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The effects of Ortho Silicon (Optysil) and *Ascophyllum nodosum* Based Seaweed Extract (KelpGreen) Applications on the Quality of Table Grape cvs. Gök Üzüm and Müşküle

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ABSTRACT

Table grapes are one of the most consumed non-climacteric fruits globally, and practices for their quality are socioeconomically important. In this study, the effects of the combined and separate applications of two plant activators Ortho Silicon (Si, Optysil, 0.5 mL L^{-1}) and *Ascophyllum nodosum*-based seaweed extract (ANE, KelpGreen 2.5 ml L^{-1}) were tested by two applications after fruit set 15 days intervals to table grapes cvs. Gök Üzüm and Müşküle in a producer vineyard at Hadim town of Konya province in middle Anatolia 37°2'15"N 32°34'53" E, 1060 m above sea level. The effects of the applications on ripening, cluster and berry characteristics and post harvest shelf life during 10 days of storage at room conditions were analyzed. Both plant activators provided an increase in cluster size and an improvement in ripening. Si+ANE was more effective on the maturation and quality retention during the post-harvest shelf-life period. All applications provided reduction in weight loss (WL), decay rate and berry dullness, and it reduced berry separation force due to the drying of the peduncle and decreased the maturity index (MI) increase in the post harvest period. Thus, it contributed to the formation and retention of fruit quality. According to the data obtained from this study, improvements in the sustainable preservation of table grape quality can be achieved by applying Ortho Silicon and *A. nodosum* based seaweed extract separately and together between after fruit set and before veraison.

1. Introduction

Table grapes are one of the most consumed non-climacteric fruits worldwide. Table grape is a fruit with a relatively low physiological activity rate, which does not ripen further after harvest. Its quality depends on different attributes related to appearance, colour, texture, flavour, and aroma. "Veraison" begins with maturation, accumulation of sugars, softening of berries, synthesis of anthocyanin, metabolism of organic acids and accumulation of aroma compounds. Soluble solids content (°Brix) and sugar/acid ratios are primary indicators of table grape quality and are minimum requirements for each variety. Table grape flavour is a complex and important quality characteristic as it is a mixture of hundreds of different volatile compounds synthesized during ripening. After harvest, table grapes deteriorate rather quickly, as they are exposed to significant WL because of the drying of the stem and the peduncle, causing browning, WL, and berry softening. In addition, rot by *Botrytis cinerea* also causes large losses, limiting conservation (Palou et al., 2010). Many internal factors such as the structure and consistency of the kernel and fruit flesh, and the ripening rate, as well as external factors such as temperature and relative humidity, are effective in maintaining quality.

Consumers' high preference for table grapes is due to their excellent organoleptic and nutritional qualities, and consumption has increased significantly in recent years. According to 2019 data from the International Vine and Wine Organization (OIV), about 36% of total grape production is for fresh consumption, with China being the largest consumer, followed by India and the European Union (EU). Table grape production has doubled in the last two decades. According to USDA data, world production for 2019/20 is estimated to be around 23.4 million tons (Romero et al., 2020). Turkey supplies 51% of approximately 3.7 million tons of grape production to the local and global markets as table grapes (TÜİK, 2022).

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Silicon is a beneficial element for higher plants, as its effects are often linked to morphological, physiological, and molecular aspects of plants (Ma et al., 2004; Lobato et al., 2009). Silicon acts as a semi-essential element for plants because its deficiency can cause various abnormalities in the growth, reproduction, and general development of plants (Lobato et al., 2009). Silicon feeding to plants improves the plant protection mechanism against diseases and insects (Dallagnol et al., 2011; Guntzer et al., 2012; Liu et al., 2014). Exogenous silicon application protected against UV-B stress by stimulating the antioxidant defense system of soybean, wheat, and corn seedlings (Tripathi et al., 2017), accelerated plant ripening (Matichenkov, 1990), increased growth in citrus fruits by 30 to 80%, increased fruit ripening. It accelerated by 2-4 weeks and increased yield (Taranovskaia, 1939) and °Brix (Matichenkov et al., 2001). Silica nanoparticles provided protection by reducing oxidative stress in pea seedlings, and the activities of enzymes such as superoxide dismutase and ascorbate peroxidase increased significantly with silica nanoparticles (Tripathi et al., 2015). It has been determined that silicon can replace phosphate in DNA and RNA molecules and increase the stability of these molecules (Snyder et al., 2016). Silicon increased the chlorophyll density in the leaf (Adatia and Besford, 1986), thus allowing the plant to use light more efficiently and to tolerate low or high light levels. Higher soluble silicon causes higher concentrations of the enzyme ribulose biphosphate carboxylase to be produced in leaf tissue (Adatia and Besford 1986). By regulating CO_2 metabolism, this enzyme supports plants to use CO_2 more efficiently.

Seaweeds are macroalgae that fit in the class Phaeophyceae and are best known as brown algae. They are mainly composed of polysaccharides such as laminarin, fucoidan and alginate. Many seaweed-based products are known to be beneficial for humans and plants. Seaweed extracts contain various bioactive compounds. Such bioactive compounds induce resistance in plants to different biotic and abiotic stresses. Seaweed extracts may also contain numerous plant bioactive inorganic and organic compounds such as mannitol, polysaccharides, oligosaccharides, phytohormones (auxins, cytokinins, gibberellins, betaine), antioxidants and vitamins. It also contains a low concentration of minerals (calcium, boron, zinc, potassium, phosphorus, magnesium, and some other trace elements). Seaweed extract can promote plant growth and increase the rate of photosynthesis. Seaweed extracts increased seed germination rates, crop growth, yield, and product shelf life. It can reduce the effect of diseases due to fungal, viral, and bacterial pathogens (Singh et al., 2021).

