Improvement of the physiological and phytochemical characteristics of guava (*psidium guajava* l.) Leaves and fruits by using foliar applications of calcium chloride, zinc sulfate and boric acid

M. K. Salama [1,*], M. A. El-Nabarawy [1], M. A. Omar [1], and M. Z. Sultan [2]

[1] *Agricultural Botany Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.*
[2] *Horticulture Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.*

* Corresponding author E-mail: mahmoudkamal@azhar.edu.eg (M. Salama)

ABSTRACT:

This investigation focused on the impacts of specific nutrients as calcium chloride ($CaCl_2$) at 0.4 and 0.6%, zinc sulfate ($ZnSO_4$) at 0.4 and 0.5% and boric acid ($B(OH)_3$) at 50 and100 ppm one and two sprays on delay senescence of leaves and fruit quality of guava yield in eleven years old guava at the Qalyub area, Qalyubeia Governorate, Egypt, under randomized block design with factorial approach. It was discovered in this study that there had been considerable improvements in the foliar application of $CaCl_2$, $ZnSO_4$ and $B(OH)_3$ on physiological and biochemical characteristics in leaves led to an increasing in the pigments of photosynthesis, proline (Pro), total sugars content (TSC), total phenolic content (TPC) and NPK contents and a decreasing in anthocyanin (ACY), poly-phenol oxidase (PPO) and peroxidase (POD) activity which reflected positively on the quality of guava fruits and led to an increase in firmness and total soluble solids (TSS) and decrease in respiration coefficient compared with the control. In all, the single spray was better compared to the two sprays, although the two sprays were distinguished in some cases from the single spray.

Keywords: Guava; pre-harvest; nutrients; enzyme activity; Pro; ACY; and respiration coefficient.

INTRODUCTION

One of the healthiest and tastiest fruits, guava is beloved by customers for its flavor and refreshing taste. The fruit has an extremely limited shelf life of only two to three days at room temperature due to its climacteric nature, which causes it to ripen quickly. Guava fruit ripening is characterized by shrinkage, loss of brightness, softening, reduction in green colour and rot development (Ali and Lazan, 1997). Guava, which is mainly consumed fresh, has a high respiration rate and ripens quickly, which causes it to expire in storage (Hong *et al.*, 2012).

One of the most popular and tasty fruits in Egypt is the guava. It also costs the least and is the greatest source of vitamin "C" (fruits with the second-highest vitamin C content). It also has modest A, B, carbohydrates, oils, and protein content. Additionally, it is abundant in pectins, which are used in industry to produce juice (Bose and Mitra, 1990). Additionally, it is an excellent supply of calcium (Ca) and phosphate (P). (Siddiqui *et al.*, 1991). Furthermore, guava fruits can be consumed fresh or made into tasty goods like jam, jelly, and juice. In several regions of the world, guava paste and guava cheeses are also well-liked foods.

The guava (*Psidium guajava* L.) is a part of the Myrtaceae plant family, and it is the specie *guajava* of the genus *Psidium*. However, the guava is undoubtedly the most significant member of this family.. Since its ancestral home is in the region between Mexico and Peru, guava trees are well known to thrive naturally in tropical and subtropical locations (Chandler, 1958). As a result, it may presently be effectively grown in more than 60 different nations.

Because of a loss in photosynthetic ability, growth inhibition, protein breakdown, and RNA degradation, nutrient deficiencies frequently result in lower yields, impacts on chlorophyll concentration, and decreased photosynthetic carbon fixation (Amtmann and Armengaud, 2009). According to Hoefgen and Nikiforova (2008), severe nutritional ion deficits lead to stress reactions like ACY buildup, early flowering, early seed set and senescence.

Neill (2002) it was noted that a huge number of plant species all over the world are red in colour because of the anthocyanins (ACYs), a very modest group of pigments in the complex flavonoid family. Their presence in fruits and flowers appears to have obvious advantages in luring pollinators and assisting in seed dissemination, but their existence in the vacuoles of leaves is yet unknown. Numerous diverse environmental and anthropogenic stressors, including UV exposure, wounding, pathogen infection, bright light, cold, pollution, osmotic stress, and nutritional deprivation, can cause the buildup of ACY pigments in leaves. ACYs are expressed throughout leaf development in some species, but only in the young, quickly developing leaves or at later phases of leaf senescence in other species.

Plants require a source of nutrients from the soil for optimum growth and consequently optimum crop output, a variety of micro-nutrients (Cu, Fe, Mo, Zn, and others) and macro-nutrients (N, P, K, and S) must both be present in the right amounts. (Amtmann and Armengaud, 2009), macronutrients (N, P, S, Mg, K, and Ca) are often provided in suitable amounts, micro-nutrients (Zn, Fe, Cu, Mo, and others) and macro-nutrients (N, P, K, and S) must both be present in the right amounts (Watanabe *et al.,* 2012). The idea of the study was to evaluate the effect of some nutrients on some physiological, chemical and quality characteristics of guava. In this study, the impact of applying $CaCl_2$, $ZnSo_4$, and B(OH)3 pre-harvest on guava leaves and fruits, has been investigated.

MATERIALS AND METHODS

Plant material:

The study was carried out during three successive seasons (2019/2020, 2020/2021 and 2021/2022) in a private guava (*Psidium guajava* L.) orchard located at Qalyub district, Qalyubeia Governorate, Egypt. The trees were 11- year-old grown in a clay loamy soil at 5x5 meters apart under flood irrigation and subjected to the same agricultural practices.

Treatments and sampling:

It is worthy to point to that a preliminary experiment was conducted in 2018/2019 season and according to the preliminary results, 14 treatments were examined and arranged as follow:

Tap water (control treatment) once spray or twice,

$CaCL_2$ at 0.4 and 0.6 % once spray or twice.

$ZnSo_4$ at 0.4 and 0.5 % once spray or twice.

Boric acid at 50 and 100 ppm once spray or twice.

Six of healthy uniform trees were selected and devoted for each treatment. The trees were sprayed early morning until wet point using hand sprayer, all spray solutions were supplemented with 0.05% tween 20 as surfactant and pH was adjusted at 6.0. The first spray was conducted in mid-November (when fruit size about 2.5 cm in diameter) and mid-December (when fruit size about 3.6 cm in diameter). Sample of eight adult leaves were collected from each tree and immediately transferred to the plant physiology laboratory, Department of Agricultural Botany, Faculty of Agriculture, Al-Azhar University, Nasr city, Cairo, Egypt.

Measurements:

Determination of chlorophyll a, b and total carotenoid contents:

Were calculated according to the formulas of Lichtenthaler and Wellburn (1985).

Determination of anthocyanin (ACY) contents:

Were determined according to (Mancinelli *et al*., 1975).

Total sugar content (TSC) by Phenol–Sulfuric Acid method:

Were determined according to Geetha and Geetha, (2014).

Total phenolic content (TPC):

The method described previously by Singleton and Rossi (1965).

Determination of proline (Pro) content:

The method described by Bates *et al.* (1973).

Determination of antioxidant enzymes activity:

Determination of polyphenol oxidase (PPO):

Were determined according to Duckworth and Coleman (1970).

Determination of peroxidase (POD) activity:

The determination of PPO activity method according to Chance and Maehly (1955).

Determination N-P-K in leaf contents:

The digested samples were used for determining N, P and K according to Chapman and Pratt (1978).

