on weight loss nor acid content in storage the pre-skin LPE application however, it was effective on fruit hardness and soluble solids. There was an increase of 7% in fruit flesh hardness as well as its preservation when compared to the control group on the 12th day of the experiment. Soluble solids content was also retained based on LPE application result. Whereas there was no effect on the total phenol and total anthocyanin contents, antioxidant capacity increased marginally with 20 ppm in the event double LPE application. Due to the sensitivity of the strawberry fruit and short preservation period, treatment with LPE is a potential remedy to an extension of preservation periods (Çeler et al, 2019). Classification of fruits was done to determine the best possible time for maturation stage of strawberry fruits as unnatural application of LPE and its optimal application for postharvest stability and quality. Because the purpose of treatments was classification of fruits into different levels of maturity (0%, 50%, 70% and 100%) whereas the air-dried stored for 40 minutes and stored again in the refrigerator at 4 °C for 12 days (Choi et al., 2016). In a lower range of concentrations (0, 2.5, 5, 10 and 25 mg/L) LPE was applied to a certain fruit at changed maturity levels. Data on new weight, hardness at vertical and horizontal loading positions, color index and sugar substance during storage were collected. However, there was no significant differences found on fresh weight, color index and sugar content level and this is based on the fruits with 70% maturity dipped in LPE concentrations (Choi et al., 2016).

2.10 Uses of Lysophosphatidylethanolamine in persimmon

Sweet persimmon is one the sweet fruits that has several bioactive molecules, like flavonoids, tannins, phenolics, carotenoids, and anthocyanidins and rich in nutrients (Butt et al., 2015). This fruit is amazing however, most of farmers worried about the disadvantage of rapid softening post-harvest. In addition, persimmon is cultivated only in the subtropical regions, since softening period the fruit is handled with a lot of care for further export (El-Ramady et al., 2015). It is therefore important to discover a more prudent way and stable chemical to be used to delay the softening of persimmon. Therefore, scientist investigated the possibility of prolonging the freshness of persimmons for overseas export using LPE (Jung et al., 2019). The LPE treatments for the fruit into cold storage facility and simulating conditions of overseas export are significantly held back the softening of the fruit after post-harvesting period. (Thompson et al., 2018). From their findings, they concluded that, after the study on the outcomes of LPE to persimmon softening and the related molecular mechanisms emphasizes that LPE can be used to delay persimmon softening (Jung et al., 2019).

2.11 Mitigation of ethylene-promoted leaf senescence using Lysophosphatidylethanolamine

In plants parts including leaf the developmental phase of senescence is majority of leaf senescence involved and extremely synchronized. However, during this process the senescence not only death of a plant part, but other parts undergoes degradation at macromolecular level that resulted for transferring of parts (Sarwat et al., 2013). Moreover, the activity of photosynthetic enzymes and leaf proteins was studied in mulberry and the special effect during high temperature. When the sugar metabolism decreased in leaf starch and its balance between sucrose and starch increased, the leaf temperature is also affected. By the increase of total amino acid content an automatic decrease in total soluble protein content occurred under heat condition (Chaitanya et al. 2001). In addition, including malformed of leaves, thickened stems, and leaves, stunting growth and curling and downward bending of leaves are caused by ethylene and the leaf senescence are visible symptoms (Shree and Amrita, 2019). In some treated potato plantlets showed sensitive leaf senescence symptoms like epinasty, stunting development, yellowing and auxiliary shoot structures (Milanović, 2018). To come up with mechanisms to deal with ethylene promoted leaf senescence, LPE was understudied using micropropagated 'Russet Burbank' potato plantlets cultivated on MS media in sterile culture tubes. However, leaves of plantlets simultaneously exposed to LPE and ethylene had greater chlorophyll content and possessed healthier leaves in comparison with plantlets grown on medium lacking LPE. They concluded based on their results that LPE may potentially decrease ethylene-promoted leaf senescence and probably guard against ethylene induced loss in apical dominance of micro propagated potato plantlets (Özgen et al., 2005).

CHAPTER III

MATERIALS AND METHODS

3.1 Description of Experiment

This study was conducted with different strawberry cultivars that were treated by applying LPE to the various cultivars under greenhouse condition. The analyses of several horticultural characteristics of the fruits were conducted in the chromatography laboratory at Niğde Ömer Halisdemir University, Turkey.

3.2 Plant Materials

Short day cultivars with low chilling requirements were used in the experiments. The selected cultivars are ‘E-22’, ‘Sabrina’, ‘Calinda’, and ‘Fortuna’. These cultivars were supplied by Yaltır Co. as fresh planting material. They had met their chilling requirements and has formed their flower buds, before transplanting. The fresh seedlings were planted on 15^{th} of October 2020. They were first prepared for transplanting (Figure 3.1) and then planted on 10 L pots filled with peat. After planting, they were irrigated by drip irrigation until they were properly established. Irrigation was done once or twice a week in winter while it was done two to three times a week during spring, summer and fall. The plants were grown in heated greenhouse with temperatures aimed at nothing below 10 °C during the winter nights. The plants were maintained with standart cultural practices (Berdaliev, 2019).