A bio stimulant can be defined as any beneficial microorganism or any organic substance that can increase plant growth, increase nutrient uptake, increase tolerance to abiotic and biotic stress, and increase crop yield. Bio stimulants have been obtained from seaweeds, bacteria, higher plants, fungi, humic acid, and other industrially processed materials according to their source. Phaeophycean seaweed, also known as brown seaweed, is the largest group with 2000 species. Their maximum biomass is found on the rocky coasts of the temperate zone of different countries. Products based on the brown seaweed *Ascophyllum nodosum* (L.) are mostly used in agriculture (Blunden and Gordon, 1986). Increased resistance to stress, improved crop yield, early germination of seeds, etc. There are numerous reports on the role of seaweed-based bio stimulants for crop protection and crop production (Beckett and Van Staden, 1989; Hankins and Hockey, 1990; Norrie and Keathley, 2005). Polysaccharide-rich extracts of seaweed have been shown to have an enhancing effect on plant growth (Hernández Herrera et al., 2016). Such activity of the extracts suggested the role of oligosaccharides as signalling molecules for the regulation of phytohormone-related genes in treated plants. However, polysaccharide-rich extracts that promote root growth in mung bean plants also demonstrated the presence of synthetic hormones in the core. A recent report suggested the role of *Ascophyllum nodosum* extract (ANE) in reducing mycotoxin production in wheat plants infected with Fusarium head blight (Gunupuru et al., 2019).

Emerging formulations based on ANE can improve plant growth as well as increase tolerance to abiotic stresses including heat, drought, and salinity. Several plant metabolic pathways are targeted by seaweed extracts to improve plant growth and tolerance to abiotic stresses (Craigie, 2011). Currently, more than 50 companies around the world produce seaweed extracts to stimulate plant growth, and these seaweed extracts are based on different types of seaweed found in the sea. ANE are the products that attract the most attention (Sharma et al., 2014). Several plant species have shown growth promotion under application of seaweed extract, but the mechanism behind such activity has not been very well studied (Battacharyya et al., 2015). Application of seaweed extracts increased seedling growth of lettuce (*Lactuca sativa* L.) (Moller and Smith, 1998). ANE formulation has been reported to increase growth and K^+ accumulation in almond plants (Prunus dulcis). Commercial products Grozyme and Megafol showed a similar effect on foliar application and stimulated plant growth (Saa et al., 2015).

In this study, the effects of pure and combined applications of Ortho Silicon and Seaweed extract (ANE) on product quality shelf life of table grapes cvs. Gök Üzüm and Müşküle were investigated.

2. Materials and Methods

In this study, table grape cvs. Gök Üzüm and Müşküle (*Vitis vinifera* L.) were used in producer vineyards in Hadim town of Konya province in middle Anatolia 37°2'15"N 32°34'53" E, 1060 m above sea level. After fruit set 15 days intervals Ortho Silicone (0.5 ml L^{-1}) and Seaweed extract (2.5 ml L^{-1}) were pulverized (Uwakiem, 2015) on vines. The samples were harvested in late (23rd) September as the normal commercial harvest time. The alternations of some quality parameters such as MI (°Brix % / Titratable acidity g L^{-1}), WL (%), Skin rupture force (N), Berry detachment force (N), Berry brightness (Hue, h°, by using a cR- 400 chromometer, Konica Minolta, Japan), and Decay rate (%) were monitored 3 days interval for 10 days.

The study was designed as completely randomized blocks, Ortho Silicone and Seaweed extract effects were compared in SPSS 17.0 statistical program (SPSS Inc, Chicago, IL, USA) Duncan multiple comparison test, the applications JMP 7 statistical programs with Student's t test at $p< 0.05$ significance level.

3. Results and Discussion

The effects of the applications were evaluated as the effects on the product quality determined at the harvest and the effects on the shelf life monitored by keeping it in room conditions for 10 days after harvest.

3.1. Quality Parameters

The effects of seaweed, silicon, and seaweed+silicone applications on cvs. Gök Üzüm and Müşküle on cluster characteristics were significant. In both cultivars, the lowest cluster length and width were determined in the control, while the applications increased the cluster length and width. The effects of individual applications of silicon and seaweed were in the same statical group in both grape cultivars. The longest and widest clusters were obtained from seaweed+silicone treatment (Table 1). Berry length and width were also affected by the treatments like the cluster. The lowest values were recorded in the control in both cultivars, while the highest values were recorded from seaweed+silicone combined applications. On the other hand, the effects of applications on berry density were insignificant (Table 1).