N: was determination by using the micro-kjeldahl technique as explained by Page *et al.* (1982).

P: was assessed spectrophotometrically in a sulfuric acid system using the method of chlorostannus-phosphomolybdic acid, Jackson (1973).

K: using the flame photometer to determine (Jen way PFP7) as described by Kalra (1998).

Fruiting parameters.

Fruit physical properties:

According to Magness and Taylor (1925).

Total soluble solids (TSS) %:

According to Chen and Mellenthin (1981).

Respiration rate:

Were calculated according to the formulas of Nair and Singh (2003).

Statistical analysis:

Data were subjected to analysis of variance (ANOVA) and significant differences among means were calculated by Duncan's multiple range test ($p \leq 0.05$). All data were analyzed statistically by one-way ANOVA using the CoStat program (version 6.3).

RESULTS AND DISCUSSIONS

Effect of $CaCl_2$, $ZnSO_4$, and B $(OH)_3$ (one and two sprays) on the contents of ACY) and photosynthetic pigments in guava leaves.

Data presented in Table 1 showed that, all the treatments of nutrients significantly improved Chl a, Car_{X+C} and total Chl contents and decreased ACY contents of guava leaves in compared with control, most favorite of the highest results showed with one spray of nutrients used and were most of the low concentrations used were better than the high concentrations. This indicates that these treatments reduced the stress on the plant as a result of the effect of cold and improved growth. The highest contents of Chl a and total Chl were produced by the treatment with one spray of $CaCl_2$ followed by $ZnSO_4$ then $B(OH)_3$ respectively as comparison to control. While the treatment with two sprays of $CaCl_2$ followed by $ZnSO_4$ were produced the highest content from Car $_{X+C}$. The highest content from Chl b was produced by the treatment with the control followed by one spray of $CaCl_2$ at concentration 0.4 % and either two sprays or one spray of $B(OH)_3$ at concentration 100 ppm respectively. The results are in accordance with Kazemi (2013b) revealed that the presence of $CaCl_2$ enhanced the chlorophyll content in cowpea and cucumber leaves. (Mohamed and Basalah, 2015). Also, El-Feky *et al.* (2014) showed that Chl (a+b) was increased 20% with $CaCl_2$, but compared to protochlorophyll and chlorophyll b, the effect was substantially more pronounced in the case of chlorophyll a. according to some theories, the intake of minerals necessary for chlorophyll production and other general impacts, such as controlling the membranes' and cytoplasm's level of hydration, are two ways that Ca levels may influence the generation of chlorophyll. Pal and Laloraya (1972). Also, Adams *et al.* (2000) according to reports, Zn is a crucial element for crop growth and fruit size. It is also necessary for the carbonic enzyme, which is a component that is present in all photosynthetic tissues and is essential for the production of chlorophyll. Mohsenzadeh and Moosavian (2017) showed that effects of foliar application of $ZnSO_4$ on physiological indices (improving the amount of antioxidants, TPC, Pro, lipid peroxidation, sugar, and carotenoids) of rosemary. Candan and Tarhan (2003) indicated that M. pulegium cultivated without Zn had lower levels of chlorophyll and carotenoids than the control in all leaf locations. B shortage weakens vascular tissues involved in ion transport, which indirectly inhibits photosynthesis (Wang *et al.*, 2015).

The lowest values of ACY content in guava leaves were produced by the treatment with one spray of $CaCl_2$ followed by $ZnSO_4$. Since the synthesis of ACY occurs at the same time that the activity of all the enzymes involved in the production of chlorophyll decreases (Kannangara and Hansson, 1998). The results are in accordance with Mahdavian (2022) he discovered that calcium (50 and 100 mM) decreased the ACY content of leaves by 14 % and 10 %, respectively. The amount of ACY content and weight reduction were not significantly affected by the various calcium salts used on jujube fruit. Moradinezhad *et al.* (2019). Zn was found to reduce total ACYs in the first season when the effects of foliar sprays of certain growth regulators and mineral nutrients were examined in pomegranate. The lowest values were achieved with 0.3% Zn (Khalil and Aly, 2013). On the other hand, Shahi and Abdossi (2019) reported that $ZnSO_4$ ACY and EC enhanced significantly of the pomegranate juice.

Effect of $CaCl_2$, $ZnSO_4$, and B $(OH)_3$ (one and two sprays) on PPO) and POD enzymes activity of guava leaves.

Data showed in figure 1 that the POD activity was increased with some of the treatments of nutrients as one spray and tow spray of $ZnSo_4$ at concentration 0.5% and tow sprays of $B(OH)_3$ at concentrations 50 and 100 ppm. While the activity of PPO in leaves significantly decreased in all the treatments of nutrients. The low concentrations used of $CaCl_2$ $ZnSO_4$ decreased POD activity, especially with the two sprays treatment. The results of the current studies are consistent with those attained by El-Shintinawy (1999) under B deficient conditions, the POD activities of the sunflower plant were evaluated in the roots and shoots, and significant increases in both shoot and root bound POD activities were observed. Furthermore, it was observed that B deficiency had little impact on the soluble POD activity of roots. Liu and Yang (2000) showed that soybean leaves' SOD, APX, and CAT activities decreased when B levels were low. Additionally, the cross-linking of polygalacturonan chains into a POD-recognized structure depends on the Ca2+ ion. (Penel *et al.,* 1999). Candan and Tarhan (2003) revealed that whereas Zn concentrations on pennyroyal were lower than those of the control, SOD and CAT activities dramatically enhanced.

Micronutrients contribute to the development of cell walls and boost plants' resistance to pests and abiotic stresses. Zn is a crucial nutrient that activates a number of enzymes, including carbonic anhydrase, aldolases, SOD, DNA and RNA polymerases, and dehydrogenases (Yadavi *et al.,* 2014). Actually, more ROS buildup occurs in plants when Zn levels are low (Hong and Jin, 2007). For optimum operation, the antioxidant enzyme SOD needs both copper and zinc. The presence of Zn is necessary for the integrity of cellular membranes and may aid in the creation of biomolecules (Khan *et al.,* 2016).

Effect of $CaCl_2$, $ZnSO_4$, and B $(OH)_3$ (one and two sprays) on Pro content, TSC and TPC of guava leaves.

Data showed in figure 2 Pro content, TSC and TPC in guava leaves significantly increased in most the treatments of nutrients as compared with the control either one or two sprays. One spray of $B(OH)_3$ at 100 ppm and $ZnSO_4$ at 0.4% produced the highest content from Pro. Under conditions of salt stress, Pro is essential for preserving photosynthetic activity and mitochondrial function. (Munns, 2012). Similarly, with Brahimian and Bybordi (2011) found that under stressful conditions, foliar Zn treatment stimulated enzymes involved in the detoxification of reactive oxygen species and Pro buildup. However, Kumar *et al.* (2004) showed that at higher $ZnSO_4$ concentrations (100-400 mM), growth is impeded coupled with yellowing of the leaves and stem and a reduction in the protein and Pro content. Sarafi *et al.* (2014) reported that B a significant increase in the concentration of Pro in pomegranate leaves. Dehnavi *et al.* (2017) demonstrated that this study's findings that foliar treatments of B and a Zn-B mixture increased Pro content.