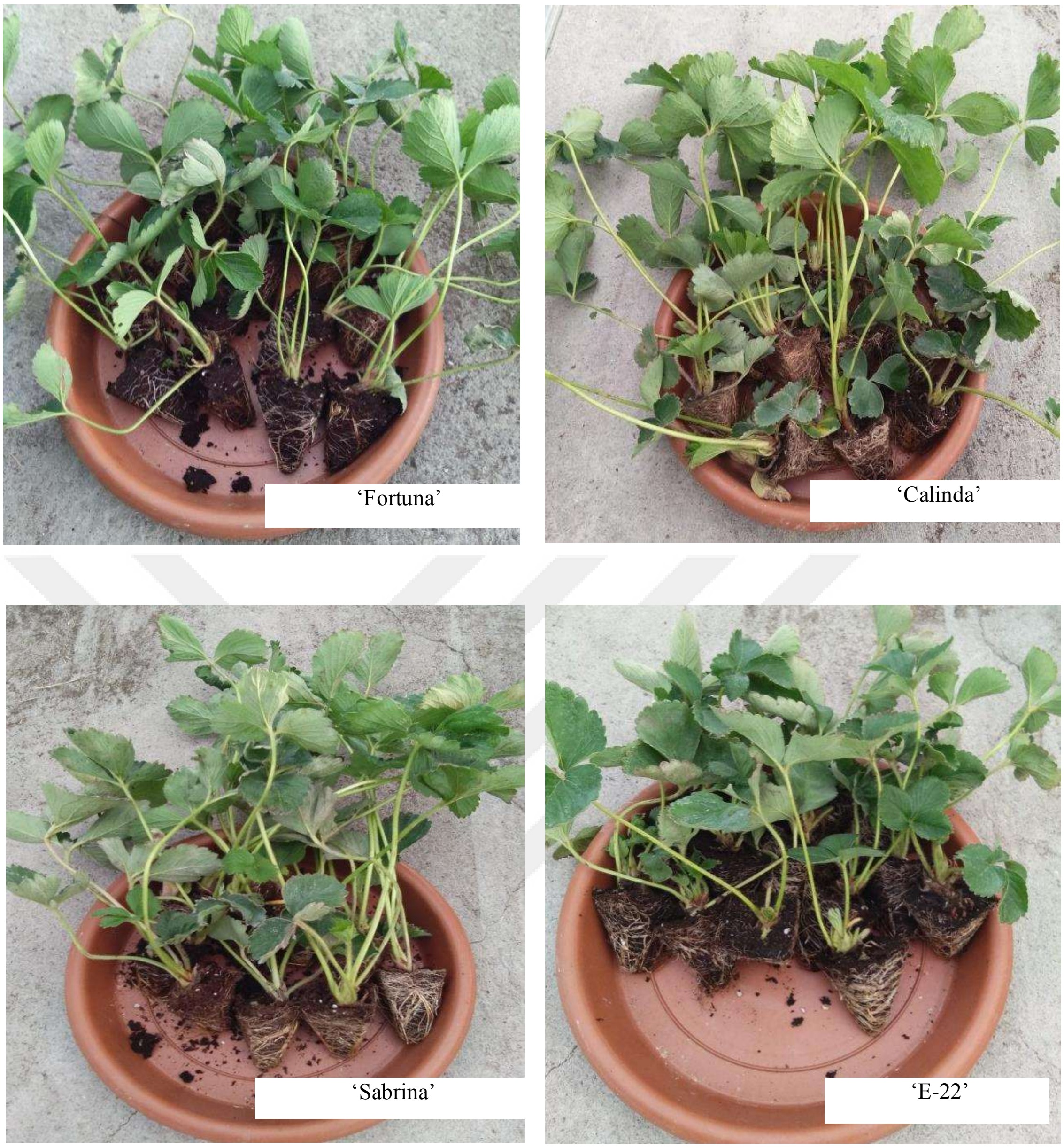

Figure 3.1. The planting material of the strawberry cultivars used in the experiment.

3.3 LPE Treatment

There were three treatments involving each experimental unit. Treatment 1 was the control and treatment 2 and 3 were the experimental samples. Treatment 2 samples were treated with LPE on weekly basis while treatments 3 were treated on two-week basis. Treatments started on the 18^{th} of January with the foliar LPE which was applied to the Treatment 2 of each cultivar while Treatment 3 was applied a week after. This process of LPE foliar application was continued until end of May (Figure 3.2).

Treatment 1: No LPE treatment (Control)

Treatment 2: 20 ppm foliar LPE treatment on weekly basis

Treatment 3: 20 ppm foliar LPE treatment on 2-week basis

Applying LPE foliar using bottle spray

Recording the number of fruits per pot

Figure 3. 2. The view of the lysophosphatidylethanolamine application during the course of the experiment.

3.4 The strawberries in bloom

The strawberries began blooming in the second week of November 2020. Fruiting in ‘E-22’ and ‘Fortuna’ cultivars started in January while cultivars ‘Sabrina’ and ‘Calinda’ started in February (Figure 3.3). Fruits were collected and examined and when they were fully matured in chromatography laboratory. By mid-February about 80% of all cultivars had already fully bloomed. Pots of each cultivar were tagged to differentiate between pots that have been harvested from those yet to be harvested (Figure 3.4).

Figure 3. 3. The view of the flowering of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Figure 3. 4. Flowering of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

3.5 Parameters Measured

The following horticultural attributes were measured while plants bloomed according to Özdemir et al. (2001).

Fruit height and width: The height width of the fruit was determined using digital caliper for sampling at least three fruit during the experiment (Figure 3.5.1).

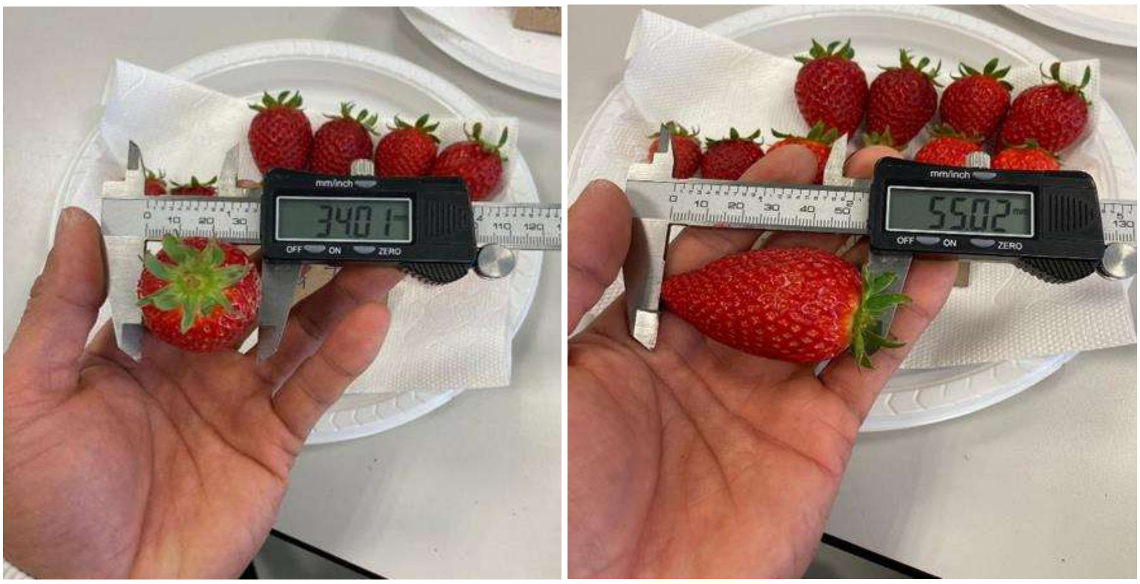

Figure 3.5.1. Fruit height and width determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Average fruit weight (g): It was calculated by dividing the fruit weights in each skin by the number of fruits. The measurements were repeated in February, March, April and May when the harvest is densest, 20 fruits taken from each replication were used for the measurements (Figure 3.5.2).