Table 1
Cluster and berry characteristics

Cultivars	Application	Cluster length	Cluster width	Berry length	Berry width	Berry density
Gök Üzüm	Control	20.96±0.62 b	13.38±0.70 b	14.57±0.14 b	16.16±0.10 c	1.05±0.04
	Seaweed	21.25±0.43 b	13.79±0.65 b	15.69±0.50 a	17.20±0.68 b	1.06±0.03
	Silicone	21.67±0.31 b	14.46±0.59 ab	15.57±0.47 a	17.11±0.46 bc	1.05±0.04
	Seaweed+Silicone	22.79±0.44 a	15.38±0.82 a	16.02±0.43 a	18.19±0.63 a	1.06±0.02
	LSD≤.05	1.04	1.48	0.78	0.85	ns
Müşküle	Control	18.50±0.50 c	9.29±0.64 b	19.95±0.12 b	21.47±0.52 b	1.03±0.02
	Seaweed	19.88±0.45 b	9.92±0.26 b	20.21±0.10 b	21.97±0.33 b	1.05±0.06
	Silicone	19.83±0.51 b	9.96±0.58 b	20.30±0.41 ab	22.15±0.10 b	1.05±0.01
	Seaweed+Silicone	20.83±0.19 a	10.88±0.25 a	20.81±0.34 a	22.98±0.30 a	1.05±0.02
	LSD≤.05	0.97	0.95	0.46	0.58	ns

The effects of the applications of Ortho Silicone cvs. Gök Üzüm and Müşküle on the juice yield were significant. While the lowest must yield was detected in seaweed application to cv. Gök Üzüm, the highest yield was in control (Table 2). In cv. Müşküle, the lowest juice yield was recorded in seaweed+silicone application, while the highest yield was recorded in silicon application (Table 2). Differential effects of cultivars on seaweed, silicon, and seaweed+silicone treatments were attributed to genotypic response difference.

Table 2
Effects on berry composition

Cultivars	Application	Must yield	Maturity index	°Brix	Ph
Gök Üzüm	Control	74.43±3.59 a	7.05±0.35 b	19.93±0.55 c	3.56±0.04 c
	Seaweed	57.20±7.98 b	7.54±0.96 ab	20.97±0.46 b	3.76±0.01 ab
	Silicone	71.50±7.48 a	8.01±0.25 ab	22.00±0.20 a	3.73±0.03 b
	Seaweed+Silicone	62.47±8.61 ab	8.19±0.39 a	22.30±0.17 a	3.79±0.01 a
	LSD≤.05	12.24	1.27	0.51	0.03
Müşküle	Control	70.48±2.36 b	8.36±0.44 b	20.50±0.30	3.97±0.04 ab
	Seaweed	64.37±5.77 bc	8.89±0.53 ab	21.07±0.40	3.97±0.02 ab
	Silicone	79.80±2.28 a	9.82±0.82 a	21.20±0.56	3.88±0.01 b
	Seaweed+Silicone	60.94±5.06 c	10.08±0.67 a	21.37±0.55	4.02±0.12 a
	LSD≤.05	8.37	1.42	ns	0.13

MI was also significantly affected by the treatments in both cultivars. The greatest effect, in other words, the acceleration of ripening was recorded in seaweed+silicone application in both cultivars. The effects on °Brix were insignificant in cv. Müşküle, but significant in cv. Gök Üzüm. The highest must pH value was recorded in Si+ANE application in both grape varieties.

3.2. Weight Loss

As a result of the silicon, seaweed, and Si+ANE treatments applied to the cv. Gök Üzüm, the lowest weight losses on the 3rd, 7th and 10th days were determined in the Si+ANE application (2.52±0.11%, 3.79±0.17% and 6.31±0.28%). The highest WL were found in the control (3.60±0.82%, 7.74±0.28%, and 12.35±1.19%) (Figure 1a). WL increased as the waiting time increased after harvest. The WL of cv. Müşküle was less than that of cv. Gök Üzüm in all treatments. The lowest WL was Si+ANE (0.46±0.43%, 1.83±0.69% and 4.17±0.20%) in the three analysis periods, 3rd, 7th, and 10th determined in the application. The highest WL in this period was observed in the control (2.98±0.71%, 5.34±0.28% and 9.47±0.86%) (Figure 1b). All the applications made contributed to the extension of the postharvest life by reducing the WL in both grape cultivars. The effect of the applications made on the cv. Müşküle on WL was positive compared to the cv. Gök Üzüm and less WL was observed.