One spray of $CaCl_2$ at 0.4% and 0.6% produced the highest content from TSC followed two sprays of $ZnSO_4$ at 0.5% and one spray of $B(OH)_3$ at 50 ppm. These findings are supported by these results Saleh and Maftoun (2008) they demonstrated that the increase in Pro was larger in the presence of Zn than in the absence of Zn, and that Pro and reducing sugar concentrations decreased with ZnSO4. $ZnSO_4$ was effective decreasing Pro concentration in rice. reported that Zn decreased as well as reducing sugar concentrations. Khalifa *et al.* (2011) reported that iris plants treated with Zn had considerably higher TCC, chlorophyll, and carotenoid levels than plants treated with control. The positive effects of Zn on photo-synthetic pigments may result from its function in accelerating photochemical reduction rates (Kumar *et al.,* 1988), photosynthesis, electron transfers during photosynthetic processes, and chloroplast structure (Romheld and Marschner, 1991). B's ability to enhance the transport of carbohydrates like starch and sugar may be the cause of its positive effects (Donald *et al.,* 1998). Singh *et al.* (1998) observed that pre-harvest $CaCl_2$ spraying improved TCC in fruits of the Amrapali mango. El-Feky et al. (2014) demonstrated that 25% SA and 26% $CaCl_2$ were sufficient to activate TCC. Additionally, according to Behera and Pathak (2015), pre-harvest treatment of $CaCl_2$ 2% with TCC was shown to be much better than all other treatments, with the control showing the lowest TCC. Zn's impact on TCC may be related to its function in the metabolism of nucleic acids and starch as well as the actions of various enzymes involved in these biochemical processes (Alloway, 2008). In contrast, B's impact on total sugars may be related to its functions in sugar transport and carbohydrate metabolism (Hansch and Mendel, 2009).

For TPC the highest content was produced by $B(OH)_3$, $ZnSO_4$ and $CaCl_2$ especially the treatment of two sprays respectively compared with the other treatments and control. These outcomes corroborated the findings of Babalik *et al.* (2018) they showed that B concentrations had the highest TPC content compared control. Gilani *et al.* (2021) revealed that the highest TPC were noticed in pear fruit that had been sprayed with B. The development of berry phenolic biosynthesis pathway genes and the findings of expression analysis indicated the Zn treatments that improve phenolic accumulation (Song *et al.,* 2015). Jan and Hadi (2015) showed that, Zn significantly enhanced the free Pro and TPC production in the leaves of sunflower. Also, Raigond *et al.* (2017) noted that, Zn increased the TPC content. Khalaj *et al.* (2015) showed that during storage, TPC dropped more noticeably in control fruits than in fruits treated with calcium and/or boron.

Effect of $CaCl_2$, $ZnSO_4$, and B $(OH)_3$ (one and two sprays) on NPK contents of guava leaves.

From data showed in figure 3 we can conclude that NPK contents in guava leaves compared to the control, nutrients in all treatments were significantly higher in either one or two sprays. N and K contents in leaves were high increased with treatments $ZnSO_4$ and $B(OH)_3$ followed $CaCl_2$ while P contents in leaves were high increased with treatments on spray of $CaCl_2$ at 0.4% followed by on spray of $ZnSO_4$ at 0.5% and $B(OH)_3$ at 100 ppm either on spray and two sprayed. B is essential for N metabolism because it raises nitrate levels (Shen *et al.,* 1993).

B affects how readily available and taken up from the soil other plant nutrients are. After B application, it appeared that P, K, N, Fe, Cu and Zn absorption and translocation in leaves, seeds and buds increased (Ahmed *et al.,* 2011). These results agree with those reported by Al-Esaily (2011) who found that foliar applications of Zn and B, regardless of concentration, had a substantial impact compared to the control (water spray), on all mineral contents (NPK) in plants. Aref (2011) showed that, whereas Zn and B levels had no appreciable effect on the NPK concentrations in the maize grain, high Zn levels caused the amounts of NPK to rise. Sarkar *et al.* (2018) reported that B has significant influence on N, while non-significant on available P and K. The concentrations of Ca applications helped in better NPK increased uptake by the crop may be caused by a better nutrient environment in the rhizosphere and plant system (Raj and Mallick, 2017).

Effect of $CaCl_2$, $ZnSO_4$, and $B(OH)_3$ (one and two sprays) on firmness, TSS and respiration rate of guava fruits.

Fruits firmness:

As shown in figure 4 fruits firmness of guava significantly increased in the treatment with one spray and two sprays of $CaCl_2$ at concentration 0.6 and 0.4% followed by one spray of $ZnSO_4$ and $B(OH)_3$. Similar observations were reported by $CaCl_2$ on fruit firmness. Gorini *et al.* (1993) demonstrated that the use of CaCl2 as a firming agent could increase the shelf life post-harvest of a variety of vegetables and fruits including apples (Sams *et al.,*1993), tomatoes (Floros *et al.,* 1992). Also, positive effects of $CaCl_2$ on fruit firmness have previously been reported (Hussain *et al.,* 2012).

TSS (^{0}Brix):

In figure 4 the data pertaining to the TSS of guava fruits significantly enhanced in all the treatments of elements in either one or two sprays compared with control, the best values of TSS were recorded in treatment with were recorded with two sprays of $B(OH)_3$ at 100 ppm and $ZnSO_4$ at 0.5%. Similarly, results are consistent with the conclusions of Singh *et al.* (2005) and Tiwari and Shant (2014) showed that the treatment of ZnSO4 spray recorded highest values of TCC and TSS on fruit. Mishra and Mishra (2021) revealed pre-harvest spray that $ZnSO_4$ at 0.4 percent improved TSS and TCC contents in guava fruits stored at 10°C. Also, Vani *et al.* (2021) concluded that the $ZnSO_4$ at 0.4% and B at 0.4% is the most effective treatment to improve guava's economics and yield.

Respiration coefficient:

The results showed that lowest levels were with $CaCl_2$ 0.4% (two sprays), followed by treatment with $ZnSO_4$ 0.5% (one spray) and treatment with ZnSO4 0.4% (two sprays), respectively. Similar findings have also been reported by Rosen and Kader (1989) fruit's physiological decay rate and respiration rate are inversely correlated, Ca delayed higher respiration rates in the treated fruits compared to the controls and lower $CaCl_2$ contents may be the cause of this. Ca has been applied both before and after harvest to increase quality and reduce diseases in a variety of crops, including strawberries, nectarines, apples and peaches (Hernandez-Munoz *et al.,* 2006; Dunn and Able, 2006). Due to its beneficial effects, particularly its ability to postpone ripening decrease respiration, senescence, lengthen shelf life, and decrease physiological problems, Ca has attracted a lot of attention in recent years. Ca may cause delayed senescence by slowing down respiration (Hussain et al., 2012; Shirzadeh et al., 2011). According to El Sayed et al. (2011), B lowers respiration and the activity of oxidative pentose phosphate enzymes. Additionally, raising B level led to appreciable increases in the sugar beetroot leaf's Chl a, Chl b, and carotenoids. They said that these findings could be explained by the fact that B is a crucial component of photosynthetic pigments, where it accelerates the rates of CO_2 fixation and O_2 evolution.

CONCLUSION

It is concluded that there are significantly improves of either pigments, POD, PPO enzymes activates, Pro, TSC, TPC and NPK contents in leaves by using foliar applications of elements as $CaCl_2$, $ZnSO_4$ and $B(OH)_3$ either once or twice led to improving the qualities of fruits such as firmness and TSS and decrease in respiration coefficient compared with the control. In all, the single spray was better compared to the two sprays, although the two sprays were distinguished in some cases from the single spray.