Figure 3.5.2. Fruit height and width determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Total soluble solids: It was determined by refractometer readings using a drop of fruit juice (Figure 3.5.3).

Figure 3.5.3. Soluble solid determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Acidity (%): In the period when fruit skins are densest, acid contents were determined by titration in terms of citric acid according to pH 8.1 (Schlering et al., 2020) (Figure 3.5.4).

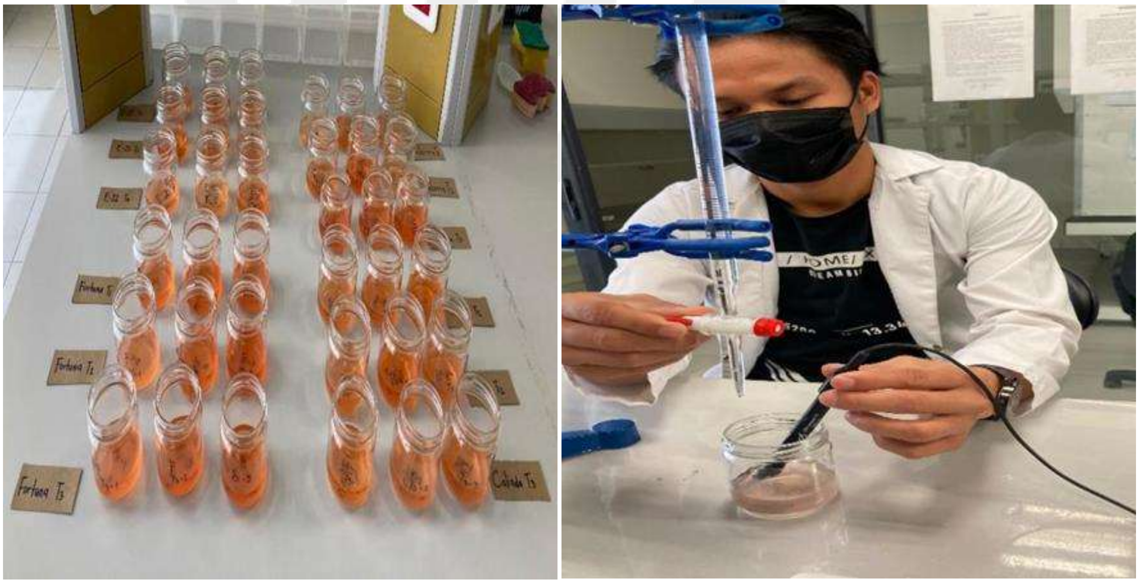

Figure 3.5.4. Acidity determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Fruit flesh firmness (kg): It was measured with a Shorometer (5 mm tip) in the equatorial region of the fruit bilaterally (Figure 3.5.5).

Figure 3.5.5. Fruit firmness determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

Fruit external and internal color: The external and internal color of the fruit were determined as two-sided L *, hue (color angle value) and Chroma (color density) values from the very center of the fruit (equatorial region). Color values were determined with the Minolta color meter (Minolta CR 300) (Sacks and Shaw 1994) (Figure 3.5.6).

Figure 3.5.6. External and internal color determination of the strawberry cultivars treated with lysophosphatidylethanolamine treatments.

3.6 Experimental Layout

The experiment was established using a split plot design having three replications with five subsamples. Among the factor studies, the harvesting dates were considered as whole-plot effect while LPE treatments and cultivars were considered to be sub-plots. The data collected from the experiment were subjected to the variance analysis using the SAS program (SAS, 2005) and the GLM procedure. The descriptive statistics were analyzed using TABULATE procedure.

CHAPTER IV

RESULTS

Four short day strawberry cultivars were grown in a heated greenhouse from October 2020 to May 2021. The standard growing practices were applied to these cultivars. The production was mimicking those of commercial producers aiming the early fruit production under Mediterranean Region. The production was considered to be successful as the plants producing satisfactory mount of fruit from January to May 2021.

Several horticulturally important fruits characteristics were evaluated as fruits matured during the season. ANOVAs indicated date the harvesting date was significant for all of the horticultural traits (Table 4.1). Similarly, the cultivars effect was found to be significant for all traits tested. The harvesting date x cultivar interactions were significant for the most of the traits tested but fruit size measurements, fruit height, width and weight. These results indicate that fruit size measurements had the same trend for the cultivars throughout the season.

The LPE treatments were not found to be significant for the most of the characteristics tested but fruit firmness and total soluble solid content. Similarly, the harvesting date x cultivar interactions were only fruit firmness and total soluble solid content variables.

The average values for the main effects of harvesting date, treatment and cultivars are presented in Table 4.2. The largest berries were harvested the beginning of the season (40.7 mm height, 31.9 mm width and 18.2 g fruit weight). The heaviest berries were harvested form 'Calinda' with 16.2 g while the fruit height was height in 'Sabrina' (37.0 mm) and width were the highest in 'Calinda' (30.6 mm). All LPE treatments were around the overall means of 35.2 mm, 28.1 mm, and 14.3 h for fruit height, width and weight, respectively.

Fruit firmness averages ranged between 1.23 and 1.67 kg for the harvesting dates. 'Sabrina' had the firmest berries (1.65). while 'Calinda' had the softest berries (1.25 kg). Similar to size variables, treatments were around the overall means of 1.47 kg.

Table 4.1. The mean squares and significance of the several fruit quality characteristics for the strawberry cultivars treated with several Lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions.