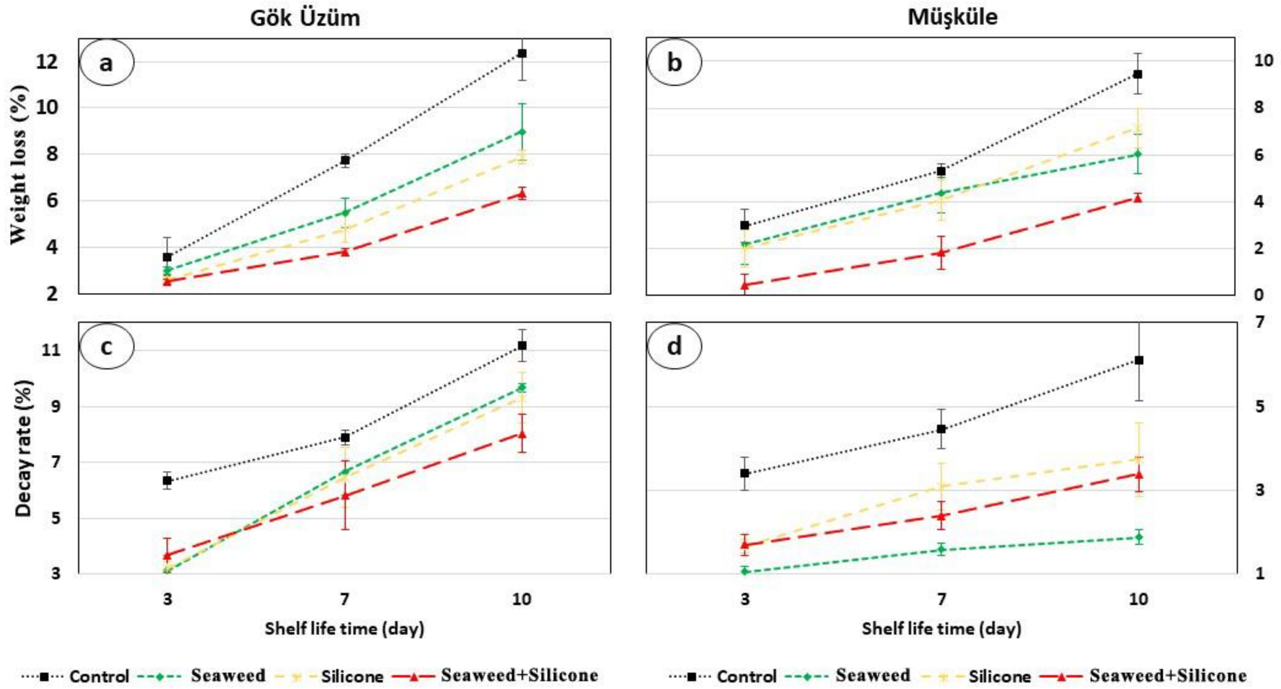

Figure 1
Effects of WL (a and b) and decay rates (c and d)

WL occurred at varying rates in the postharvest process of table grapes, depending on the various factors mentioned (Serrano et al., 2005). Different applications and new developments that have the effect of reducing WL results have shed light on today's modern preservation techniques. Like the results of some previous studies (Serrano et al., 2005; Valero et al., 2006), our different practices in this study were effective in reducing WL. ANE application increased the isopropanol fraction in vines (*Vitis vinifera* L.) and water potential and stomatal conductivity in K^+ and Ca_2^+ flows under drought stress (Mancuso et al., 2006). With the accumulation of K+, ionic and osmotic stresses can be overcome. Application of ANE increased water use efficiency under drought stress in the orange tree *Citrus sinensis* (Spann and Little, 2011). The use of ANE in vineyards with irregular irrigation may be a useful application by increasing water use efficiency in drought stress.

3.3. Decay Rate

The effect of the applications on the decay rate in cv. Gök Üzüm was highest in the control (6.34±0.30%, 7.90±0.26% and 11.16±0.57%) at the end of the 3rd, 7th, and 10th days, while the lowest decay was in the seaweed on the 3rd day (3.14±0.53%), and on the 7th and 10th days, Si+ANE (5.81±1.23% and 8.04±0.67%) was applied (Figure 1c). In cv. Müşküle, the highest decay rates were determined in the control (3.40±0.39%, 4.46±0.46% and 6.11±0.97%) during the post-harvest period, while the lowest decay was obtained by seaweed (1.07±0.12%, 1.58±0.15% and 1.89±0.17%), (Figure 1d). All applications were more effective in the cv. Müşküle and reduced rot in both cultivars.

Plant diseases pose a great threat to agricultural production and cause serious crop yield and quality loss worldwide (Etesami and Alikhani, 2017). The use of mineral nutrition to increase disease resistance in plants may be a practical alternative (Marschner, 1995). Silicon stands out among the minerals due to its effectiveness in reducing the severity of various plant diseases (Epstein, 1999). As a result of the emergence of serious physiological diseases and the reduction of quality and storage problems, the use of silicone has increasingly attracted people's attention. The use of silicon is known as one of the most environmentally friendly and sustainable ways to combat plant diseases and pests. It has been determined that silicon increases plant cell wall properties (Lux et al., 2002) and plant resistance against diseases (Fauteux et al., 2005).

Silicic acid polymerization within the apoplast creates an amorphous silica barrier and helps deter pathogen infection (Guerriero et al., 2016). Improved overall mechanical strength and an added outer layer of protection for plants explain many of the reported benefits in crop quality and yield after silicon fertilization. Successful infection enters the host plant by overcoming physical barriers of plant pathogens such as the waxy layer, cuticle, and cell walls. Physical barrier formation is a mechanism to control plant diseases (Kim et al., 2002), and make plant cells more vulnerable to fungal pathogen invasion and subsequent enzymatic degradation (Fauteux et al., 2005). Silicon supports plant growth by forming an outer protective layer and increasing the mechanical strength of plants. Silicon is typically cross-linked to hemicellulose, which improves the mechanical properties and regeneration of cell walls (Guerriero et al 2016). Silicon plays a role in cell wall stiffness and reinforcement and helps increase elasticity during elongation (Marschner, 2012). In primary cell walls, silicon interacts with cell wall components such as polyphenols and pectins, contributing to increased flexibility during longitudinal growth (Fauteux et al 2005; Liang et al 2015a). Well fed plants are known to be more resistant to diseases. Another mechanism by which silicon increases resistance to plant diseases is that it affects plant mineral nutrition. It contributes to the uptake of silicon substances, can increase the concentration of essential nutrients in plants. The silicate anion competes for adsorption sites in the soil, increasing the availability of sulfate, nitrate and phosphate in the soil and the ability of plants to retain these anions (Pozza et al., 2015). Marschner (1988) reported that macronutrient and micronutrient imbalances affect the growth power of plants, defense responses and affect the host's susceptibility to diseases. They can work directly on secondary metabolic pathways where cell wall defense system expansion and formation of fungistatic phenolic compounds occur by increasing mid lamella resistance or by creating physical and chemical barriers as in calcium conditions.