REFERENCES

Adams, M.L., Norvell, W.A., Philpot, W.D., Peverly, J.H. 2000: Spectral detection of micronutrient deficiency in bragg soybean. Agronomy Journal, 92: 261-268.

Ahmed, N., Abid, M., Ahmad, F., Ullah, M.A., Javaid, Q., Ali, M.A. 2011: Impact of boron fertilization on dry matter production and mineral constitution of irrigated cotton. Pak. J. Bot. 43:2903-2910.

Al-Esaily, I. 2011: Effect of foliar spray with zinc and boron on growth, yield and fruit quality of strawberry (Fragaria× ananassa Duch cv. Camarosa) plants grown in sandy soil. Journal of Productivity and Development, 16(3), 483-506.

Ali, Z.M., Lazan, H. 1997: Guava, postharvest physiol, storage of tropical and subtropical fruits in Mitra SK, editors. Wallingford: Cab International, 1997.

Alloway, B.J. 2008: Zinc in soils and crop nutrition. international zinc fertilizer industry association, Brussels Belgium, pp. 30-35.

Amtmann, A., Armengaud, P. 2009: Effects of N, P, K and S on metabolism: new knowledge gained from multi-level analysis. Curr. Opin. Plant Biol.12: 275-283.

Aref, F. 2011: The effect of boron and zinc application on concentration and uptake of nitrogen, phosphorous and potassium in corn grain. Indian J. Sci. Technol, 4(7), 785-791.

Babalik, Z.E., Demirci, T., Aşci, Ö.A., Baydar, N.G. 2018: The influence of pre-harvest boric acid applications on the accumulation of some antioxidant components in Alphonse lavallée grape cultivar. scientific papers-series b-horticulture, 62, 299-304.

Bates, L.S., Waldren, R.P., Teare, I.D. 1973: Rapid determination of free proline for water-stress studies. Plant Soil. 39: 205-207.

Behera, S.D., Pathak, S. 2015: Pre-harvest treatments for fruit quality improvement in rainy season guava (*Psidium guajava*). International Journal of Science and Research (IJSR) 6 (10)-1358;1361.

Bose, T.K., Mitra, S.K. 1990: Guava in fruit subtropical. Bose. (Ed.), Nayaprakash.

Brahimian, E., Bybordi, A. 2011: Exogenous selenium and zinc increase antioxidant enzyme activity and alleviate salt stress in leaves of sunflower. Journal of Food, Agriculture and Environment 9(1):422-427.

Candan, N., Tarhan, L. 2003: Changes in chlorophyll-carotenoid contents, antioxidant enzyme activities and lipid peroxidation levels in Zn-stressed *Mentha pulegium*. Turkish Journal of Chemistry, 27(1), 21-30.

Chance, B., Maehly, C. 1955: Assay of catalase and peroxidases. Methods in enzymology, 2 :764-775.

Chandler, W.H. 1958: Evergreen Orchards. Henry Kimpton, London, pp: 452.

Chapman, H.D., Pratt, P.F. 1978: Methods of analysis for soils, plant and waters. Univ. California Division Agric. Sci.

Chen, P.K., Mellenthin, W.M. 1981: Effect of harvest date on ripening capacity and post-harvest life of Anjou pears. J. Amer. Soc. Hort., Sci., (106): 138.

Dehnavi, M.M., Misagh, M., Yadavi, A., Merajipoor, M. 2017: Physiological responses of sesame (*Sesamum indicum* L.) to foliar application of boron and zinc under drought stress. J Plant Process Funct, 6(20), 27-35.

Donald, D.H., Gwathmey, C.O., Sams, C.E. 1998: Foliar feeding on cotton: Evaluation potassium sources, potassium solution buffering and boron. Agron. J., 90: 740-746.

Duckworth, H.W., Coleman, J.E. 1970: Physicochemical and kinetic properties of *Mushroom tyrosinase*. Journal of Biological Chemistry, 245(7), 1613-1625.

Dunn, J.L., Able, A.J. 2006: Pre-harvest calcium effects on sensory quality and calcium mobility in strawberry fruit. Acta Hort., 708: 307-312.

El Sayed, Safaa S.M., Abo El-Ghait, R.A., Aboshady, K. 2011: Physiological response to foliar application of cobalt and boron on some physiological proprieties, yield and quality of sugar beet. Egypt. J. Appl. Sci. 26(12B), 859-874.

El-Feky, S.S., El-Shintinawy, F.A., Shaker, E.M. 2014: Role of $CaCl_2$ and salicylic acid on metabolic activities and productivity of boron stressed barley (*Hordeum vulgare* L.). Int J Curr Microbiol Appl Sci, 3, 368-380.

El-Shintinawy, F. 1999: Structural and functional damage caused by boron deficiency in sunflower leaves, Photosynthetica, 36 :573.

Floros, J.D., Ekanayake, A., Abide, G.P., Nelson, P.E. 1992: Optimization of diced tomato calcification process. J. Food Science, 57: 1144.

Geetha, T.S., Geetha, N. 2014: Phytochemical screening, quantitative analysis of primary and secondary metabolites of *Cymbopogan citratus* (DC) STAPF. leaves from Kodaikanal hills, Tamilnadu: Int.J.PharmTech Res.,6(2), 521-529.

Gilani, S.A., Basit, A., Sajid, M., Shah, S.T., Ullah, I., Mohamed, H.I. 2021: Gibberellic acid and boron enhance antioxidant activity, phenolic content, and yield quality in Pyrus Communis L. Gesunde Pflanzen, 73(4), 395-406.

Gorini, F., Testoni, A., Cazzola, R., Lovati, F., Bianco, M.G., Chessa, I., Schirra, M., Budroni, M., Barbera, G. 1993: Technological aspects: Conservation and quality of prickly pear and avocado. The Agricultural Informer, 1: 89-92.

Hansch, R., Mendel, R. 2009: Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl). Curr. Opin. Plant Biol. 12, 259-266.

Hernandez-Munoz, P., Almenar, E., Ocio, M.J., Gavara, R. 2006: Effects of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria ananassa*). Postharvest Biol. Tech. 39: 247-253.

Hoefgen, R., Nikiforova, V.J. 2008: Metabolomics integrated with transcriptomics: assessing systems response to sulfur-deficiency stress. Physiol. Plant. 132,190-198.

Hong, K., Xie, J., Zhang, L., Sun, D., Gong, D. 2012: Effects of chitosan coating on postharvest life and quality of guava (*Psidium guajava* L.) fruit during cold storage. Scientia Horticulturae, 144: 172-178.

Hong, W.A., Jin, J.Y. 2007: Effects of zinc deficiency and drought on plant growth and metabolism of reactive oxygen species in maize (*Zea mays* L). Agricultural Sciences in China. 1;6(8):988-95.

Hussain, P.R., Meena, R.S., Dar, M.A., Wani, A.M. 2012: Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of red delicious apple. J. Food Sci. Technol. 94(4): 415-426.

Jackson, M.L. 1973: Soil chemical analysis. prentice –Hall, Inc. Englewood cliffs, N.J. New Delhi, India.