Source	Degree of freedom	Height	Width	Weight	Firmness	Total soluble solids (%)	External			Internal		
							L	a	b	L	a	b
Date (D)	23	**202***	**112***	**213***	**0.38***	**40.8***	**23.2***	**331***	**60***	**23***	**386***	**73***
Replication /D	454	34	14	32	**0.12***	**0.0***	**5.3***	13	**10***	5	12	10
Treatment (T)	2	11	19	16	**0.01***	**16.3***	0.1	22	5	7	5	8
Cultivar (C)	3	**1323***	**902***	**752***	**7.79***	**100.8***	**12.2***	**363***	**61***	**28***	**455***	**135***
T x C	6	45	23	31	**0.02***	**3.4***	5.0	20	**22***	4	24	16
D x T	44	43	17	27	**0.05***	**2.5***	5.1	9	6	7	15	8
D x C	65	**398***	**147***	**372***	**0.15***	**9.6***	**14.9***	**57***	**24***	**23***	**77***	**31***
D x T x C	116	38	15	28	**0.07***	**2.5***	**11.4***	**25***	**12***	**17***	**32***	**15***
Error	2200	35	14	32	0.00	0.0	4.2	13	9	7	14	11

*The significant mean squares, at 5%, are marked with a star.

Table 4.2. The mean values variance for the several fruit quality characteristics of the strawberry cultivars treated with several Lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions.

Source	Height (mm)	Width (mm)	Weight (g)	Firmness (kg)	Total soluble solids (%)	External L	External a	External b	Internal L	Internal a	Internal b
Date											
12.01.2021	40.7	31.9	18.2	1.39	4.7	41.0	21.8	15.6	43.1	20.3	14.9
27.01.2021	35.1	30.6	14.5	1.50	5.3	43.1	23.8	17.9	43.6	24.2	17.5
02.02.2021	32.9	28.7	11.8	1.67	6.1	43.0	23.5	17.2	43.6	24.9	19.1
09.02.2021	32.3	29.7	13.2	1.55	5.7	41.5	21.2	16.6	41.8	21.4	17.1
16.02.2021	34.0	28.3	13.9	1.52	5.6	40.7	19.7	15.6	39.9	18.6	15.2
23.02.2021	38.4	29.3	17.5	1.59	6.7	41.8	22.4	16.5	42.4	23.8	17.3
02.03.2021	37.2	29.6	16.0	1.57	8.6	41.0	22.2	16.4	41.6	21.9	16.9
05.03.2021	37.4	28.9	15.2	1.46	8.6	41.9	22.1	16.6	42.5	22.9	17.2
09.03.2021	36.8	27.5	14.0	1.47	9.1	42.0	23.0	16.6	42.4	23.1	17.0
17.03.2021	37.0	28.0	14.7	1.49	8.3	41.4	21.7	15.7	42.0	22.7	16.6
23.03.2021	38.0	29.7	17.4	1.37	8.3	41.5	21.2	15.5	41.7	21.3	16.0
30.03.2021	37.3	31.3	18.2	1.50	8.5	42.2	21.5	16.0	42.2	21.2	16.2
06.04.2021	37.1	30.2	17.6	1.49	9.2	41.6	19.7	14.9	41.8	20.2	15.3
14.04.2021	36.2	28.9	15.8	1.50	8.7	40.9	18.2	14.1	41.3	18.5	14.5
20.04.2021	34.0	26.5	13.1	1.55	8.0	40.7	22.3	15.8	40.9	22.3	15.9
27.04.2021	33.7	27.3	12.8	1.51	9.9	40.4	25.6	16.9	40.7	26.0	17.4
04.05.2021	34.4	27.5	13.7	1.45	8.3	40.0	24.0	16.5	40.2	24.2	16.6
07.05.2021	37.9	29.5	17.3	1.46	7.5	40.4	25.4	17.1	40.7	25.6	17.2
12.05.2021	35.6	28.1	14.2	1.44	8.4	40.1	25.3	16.5	40.4	25.6	17.1
17.05.2021	33.3	26.2	11.8	1.51	8.4	40.8	27.7	18.3	41.4	28.6	19.3
22.05.2021	33.9	26.1	13.2	1.37	8.9	40.4	26.7	17.6	40.8	27.2	18.3
25.05.2021	34.2	26.9	12.5	1.23	7.5	41.0	27.8	18.3	41.9	28.0	18.7

Table 4.2 (Continuation). The mean values variance for the several fruit quality characteristics of the strawberry cultivars treated with several Lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions.

Source	Height (mm)	Width (mm)	Weight (g)	Firmness (kg)	Total soluble solids (%)	External Internal L	a	b	L	a	
28.05.2021	32.5	26.9	12.2	1.42	8.5	40.6	27.1	18.1	40.9	27.0	18.5
31.05.2021	32.7	26.2	11.2	1.44	8.4	41.5	27.5	18.5	41.8	28.0	19.3
Cultivar											
Calinda	34.1	30.6	16.2	1.25	8.9	40.9	22.0	16.1	41.1	22.2	16.4
E-22	34.3	28.0	13.3	1.46	7.4	40.8	24.8	16.9	41.3	25.2	17.7
Fortuna	34.4	26.4	12.1	1.47	6.8	41.3	24.9	17.7	41.7	25.4	18.2
Sabrina	37.0	27.1	14.7	1.65	8.7	41.0	23.9	16.5	41.3	24.0	16.9
Treatment											
T1	35.1	27.9	14.2	1.47	7.8	40.8	23.6	16.6	41.2	23.8	17.2
T2	35.3	28.0	14.2	1.48	8.4	41.1	23.9	16.8	41.4	24.3	17.3
T3	35.1	28.2	14.4	1.47	8.2	41.0	23.9	16.7	41.3	24.0	17.1
Overall	35.2	28.1	14.3	1.47	8.1	41.0	23.8	16.7	41.3	24.0	17.2

The soluble solid content increased as the season progress at reached at its height at the end of April. The content was highest in ‘Calinda’ (8.9%) and the lowest in ‘Fortuna’. The averages of All LPE treatments were similar to 8.1%, the overall mean.

Because harvesting “date x cultivar” interactions were significant, the averages of the interactions were presented separately in figures. The changes in fruit height were presented in Figure 4.1 where the highest averages were recovered from ‘Sabrina’ in February. Similarly, the height average was recorded in ‘Sabrina’ at the end of February (Figure 4.2). The same trend was also present in fruit weight (Figure 4.2). Although there was a fluctuation, ‘Sabriana’ usually had the firmest berries on several harvesting dates (Figure 4.4). For the soluble solid content, however, the highest values usually recorded in ‘Calinda’ (Figure 4.5).