Climate changes and unscientific agricultural practices directly affect agricultural products negatively by weakening the defence system in plants and causing diseases (Anderson et al., 2004; Ayliffe and Lagudah., 2004). Plant diseases directly damage productivity. To prevent disease infection, plants have developed inducible defence processes (Conrath et al., 2002; Wiesel et al., 2014). Two types of disease defence mechanisms have been identified, namely induced systemic resistance (ISR) and systemic acquired resistance (SAR). To protect plants from a variety of pathogens, ISR mediates defence responses to jasmonate (JA) and ethylene (ET), while salicylic acid (SA) is important for PR (pathogenesis-related) gene activation for SAR mechanisms (Gaffney et al., 1993; Van Loon et al., 1998). In plants, elicitor molecules from pathogens are responsible for stimulating the defence system (Conrath et al., 2002; Wiesel et al., 2014). Not only chitin, lipopolysaccharides, and flagella of microbes, but also some chemically synthesized components such as 2,6-dichloro isonicotinic acid, b-aminobutyric acid, chitosan, benzothiadiazole and methyl jasmonate can induce SAR/ISR mechanisms against a wide variety of pathogens (Dixon, 2001; Mercier et al, 2001; Bektas and Eulgem, 2015; Iriti and Varoni, 2015). Different seaweeds have equipped themselves with important defence mechanisms to protect themselves from their pathogens (Potin et al., 1999; Shukla et al., 2016). In seaweeds, they show resistance to a wide variety of pathogens, with some important bioactive components such as carrageenans, fucans, ulvans, and fucose-containing polymers (or laminarins) (Klarzynski et al., 2003; Sangha et al., 2010). These bioactive components of seaweed work as elicitor molecules and play a role in stimulating defence mechanisms against pathogens (Khan et al., 2009; Sharma et al., 2014; Shukla et al 2016). These elicitors can act as pathogen-associated molecular models (PAMPs) (Sharma et al., 2014). PAMPs bind to host pattern recognition receptors (PRRs), which are transmembrane proteins, and protect plants by inducing the defence mechanisms ISR and SAR through a systemic signal (Eckardt, 2008; Zipfel, 2009). Plants treated with *A. nodosum* extract (ANE) showed a higher defence response than control plants during pathogen infections. ANE bioactive components induce defensive responses against different pathogens (Patier et al., 1995; Sharma et al., 2014). ANE induced defence against *Phytophthora melonis* in cucumber plants (Abkhoo and Sabbagh, 2016). ANE induced the activation of some important disease resistance enzymes such as polyphenol oxidase (PPO), peroxidase (PO), phenylalanine ammonia-lyase (PAL), lipoxygenase and β 1,3-glucanase (Abkhoo and Sabbagh 2016). Panjehkeh and Abkhoo, (2016), determined that ANE can induce resistance (ISR) against *Phytophthora capsici* in tomato. In cucumber, ANE has been shown to reduce the ability of fungal pathogens to cause disease by inducing certain defence genes and enzymes (Jayaraman et al., 2011), JANE induces plant immunity by increasing the concentration of ROS through hydrogen peroxide synthesis (Cook et al., 2018). *A. thaliana* plants treated with 1 g/L ANE showed resistance to the necrotic fungal pathogen *Sclerotinia sclerotiorum* (Subramanian et al., 2011). In carrots, ANE induced defence-related enzymes (Mukherjee and Patel, 2020) and prevented disease development of *A. radicina* and *B. cinerea* (Jayaraj et al., 2008).

In previous studies, the effectiveness of silicon and ANE applications with different mechanisms has been reported. In this study, the application of the two products separately and together positively affected the quality and post-harvest shelf life of the harvested table grapes.

3.4. Berry Detachment Force

Applications to cv. Gök Üzüm increased the berry detachment force of the stem. The lowest stem breaking resistances were determined in the control (2.25±0.12, 1.79±0.03, 1.26±0.14 and 1.12±0.10) at harvest (0th day), 3rd, 7th, and 10th days. The highest values in seaweed application (3.94±0.03) at harvest (0th day), silicon application (2.75±0.24 and 1.86±0.13) on 3rd and 7th days, and Si+ANE application (1.54±0.16) on 10th day determined (Figure 2a). In the applications made to cv. Müşküle, the lowest stem rupture resistance was found in the control (5.03±0.34, 4.15±0.30, 3.08±0.16, 2.92±0.11), while the highest values were found in the Si+ANE application on the 0th, and 7th days (6.82±0.36, 4.63±0.37) and Si+ANE (5.07±0.14, 3.65±0.19) applications on the 3rd, and 10th days. Applications of both cultivars increased stem breaking strength (Figure 2b). As the waiting time increased after harvest, the stem breaking resistance decreased in all applications and varieties.