Jan, A.U., Hadi, F. 2015: Potassium, zinc and gibberellic acid foliar application enhanced salinity stress tolerance, proline and total phenolic in sunflower (*Helianthus annuus* L.). American-Eurasian Journal of Agricultural & Environmental Sciences, 15, 1835-1844.

Kalra, Y.P. 1998: Handbook of reference methods for plant analysis. CRC Press Taylor and Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742.

Kannangara, G.G., Hansson, M. 1998: Arrest of chlorophyll accumulation prior to anthocyanin formation in euphorbia pulcherrima. Plant Physiol. Biochem. 36:843-848.

Kazemi, M. 2013b: Response of cucumber plants to foliar application of calcium chloride and paclobutrazol under greenhouse conditions. Bull. Env., Pharmacol. Life Sci., 2 (11): 15-18.

Khalaj, K., Ahmadi, N., Souri, M.K. 2015: Effect of calcium and boron foliar application on fruit quality in Asian pear cultivar 'KS10'. Journal of Crop Production and Processing, 4 (14): 89-97.

Khalifa, R.K.H.M., Shaaban, S.H.A., Rawia, A. 2011: Effect of foliar application of zinc sulfate and boric acid on growth, yield and chemical constituents of iris plants. Ozean J. Appl. Sci, 4(2), 129-144.

Khalil, H.A., Aly, H.S.H. 2013: Cracking and fruit quality of pomegranate (*Punica granatum* L.) as affected by pre-harvest sprays of some growth regulators and mineral nutrients. J. Hortic. Sci. Ornament. Plants 5, 71-76.

Khan, M.N.M.A., Masroor, A., Gautam, C., Mohammad, F., Siddiqui, M.H., Naeem, M., Khan, M.N. 2016: Effect of gibberellic acid spray on performance of tomato. Turkish Journal of Biology, 30(1), 11-16.

Kumar, K., Arvind, K., Vidyasagar, R., Rao, K. 1988: Studies on growth and activity of photosynthetic enzymes on *Sorghum bicolor* L. as influenced by micronutrients. Procendian Natl. Sci. Acard Part B Biol. Sci., 54: 75-80.

Kumar, S., Narula, A., Sharma, M.P., Srivastava, P.S. 2004: In vitro propagation of *Pluchea lanceolata*, a medicinal plant, and effect of heavy metals and different aminopurines on quercetin content. In vitro Cellular & Developmental Biology-Plant, 40(2), 171-176.

Lichtenthaler, H.K., Wellburn, A.R. 1985: Determination of total carotenoids and chlorophylls a and b of leaf in different solvents. Biochemical Society Transactions, 11: 591-592.

Liu, P., Yang, Y.A. 2000: Effects of molybdenum and boron on membrane lipid peroxidation and endogenous protective systems of soybean leaves, Acta Bot. Sinica 42: 461-466.

Magness, J.R., Taylor, G.F. 1925: An improved type of pressure tester for the determination of fruit maturity. U.S. Dept. Agric. Circ., 350 8p.

Mahdavian, K. 2022: Effect of salicylic acid and calcium chloride on lipid peroxidation and scavenging capacity of radical of red bean (*Phaseolus calcaratus* L.) under salt stress. Int J Hortic Sci Technol 9(1):55-72.

Mancinelli, A.L., Yang, C.P.H., Lindquist, P., Anderson, O.R., Rabino, I. 1975: Photocontrol of anthocyanin synthesis: III. The action of streptomycin on the synthesis of chlorophyll and anthocyanin. Plant physiology, 55(2), 251-257.

Marschner, H. 1995: Mineral nutrition of higher plants. Academic Press, London. 897 p.

Mohamed, A.K., Basalah, M.O. 2015: The active role of calcium chloride on growth and photosynthetic pigments of cowpea "*Vigna unguiculata* L. (Walp)" under salinity stress conditions. American-Eurasian J. Agric. & Environ. Sci., 15 (10): 2011-2020.

Mohsenzadeh, S., Moosavian, S.S. 2017: Zinc sulphate and nano-zinc oxide effects on some physiological parameters of Rosmarinus officinalis. American Journal of Plant Sciences, 8(11): 26-35.

Moradinezhad, F., Ghesmati, M., Khayyat, M. 2019: Postharvest calcium salt treatment of fresh jujube fruit and its effects on biochemical characteristics and quality after cold storage. J. Hortic. Res.

Munns, R., James, R.A., Xu, B., Athman, A., Conn, S.J., Jordans, C., Plett, D. 2012: Wheat grain yield on saline soils is improved by an ancestral Na+ transporter gene. Nat Biotechnol 30:360-364.

Nair, S., Singh, Z. 2003: Pre-storage ethrel dip reduces chilling injury, enhances respiration rate, ethylene production and improves fruit quality of 'Kensington'mango. Food, Agriculture & Environment, 1(2), 93-97.

Neill, S.O. 2002: The functional role of anthocyanins in leaves (PhD Thesis, ResearchSpace@ Auckland).

Page, A.L., Miller, R.H., Keeney, D.R. 1982: Method of soil analysis. Part 2: chemical and microbiological properties. 2nd ed. Amer. Soc. Agron. Inc. Soil Sci. Soc. Of Am., Madison, 49-84.

Pal, R.N., Laloraya, M.M. 1972: Effect of calcium levels on chlorophyll synthesis in peanut and linseed plants. Biochemie und Physiologie der Pflanzen, 163(5): 443-449.

Penel, C., van Cutsem, P., Greppin, H. 1999: Interactions of a plant peroxidase with oligogalacturonides in the presence of calcium ions. Phytochemistry 51, 193-198.

Raigond, P., Raigond, B., Kaundal, B., Singh, B., Joshi, A., Dutt, S. 2017: Effect of zinc nanoparticles on antioxidative system of potato plants. Journal of Environmental Biology, 38(3), 435

Raj, A., Mallick, R.B. 2017: Effect of nitrogen and foliar spray of potassium nitrate and calcium nitrate on growth and productivity of yellow sarson (*Brassica campestris* L var. yellow sarson) crop under irrigated condition. Journal of Applied and Natural Science. 9(02):888-892.

Romheld, V., Marschner, H. 1991: Function of micronutrients in plants. In "Micronutrients in Agriculture" Published by Soil Sci. Soc. Amer. Inc. Madison Wisconsin, USA, pp. 297-299.

Rosen, J.C., Kader, A.A. 1989: Postharvest physiology and quality maintenance of sliced pear and strawberry fruits. J. Food. Sci., 54: 656-659.

Saleh, J., Maftoun, M. 2008: Interactive effects of NaCl levels and zinc sources and levels on the growth and mineral composition of rice. Journal of Agricultural Science and Technology, 10(4), 325-336.

Sams, C.E., Conway, S.W., Abbott, J.A, Lewis, R.J., Benshalom, N. 1993: Firmness and decay of apples following post-harvest pressure infiltration of calcium and heat treatment. J. Amer. Soc. Hortic. Science, 118: 623.

Sarafi, E., Chatzissavvidis, C., Therios, I. 2014: Effect of calcium and boron on the ion status, carbohydrate and proline content, gas exchange parameters and growth performance of pomegranate cv. Wonderful plants grown under NaCl stress. Türk Tarım ve Doğa Bilimleri Dergisi, 1(Özel Sayı-2), 1606-1617.