The large amount of fruits required to conduct acidity analyses. Thus, the acidity analysis was only conducted in April 2021 when the height amounts of fruits were harvested. The ANOVA of the acidity values indicated that the LPE treatments, cultivar and the treatment x cultivar interaction were not significantly different for acidity measurements (Table 4.3). The average values for the acidity were presented in Table 4.4 and the overall average was 5.5.

Figure 4.1. The changes in the fruit height of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions during the 2021 growing season.

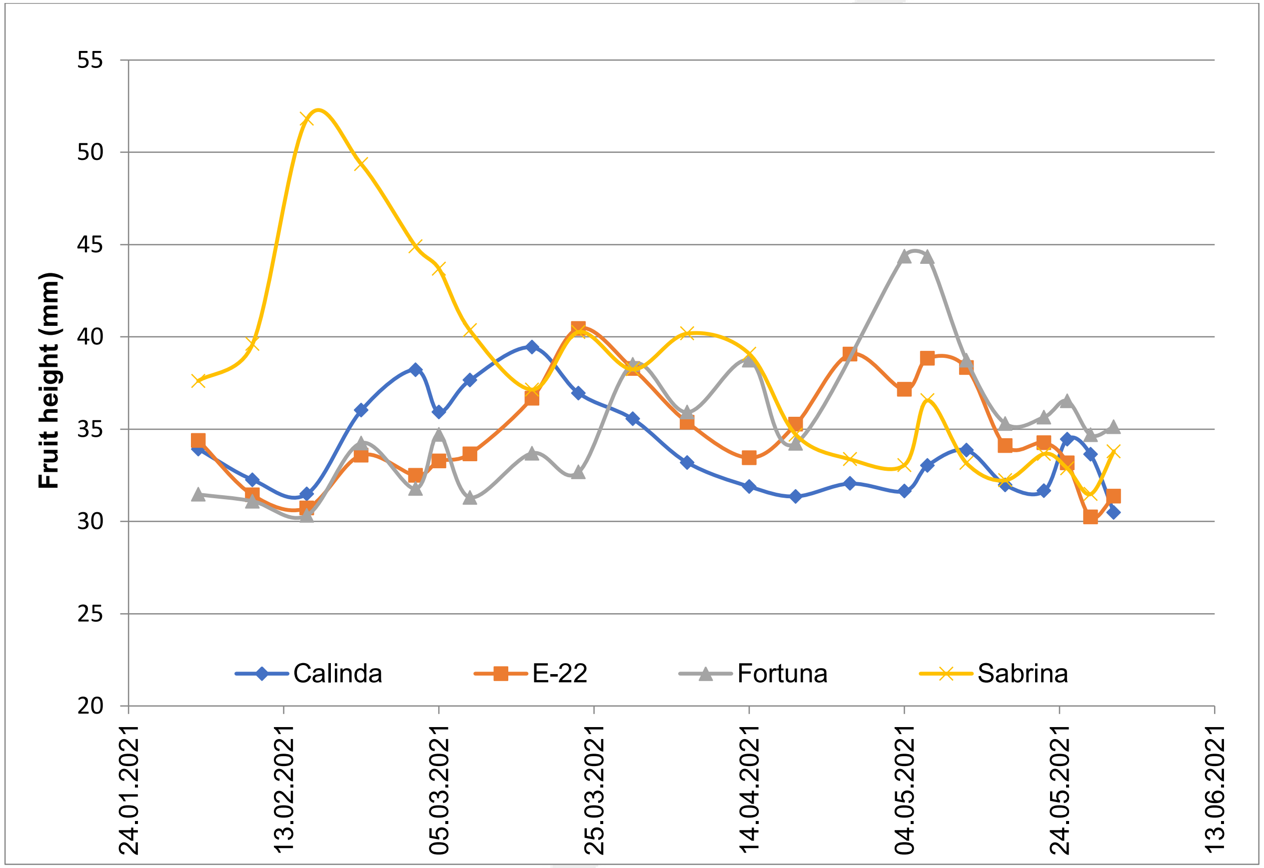

Figure 4.2. The changes in the fruit width of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions during the 2021 growing season.