3.5. Skin Rupture Force

All applications increased the skin rupture resistance of cv. Gök Üzüm, while the increases were more limited in cv. Müşküle. The lowest skin rupture strength was found in the control (1.72±0.09, 1.38±0.15, 1.35±0.06, 1.16±0.10) in all analyses, and the highest rupture strength was found in the silicone application (2.09±0.18, 2.03±0.11, 1.78±0.18, 1.59±0.10) (Fig. 2c). In cv. Müşküle, the lowest skin rupture resistance was recorded in the control (2.55±0.21, 2.04±0.24, 1.52±0.08) on the 0th, 3rd, and 10th days, and in the silicone application (1.72±0.06) on the 7th day. The highest skin rupture resistance was determined in the 0th, and 3rd days of Si+ANE application (2.79±0.13, 2.27±0.16) and the 7th and 10th days of the seaweed application (2.11±0.06, 1.84±0.11) (Figure 2d). As the waiting time after harvest increased, the skin rupture resistance of the samples taken from all applications decreased.

The berry skin rupture varies according to cultivars. Skin thickness, berry skin rupture and extracted anthocyanin rate have a significant regression (Segade et al., 2008). Previous studies the hardness of fruit at the end of storage period dropped slightly in all applications (Letaief et al 2008) and this decline over time pectin polymers have been reported to be associated with fragmentation (Pretel et al., 2006).

Previous studies have shown that since silicon improves photosynthesis by promoting leaf chlorophyll content, preventing decay and premature aging, promoting growth and development, regulating the absorption of potassium, nitrogen, phosphorus, and micronutrients, effectively preventing cracking, premature defoliation, and other physiological diseases, in leaves and fruits. It has been found to prevent moisture loss, increase fruit firmness, and improve storage and transportation (Jiangyu and Xuelong, 2005).

Optimal pre-harvest and post-harvest management practices ensure the preservation of fruit quality over longer storage periods and increase consumer confidence (Tesfay et al., 2011). Silicon can increase the amount of free phenol. In other words, silicon acts as the main elicitor in increasing free polyphenol levels. Silicon applications in avocado increased fruit quality by increasing free phenol accumulation in mesocarp. Silicon may be an important factor in improving postharvest fruit quality by increasing the free phenols released from the membrane bound form and consequently increasing the antioxidant pool in fruit (Tesfay et al 2011). Fruits treated with silicone lose less weight than control. Silicon probably contributes to retaining moisture in the fruit. Silicone applications reduce fruit respiration and WL by wrapping the fruit stomata with a silicone layer (Hammash and Assi 2007). Reduced activity levels of polyphenol oxidase limit mesocarp blackening of cut avocados (Bower and Dennison 2005). Decreased polyphenol oxidase activity causes leaching of membrane-bound phenols and acts as an antioxidant without oxidant interference to reduce browning. Silicon can reduce oxidant accumulation as it functions to bind cellular oxygen. Silicon is oxidized to form solid silicon dioxide, where a lattice is formed with a silicon atom surrounded by four oxygen atoms (Bekker et al 2007).

Hanumanthaiah et al. (2015), reported that foliar application of silicon at 15-day intervals it effectively improved quality parameters such as (26.67 °Brix), shelf life (6.33 days), skin/fruit ratio (7.44), acidity (0.26%), reducing sugar (19.93%) and non-reducing sugar (2.24). In addition, calcium silicate applications increased chlorophyll a and b and total chlorophyll levels in bananas (Putra et al., 2010).

Costa et al., (2015) identified an increase in diameter of mango trees treated with 1600 kg ha^{-1} of agrosilicone. More et al. (2015), stabilized silicic acid spray improved yield and quality in the early stages of fruit growth (before flowering and 15, 30, 45 and 60 days after flowering) in Alphonso mango (*Mangifera indica* L.). Silicon application improves endogenous levels of indole-3-acetic acid (IAA), gibberellins (GA) and cytokinins (CK) in mango trees, while abscisic acid (ABA), peroxidase (POX), catalase (CAT) and superoxide dismutase (SOD) enzymes levels (Helaly et al., 2017).

Silicon fertilization increased fruit size and quality in apples (Cai and Qian, 1995). Silicone applications can significantly increase the silicon content in apple leaves, fruit skin, flesh, and whole fruit. This situation favorably affects apple fruits, since silicon is the main component of the cell wall, it accumulates in the plant cell wall and root cortical cells, forming a layer of silica with host cells that acts as a barrier against pathogen invasion. Therefore, silicon plays an effective role in improving flesh firmness and pest resistance (Wang et al., 2016). Polygalacturonase (PG) is the predominant factor of cell wall and pectin degradation and is a key enzyme of various fruit softening processes. PG is an enzyme that can break down pectin; however, pectin plays a very important role in maintaining the indoor and outdoor environments and maintaining the firmness of fruit skins. In the apple storage process, a lower PG content better preserves apple quality and produces a longer storage period in apple trees treated with silicon fertilization (100 g/tree). The yield of trees treated with silicon decreased 19.7%. Silicon is the main component that maintains fruit firmness by tightening the cell wall structure. Therefore, a high amount of silicon fertilization can increase the cell wall's ability to defend against malondialdehyde (MDA) and PG activity, and subsequently prolong the storage time of the harvested apple. Gao et al., (2006), studied the effects of silicon applications on apple inner black necrosis (IBN) caused by high manganese levels, simultaneous administration of both silicon and manganese at 400 mg/kg effectively inhibited IBN development in Fuji apples. Su et al., (2011) showed that silicon can significantly reduce the titratable acid content of apple fruits grown in acidic soils, increase the contents of °Brix and vitamin C, but not affect the hardness.