Sarkar, S., Banerjee, H., Ray, K., Ghosh, D. 2018: Boron fertilization effects in processing grade potato on an inceptisol of West Bengal, India. Journal of Plant Nutrition, 41(11), 1456-1470.

Shahi, P., Abdossi, V. 2019: Investigating the effect of various forms of zinc on pomegranate and pomegranate juice characteristics, journal of Food Technology and Nutrition 1: 90-81.

Sharma, R.M., Yamdagni, R., Gaur, H., Shukla, R.K. 1996: Role of calcium in horticulture - A review. Haryana J. Hort. Sci. 25(4): 205-208.

Shen Z.G., Liang Y.C., Shen, K. 1993: Effect of boron on the nitrate reductase activity in oilseed rape plants. J. Plant Nutr. 16:1229-1239.

Shirzadeh, E., Rabiei, V., Sharafim, Y. 2011: Effect of calcium chloride ($CaCl_2$) on postharvest quality of apple fruits. Afr. J. Agr. Res., 6(22): 5139-5143.

Siddiqui, S., Sharma, R.K., Gupta, O.P. 1991: Physiological and quality response of guava fruits to posture during shelf life. Hort. Sci., (26): 1295-1297.

Singh, R., Chaturvedi, O.P., Gaur, G.S., Singh, G. 2005: Effect of pre-harvest spray of zinc, calcium and boron on the storage behaviour of guava (*Psidium guajava* L.) fruits cv. Allahabad Safeda. In I International Guava Symposium 735, pp. 633-638.

Singh, S., Brahmachari, V.S., Jha, K.K. 1998: Effect of calcium and polythene wrapping on storage life of mango. Indian J. Hort., 55(3):218-22.

Singleton, V., Rossi, J. 1965: Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. American Journal of Enology and Viticulture 16:144-158.

Song, C.Z., Liu, M.Y., Meng, J.F., Chi, M., Xi, Z.M., Zhang, Z.W. 2015: Promoting effect of foliage sprayed zinc sulfate on accumulation of sugar and phenolics in berries of Vitis vinifera cv. Merlot growing on zinc deficient soil. Molecules, 20(2), 2536-2554.

Tiwari, J.P., Shant, L. 2014: Effect of foliar application of zinc and boron on fruit yield and quality of winter season guava (*Psidium guajava*) cv. Pant Prabhat. Annals of Agri Bio Research, 19(1), 105-108.

Vani, N.U., Bhagwan, A., Kumar, A.K., Sreedhar, M., Sharath, S.R., Suma, B. 2021: Studies on effect of pre harvest sprays of plant growth regulators and micronutrients on yield and economics of guava (*Psidium guajava* L.) cv. Lucknow-49. Journal of Pharmacognosy and Phytochemistry, *10*(1), 413-418.

Wang, N., Yang, C., Pan, Z., Liu, Y., Peng, S. 2015: Boron deficiency in woody plants: Various responses and tolerance mechanism. Frontiers in Plant Science, 6, 916.

Watanabe, M, Hubberten, H.M., Hoefgen, R. 2012: Plant response to mineral ion availability: transcriptome responses to sulfate, selenium and iron. In: De Kok LJ, Tausz M, Hawkesford MJ, Hoefgen R, McManus MT, Norton RM, Rennenberg H, Saito K, Schnug E, Tabe, L (eds) Sulfur metabolism in plants: mechanisms and application to food security, and responses to climate change. Dordrecht Heidelberg London New York, pp 123-134.

Yadavi, A., Aboueshaghi, R.S., Dehnavi, M.M., Balouchi, H. 2014: Effect of micronutrients foliar application on grain qualitative characteristics and some physiological traits of bean.

Table 1: Effect of foliar applications of $CaCl_2$ $ZnSO_4$ and $B(OH)_3$ on leaf photosynthesis pigments.

Treatments	Measurements									
	Chl. a mg/g FW		Chl. b mg/g FW		Total Chl. mg/g FW		Car $_{x+c}$ mg/g FW		ACY mg/g FW	
	One spray	Two sprays	One spray	Two sprays	One spray	Two sprays	One spray	Two sprays	One spray	Two sprays
control	13.89		4.72		18.61		3.09		0.4257	
$CaCl_2$ 0.4%	17.05	14.72	4.63	3.38	21.68	18.1	2.67	5.9	0.328	0.331
$CaCl_2$ 0.6%	17.83	15.87	3.46	1.9	21.3	17.78	2.9	6.49	0.303	0.337
$ZnSO_4$ 0.4%	17.64	17.47	2.73	1.91	20.37	19.38	2.98	5.33	0.317	0.347
$ZnSO_4$ 0.5%	17.74	14.99	3.07	2.43	20.81	17.41	4.53	3.35	0.344	0.357
$B(OH)_3$ 50 ppm	17.43	14.9	1.75	3.04	19.18	17.93	4.31	2.52	0.356	0.340
$B(OH)_3$ 100 ppm	15.36	14.33	3.91	4.34	19.26	18.67	4.29	2.99	0.342	0.362
LSD 0.05	1.99		0.99		1.64		0.82		0.082	

(*Phaseolus vulgaris* L.) under drought stress. Indian Journal of Fundamental and Applied Life Sciences. 4(4):124-31.

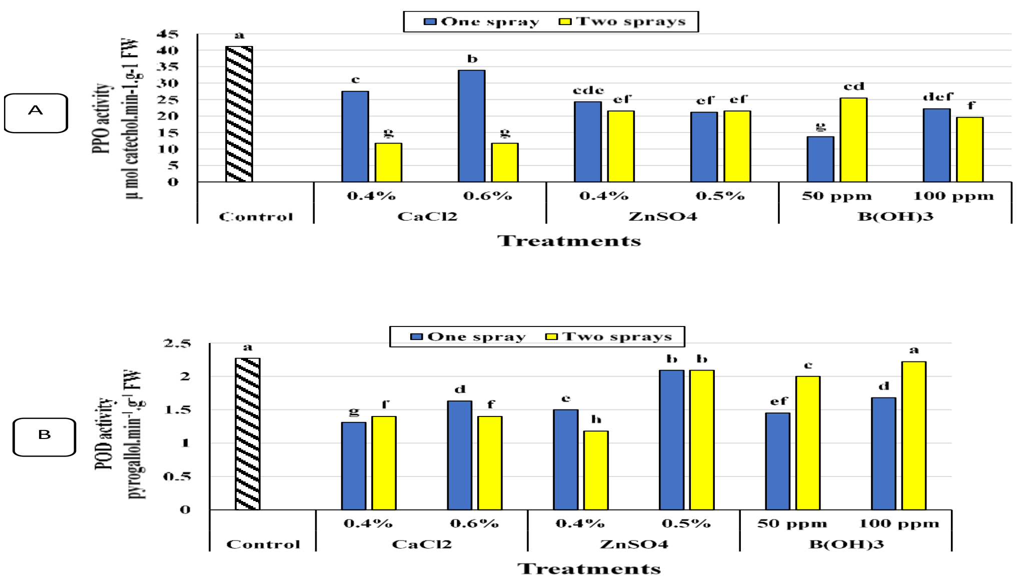

Fig. 1 (A, B): Effect of once or twice foliar applications of $CaCl_2$, $ZnSO_4$ and $B(OH)_3$ on PPO and POD enzymes activity of guava leaves.