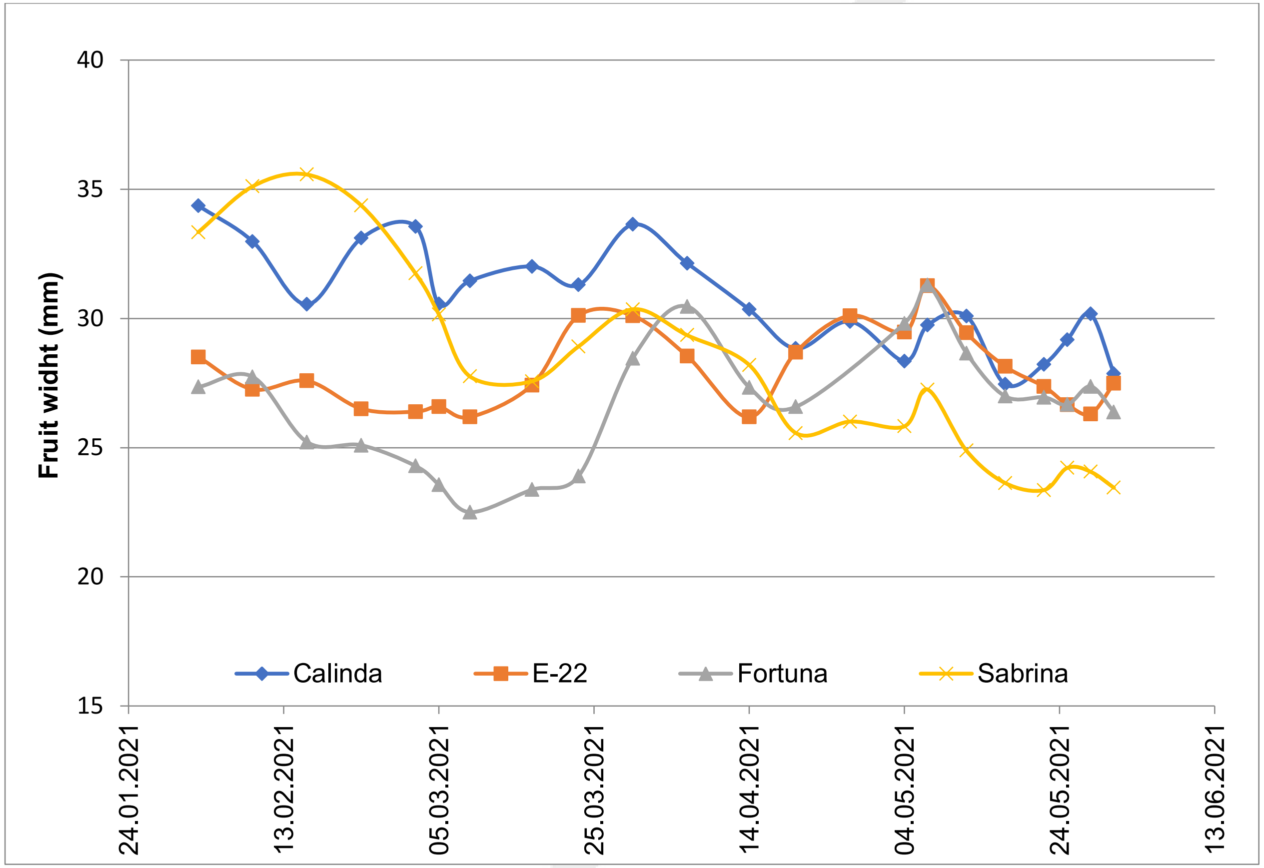

Figure 4.3. The changes in the fruit weight of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions during the 2021 growing season.

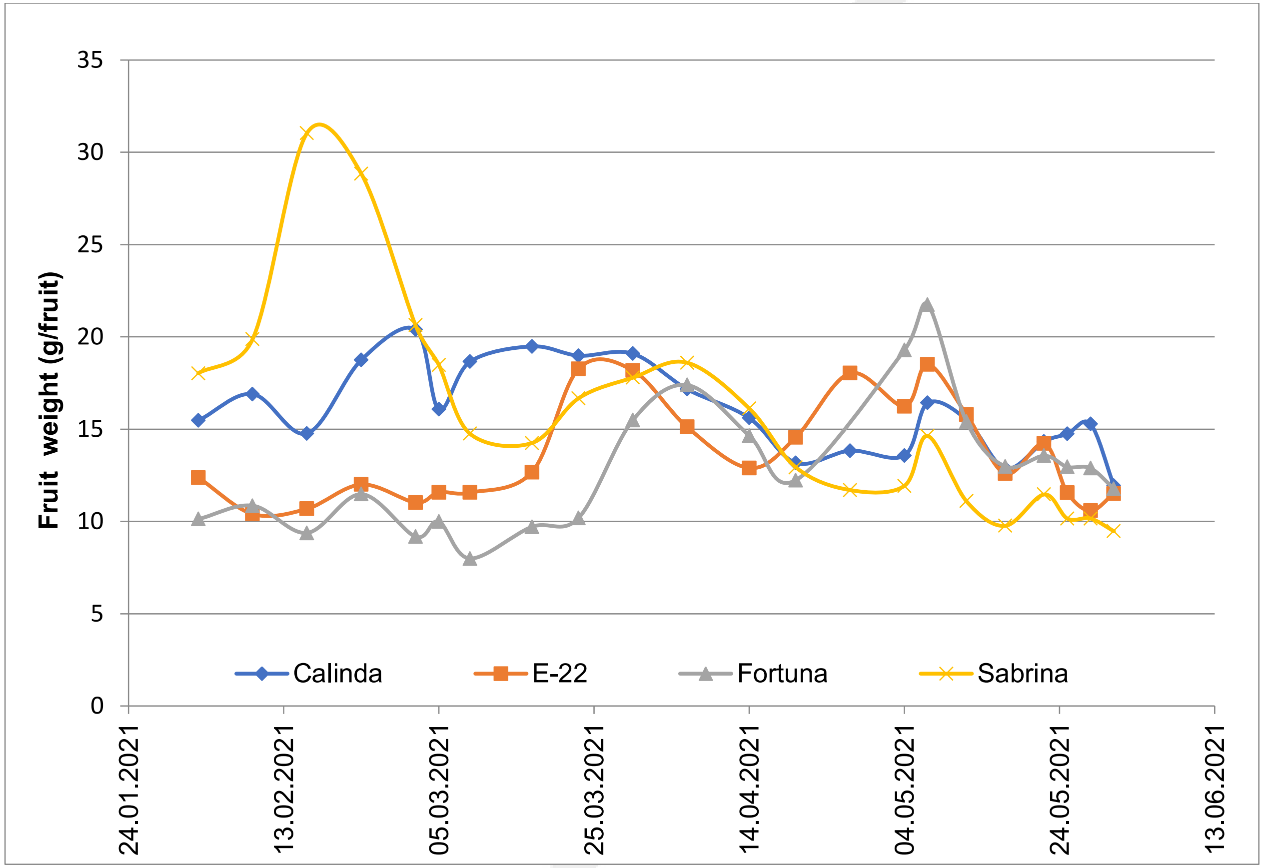

Figure 4.4. The changes in the fruit firmness of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions during the 2021 growing season.