In our study, skin rupture force decreased with the loss of water towards the end of the postharvest period. Due to the drying of pedicels, WL increased, and the skin rupture force decreased. In both varieties, our treatments gave better values than control. It shows that seaweed and silicate fertilization can effectively improve fruit quality and contribute to increasing yield and maintaining quality after harvest.

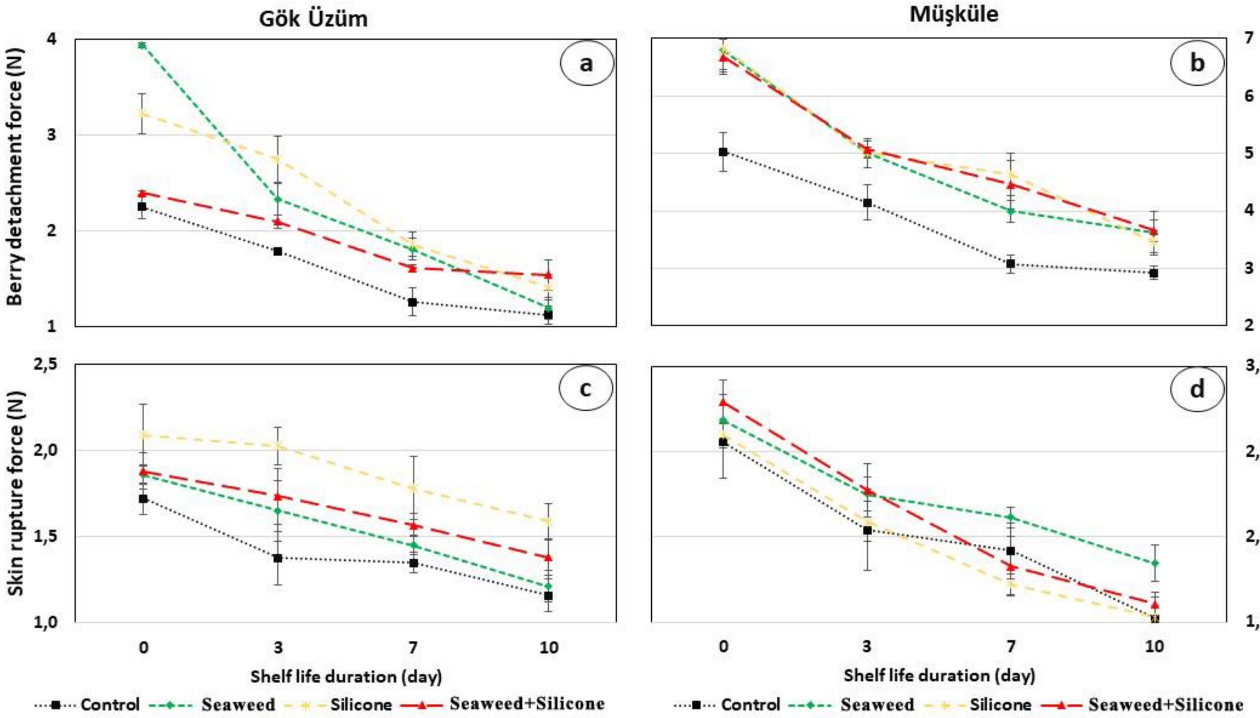

Figure 2
Effects on stem break (a and b) and shell tear resistance (c and d)

3.6. Berry Brightness (*Hue Value, h°*)

The lowest h° values in the applications made to the cv. Gök Üzüm were silicon application on the 0th day (124.39±7.23), the Si+ANE application on the 3rd day (121.87±2.01), and the seaweed application on the 7th and 10th days (110.68±6.31 and 08.66±4.33) was determined. The highest h° values were recorded in the control (133.07±3.29, 131.55±4.52, 120.59±4.88) on days 0th, 3rd, and 7th, and in Si+ANE application (116.68±7.47) on day 10th (Figure 3a). The lowest h° values in the cv. Müşküle were determined in seaweed (114.02±2.58, 105.05±7.57) days 0th, and 7th, control (108.40±0.45) on the 3rd day and silicon application (101.73±7.98) on the 10th day. The highest h° values were recorded in the Si+ANE application in the postharvest period. In general, our applications slowed down the decrease in the h° value in both varieties, in other words, the dulling of the berry colours.

The quality of grapes largely depends on skin colour. Skin colour often varies depending on anthocyanin content and composition (Carreño et al., 1995). Anthocyanin composition is determined primarily by anthocyanin accumulation due to genetic factors and various agroecological factors (diversity, climate, and cultural practices) (Cacho et al., 1992; Pomar et al., 2005; Segade et al., 2008). According to the findings of this study, the brightness value decreased as the post-harvest period was prolonged. As reported in previous studies, towards the end of the post-harvest period, the brightness value gradually decreases and the fruits become opaque (Artés-Hernández et al., 2004; Pretel et al., 2006).