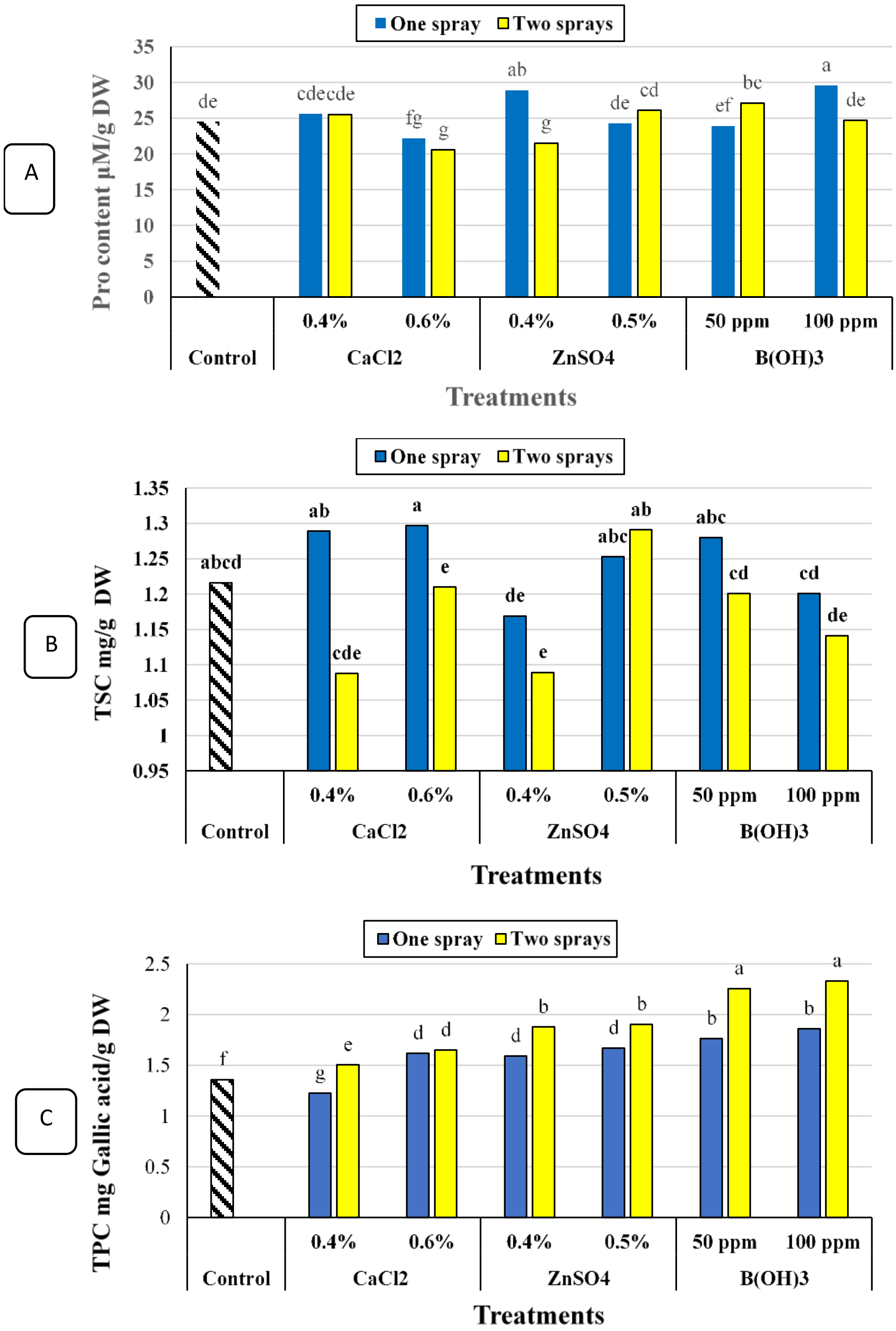

Fig. 2 (A, B, C): Effect of once or twice foliar applications of $CaCl_2$, $ZnSO_4$ and boric acid on Pro content µM/g DW (A), TSC mg/g-1 DW (B) and TPC mg Gallic acid/g DW (C) of guava leaves.

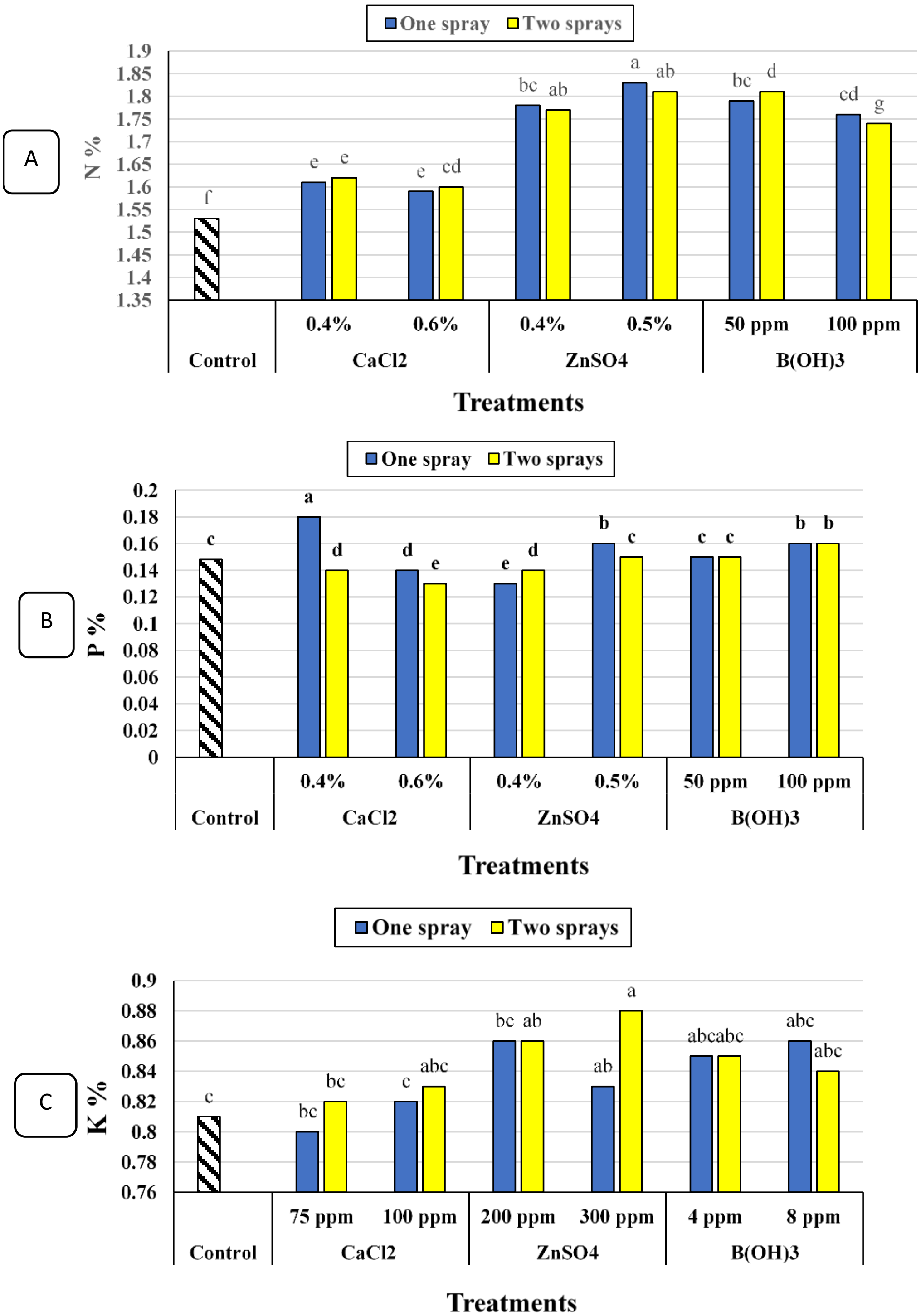

Fig. 3 (A, B, C): Effect of once or twice foliar applications of $CaCl_2$, $ZnSO_4$ and $B(OH)_3$ on NPK contents of guava leaves.