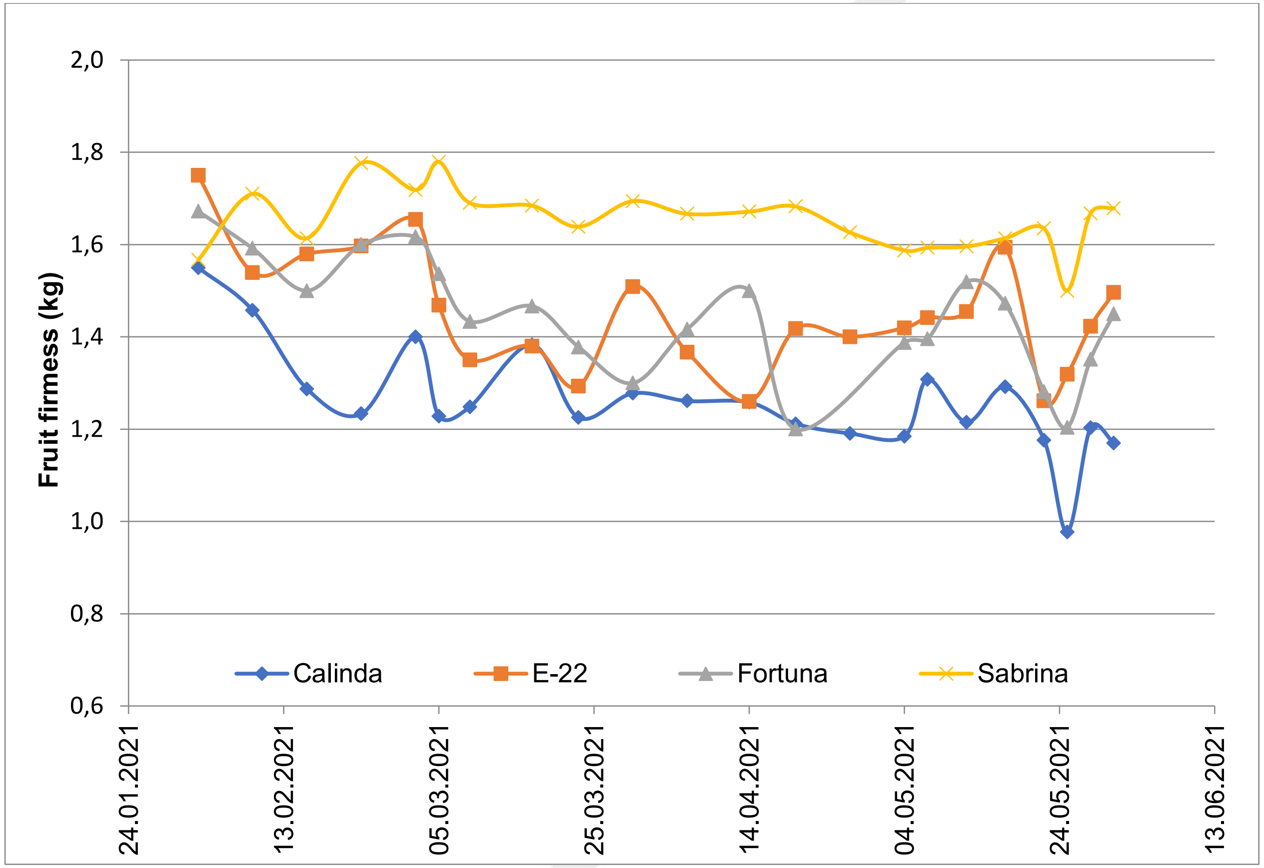

Figure 4.5. The changes in the soluble solids of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions during the 2021 growing season.

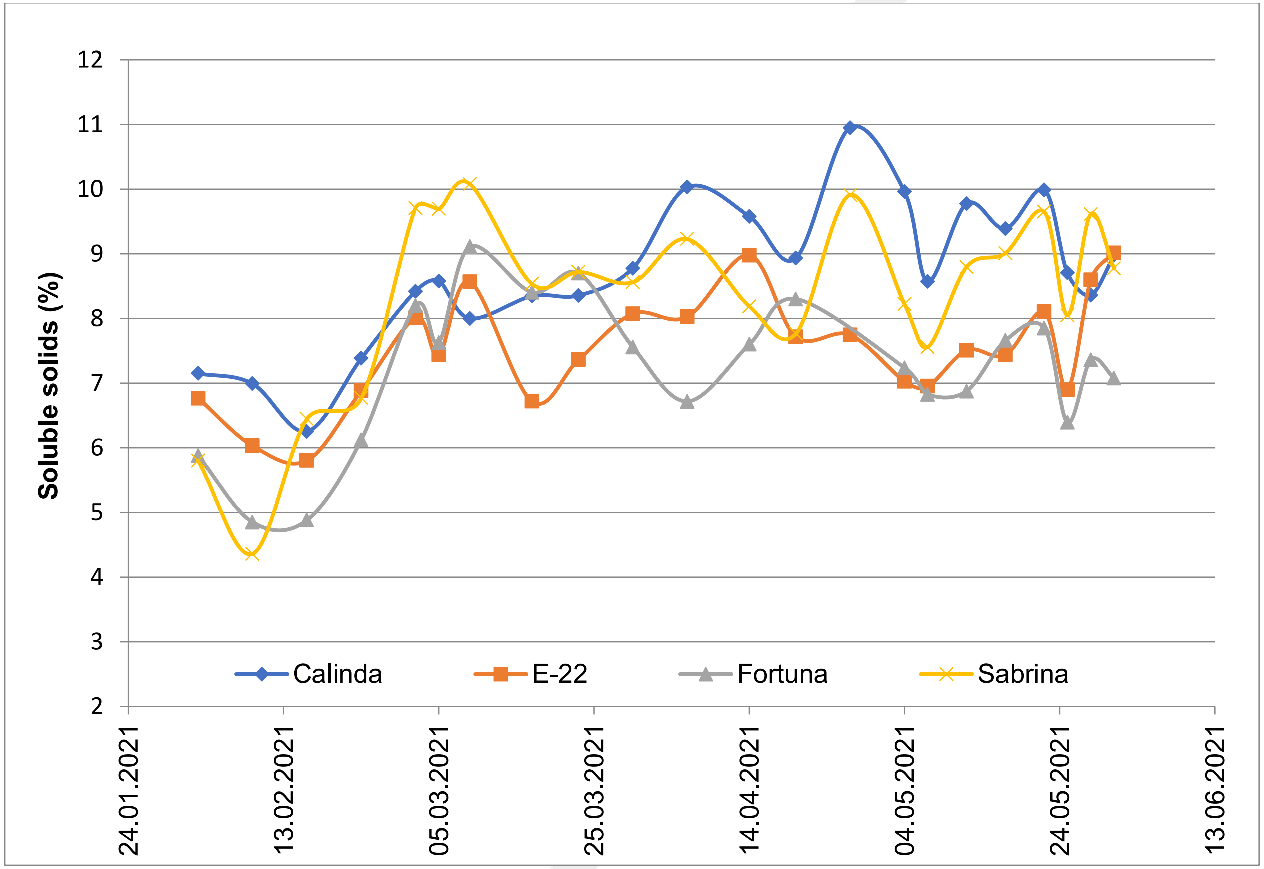

Table 4.3. The analysis of variance for acidity of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions.