3.7. Maturity Index

Seaweed, silicon, and Si+ANE applications to the cvs. Gök Üzüm and Müşküle increased the MI in the post-harvest period. The lowest MI values were 14.09±0.69, 15.09±1.92, 16.01±0.49 and 16.38±0.78 in the control group, respectively, while the highest values were 17.82±0.99, 20.85±0.67, 20.60±0.62, and 24.56±1.53 in Si+ANE application (Figure 3c). Cv. Müşküle was affected similarly to MI cv. Gök Üzüm. The lowest MI was found to be 16.71±0.89, 17.78±1.05, 19.63±1.63 and 20.16±1.34 in the control group, respectively, while the highest values were 22.49±1.23, 27.73±0.89, 26.42±2.11 and 30.02±1.89 in Si+ANE application according to the analysis dates.

Crisosto and Mitchell (2002) and Sabir A et al. (2006), are also reported at the end of the storage period °Brix and acidity changes depending on the MI values can be seen in the increase. In this study, which was maintained in the form of cluster of 'AK' MI values in applications other than grape varieties have been detected only slight increases during storage period.

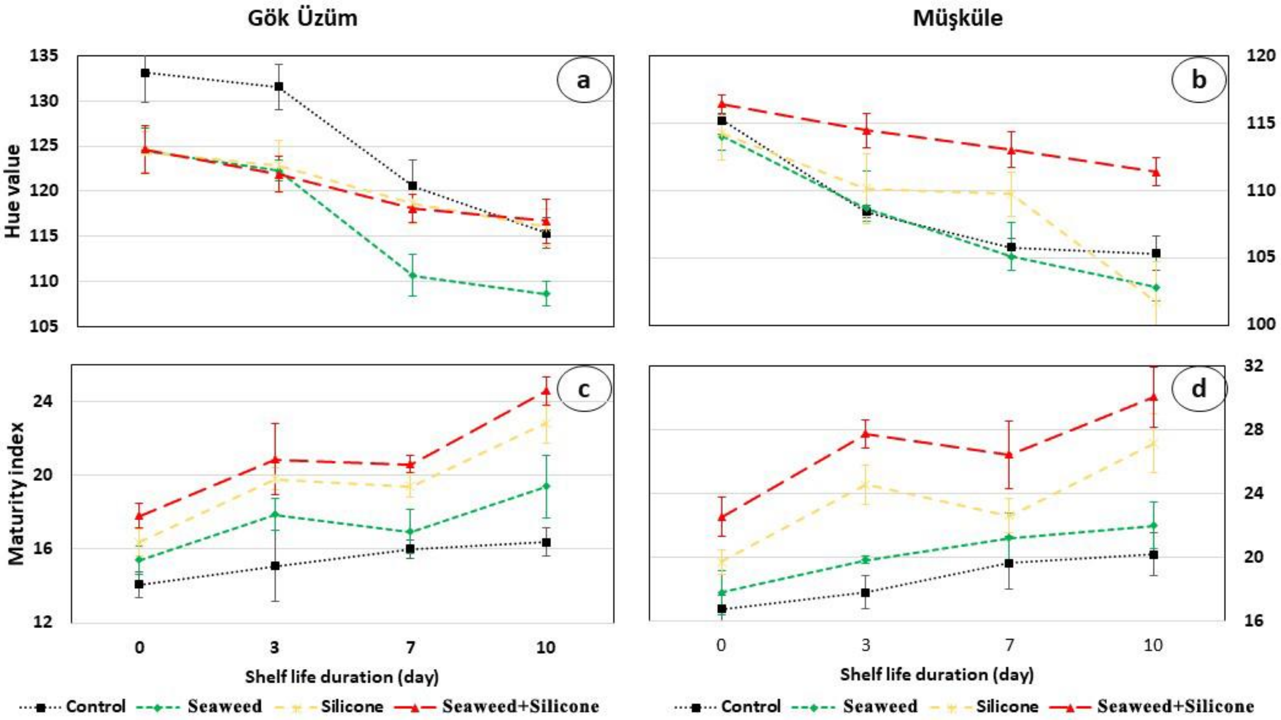

Figure 3
Effects on hue value (a and b) and MI (c and d)

4. Conclusion

Application of Ortho silicon (0.5 mL L^{-1}) and seaweed extract (2.5 mL L^{-1}) to cvs. Müşküle and Gök Üzüm after fruit set 15 days intervals resulted in improvements in the peduncle and in accelerating of ripening. The improvement in the studied properties increased with the co-administration of these two plant activators. In the 4-repeat analyzes carried out during the 10-day storage period at room conditions after harvest, the preservation of quality characteristics such as WL, berry detachment force, skin rupture force, MI, brightness (hue h°) and decay rate were positively affected by the applications. In this process, the combined application of Si+ANE was found to be more effective than the individual applications of these activators. According to the data obtained from this study, improvements in the sustainable preservation of quality can be achieved by applying Ortho Silicon and seaweed extract separately and together after fruit setting and before veraison to preserve the quality of table grape production and post-harvest.

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