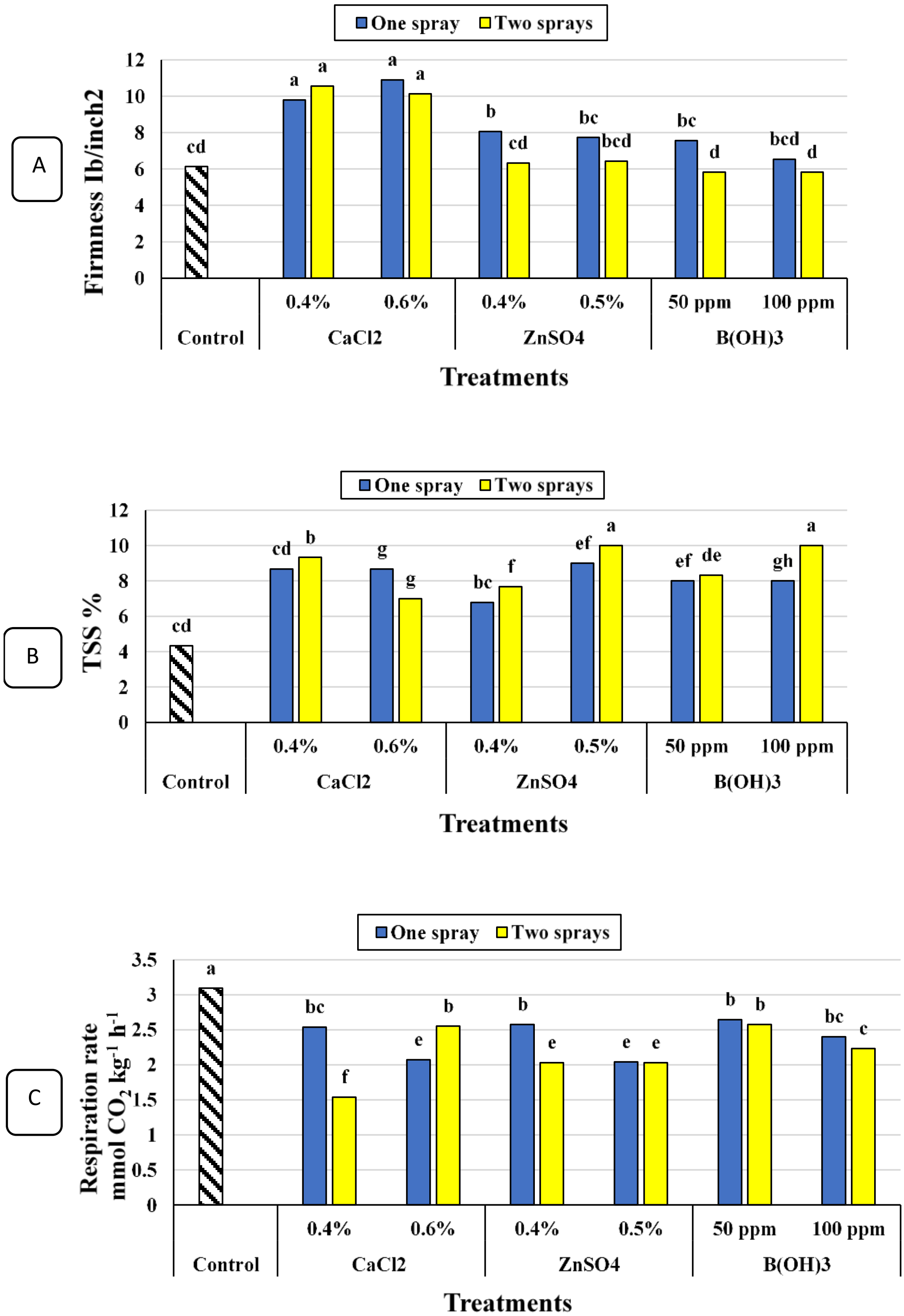

Fig. 4 (A, B, C): Effect of once or twice foliar applications of $CaCl_2$, $ZnSO_4$ and $B(OH)_3$ on some of fruit quality (firmness, TSS, and respiration rate) of guava.

تحسين الصفات الفسيولوجية والبيوكيميائية لأوراق وثمار الجوافة بأستخدام الرش الورقى لكل من كلوريد الكالسيوم، كبريتات الزنك وحمض البوريك.

محمود كمال سلامه [1,*]، مصطفي عبد القادر النبراوي [1]، مجدى عبدالوهاب عمر [1]، مصطفى زكي سلطان [2]

[1] *قسم النبات الزراعي, كلية الزراعة, جامعة الازهر, القاهرة, مصر.*
[2] *قسم البساتين, كلية الزراعة, جامعة الازهر, القاهرة, مصر.*

* البريد الإلكتروني للباحث الرئيسي:mahmoudkamal@azhar.edu.eg

الملخص العربي

ركزت هذة الدراسة على تأثيرات بعض العناصر الغذائية مثل كلوريد الكالسيوم بتركيز 0.4 و 0.6٪ ، كبريتات الزنك عند 0.4 و 0.5٪ وحمض البوريك عند 50 و 100 جزء في المليون رشة واحد واثنتان. في تأخير شيخوخة الأوراق وجودة الثمار لمحصول الجوافة. التي يبلغ عمرها أحد عشر سنة تحت تصميم البلوكات العشوائية فى مزرعة تجارية مخصصة لزراعة الجوافة بمركز قليوب بمحافظة القليوبية، مصر. اتضح في هذه التجربة، تحسن كبير للرش الورقي بكلوريد الكالسيوم ، كبريتات الزنك وحمض البوريك على الخصائص الفسيولوجية والبيوكيميائية في الأوراق مما أدى إلى زيادة في صبغات التمثيل الضوئي، والبرولين و محتوى السكريات الكلية والفينولات الكلية ومحتوي النيتروجين والفوسفور والبوتاسيوم وانخفاض فى الأنثوسيانين وانزيمات مضادات الأكسدة (البيروكسيديز والبولي فينول أوكسديز) مما انعكس إيجابيًا على جودة ثمار الجوافة وأدى إلى زيادة الصلابة والمواد الصلبة الكلية الذائبة وانخفاض معامل التنفس مقارنة مع الكنترول، فى كل المعاملات كانت الرشة الواحدة افضل من الرشتين، علي الرغم من تميز الرشتين فى بعض الحالات عن الرشة الواحدة.

الكلمات الاسترشادية: الجوافة ؛ معاملات قبل الحصاد؛ المغذيات؛ النشاط الانزيمي؛ برولين؛ انثوسيانين؛ ومعامل التنفس.