Source	Degree of freedom	Sum of square	Mean Square	F value	P value
Treatment (T)	2	0.57	0.29	0.18	0.841
Cultivar (C)	3	3.41	1.14	0.70	0.562
T x C	6	12.55	2.09	1.28	0.302
Error	24	39.11	1.63		
Total	35	55.64			

Table 4.4. The mean values for fruit acidity of the strawberry cultivars treated with several lysophosphatidylethanolamine (LPE) treatments under greenhouse conditions.

Source	Acidity
Treatment	
T1	5.6
T2	5.9
T3	5.7
Cultivar	
Calinda	6.0
E-22	5.5
Fortuna	5.3
Sabrina	6.1
Overall	5.7

CHAPTER V

DISCUSSION

An understanding of how plants grow is not only a challenge to many people but also for scientist especially those in the applied biology field. Plant growth regulators have played a very important role in this modern generation (Roberts, 2012). Scientist came up with an idea on how to develop and improve the problems of fruits and vegetables especially perishables crops. Many crops have very short shelf life and consumers need them fresh and of good quality. An environmentally friendly tactic to resolve this issue is application of edible films and coverings of agricultural products (Ashraf et al., 2021). Phosphatidylethanolamine is a membrane phospholipid that has two fatty acids acyl chains and an ethanolamine head group. Phospholipids are found in biological membranes but their concentration changes when plants are exposed to freezing (Lee et al., 1997; Scherer, 2002). Plant growth regulators are used to enhance the growth and development of plants. Plant growth regulators like lysophosphatidylethanolamine (LPE) have been used in pre and postharvest submissions to accomplish variety of goals. These regulators can enhance the growth and development of several crops. LPE is a plant growth regulator that have been used to improve the quality of cranberry and many other fruit species (Özgen and Palta, 1999).

Lysophosphatidylethanolamine is a naturally occurring lipid with regulatory effects in senescence and ripening. The nature of LPE, is a chemical compound coming from the partial synthesis of phosphatidylethanolamine (AKM et al., 2017). It is natural and does not cause any residual problems in application. LPE is commercially derived from egg and soy lecithin (Cui et al., 2012). LPE plays a role in cell-mediated cell signaling and activation of other enzymes, speeds up ripening, prolongs the shelf life of the tomato fruit, retard senescence in attached and detach leaves and fruits. Moreover, LPE restrained the activity of phospholipase D, a membrane degrading enzyme, whose activity increases during senescence (Selvy et al., 2011). Furthermore, the result from our study shows that LPE impacts on fruit ripening, guards against senescence and delays fruits and leaves senescence as well as mitigating against stress of ethylene-induction. In addition, studies conducted on tomatoes, peppers, grapes, cranberry, and oranges using LPE increased the color, sugar content of the fruits and the shelf life of these species (AKM et al., 2017).

Nowadays, LPE are used in many plant commodities such as banana fruit, cranberries, tomato, red pepper, cut flowers, persimmon, potato, radish, apple, grapes and even strawberry. The effect of LPE is varied, depending on the processes of harvesting, growing and planting (Hong et al., 2007). Due to the treatment of banana fruit with LPE, the ethylene production decreased, firmness loss was also delayed, decreased ion and protein leakage was as well observed. It also extended the shelf life, increased the fruit diameter, lowered the respiration rate and delayed senescence (Ahmed and Palta, 2011a; Workmaster and Palta, 1996). Moreover, cranberry fruits increased in anthocynin content, uniformity in the fruit color, increased fruit set and improved the fruit firmness (Özgen and Palta 2003). In radish there was no effect on acid invertase activity, glucose and sucrose level but there is an increased-on PAL and insoluble acid invertase (Hong et al., 2009). In addition, red pepper saw an increase in ripened fruit yield and the mitigation of ethephon-induced foliage injury (Kang et al., 2003). In some study for tomato, there was a reduction in firmness loss, reduced the foliar injury by ethephon, lowered the PLD activity and including the polygalactronase activity inhibation (Özgen et al., 2000). Furthermore, the improved postharvest fruit firmness of the apple and color uniformity, increased fruit peel anthocynin content, simulated ethylene production and no effect on respiration rate. This was the case when apple was treated with LPE (Farag and Palta, 1991).

According to the study conducted by Çeler et. al 2019 it was found out that applied LPE on strawberry skin gave an outstanding impact which prolonged the product life. Due to the natural process of LPE there was no residual waste. In fact, LPE treatments have no impact on the weight loss that normally observed in fruits which can vary between 1.2- 4.7% depending on the application process and time length of storage. However, LPE application did not show any effect on the total phenolic content of strawberries. On the other hand, the exposure to direct light, sunlight, dry length, skin time growth, and weight loss were found to be very low, LPE applications increased the antioxidant capacity when compared to the control and increased the protection of the strawberry fruit.

The current research was conducted in Niğde Omer Halisdemir University to determine the effect of LPE on ripping stages of different strawberry cultivars. Turkey's one-way ANOVA was performed to check the significance of these cultivars. The results revealed that no effect of LPE on different strawberry cultivars. The result varies from literature maybe due to environmental impact, stage of ripening, species of strawberries or methodologies we used in this experiment.

CHAPTER VI

CONCLUSION

Strawberries are high value crop which can be grown on many different areas in the World. Strawberry culture is considered as a high value crop which can be grown in several constructing systems. LPE effect has been demonstrated in several horticultural crop species including apple, cherry, peach, grape, persimmon, cranberry and several cut flowers. LPE effect on these crops was apparent in elevated quality characteristics.

LPE has been experimented in open-field strawberry production with inconclusive results previously. In this study, four short day cultivars with low chilling requirements were grown in a heated greenhouse and exposed to two LPE treatments where LPE has been applied either week or two-week basis along with an untreated control. The fruits were harvested at their maturity and several quality characteristics during the production period. The results exhibited that LPE application did not affect the quality characteristics on these short their cultivars when they were grown on a controlled scheme. The effects of harvest date, cultivar and their interactions were found to be significant for both characteristics.

In other horticultural crop species where LPE had an effect on yield and/or quality characteristics, the mode of action was mitigation of the stress factors which crop species experienced during the production. It is possible that LPE has no effect in fruit quality characteristics especially when the strawberries are grown under greenhouse conditions where they experience no or little environmental stress. Not having any stress factor or having a little amount of stress may prevent the action of LPE on these short day strawberry cultivars. In conclusion, it was concluded that LPE effect on strawberry culture under greenhouse conditions aiming for early production are complex.

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