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Effect of humic acid and zinc sulphate on fruit quality and post-harvest life of acid lime (*Citrus aurantifolia* Swingle)

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Abstract
The present investigation was undertaken with the view of determining the "effect of humic acid and zinc sulphate on quality and post-harvest life acid lime (*Citrus aurantifolia* Swingle)". The experiment was carried out in a completely randomized design with three repetitions and seven treatments comprised of foliar application at pea stage of humic acid alone or with a combination of zinc sulphate. Results obtained, among all the treatments, T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) was the most effective and it recorded significantly the maximum shelf life (16.14 days) the lowest physiological in weight (8.36%) spoilage % (3.55%) and average seed content (8.97). The foliar application of humic acid and zinc sulphate significantly affected quality parameters, *viz.*, TSS (oBrix), ascorbic acid (mg/100 ml of juice) and juice content (%). Among all the treatments, the T6 treatment was the most effective and recorded significantly the maximum TSS (8.27 oBrix), ascorbic acid (37.70 mg/100 ml) and juice content (46.73%), while treatment T1 (Control) recorded significantly the maximum acidity (8.21%). Similarly, 10 days after harvest, the same treatment T6 had the highest TSS (8.50 oBrix), ascorbic acid (34.37 mg/100 ml), and juice content (46.73%), while treatment T1 (control) had the highest acidity retention (8.14%).

Keywords: *Citrus aurantifolia* Swingle, Humic acid $ZnSO_4$, shelf-life, quality attributes

Introduction

With its lovely evergreen foliage and blossoms, acid lime has a lovely appearance, as well as a wonderful scent that adds to its aesthetic and flavorful value. The fruits are also prized for their superior nutritional qualities. Acid lime juice is an excellent food source that is high in vitamins and other nutritional qualities due to its balanced ratio and precise combination of acidity and sweetness. Vitamin C (62.95 mg/100 m1), vitamin B1 (0.02 mg/100 m1), vitamin B2 (0.06 mg/100 m1), calcium (90 mg/100 m1), phosphorous (20 mg/100 m1), and iron (0.3 mg/100 m1) are all present in high concentrations.

Acid lime is a polyembryonic shrub with thorns. On the leaves, petiole wings are visible. The white flowers grow in clusters and are small. The fruits are smooth, round or oval, and have a thin rind (paper) that is lightly attached. The juice is very acidic and greenish-white in colour.

Acid lime begins to produce flowers and fruits after the fourth year of planting. The trees bloom all year in their natural habitat, with new blossoms appearing with each flush. The fruit matures six months after flowering. The species, varieties, and cultivation regions all influence acid lime harvesting. On average, a mature acid lime plant (7 years old) produces 600-800 fruits. The acid lime plant produces throughout the year, but the main season is from July to September.

Humic acid is one of the bio-stimulants, which are organic materials that promote plant growth and help plants to withstand harsh environments, when used in small amounts. It promotes proper plant growth while also increasing nutrient uptake, tolerance to drought and temperature extremes, the activity of beneficial soil microorganisms, and the availability of soil nutrients, especially in alkaline soils with low organic matter. Humic acid stimulates and increases plant enzyme production. It has been shown to thicken the cell wall of fruit, thereby extending storage and shelf life. Humic acid also promotes plant growth (increased biomass production) by hastening cell division, quickening root system development, and increasing dry matter yield. As a result, the use of humic acid improves nutrient availability, particularly micro element availability, in calcareous soil because it acts as a chelating agent and promotes nutrient uptake.

Materials and Methods

An experiment was carried out on thirteen-year-old acid lime trees established at the Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand, during the academic year 2017-18. Photographs were taken of a thirteen-year-old acid lime orchard with well-maintained trees of comparable heights and canopy. The experiment used a completely randomized design, with seven treatments and three replications of one plant each. T1) One of the treatments considered was control. T2) Humic acid 20 mg/l, T3) Humic acid 20 mg/l + $ZnSO_4$ 0.5%, T4) Humic acid 20 mg/l + $ZnSO_4$ 1.0%, T5) Humic acid 40 mg/l, T6) Humic acid 40 mg/l + $ZnSO_4$ 0.5%, and T7) Humic acid 40 mg/l + $ZnSO_4$ 1.0%.

The application was made as a foliar spray at the pea stage, and the second spray was made 30 days after the first. The foliar spray of humic acid was applied in the morning hour at the pea stage (3rd week of March), and $ZnSO_4$ was sprayed after 4 days, and the second spray was done 30 days after the first spray with the help of a 'foot spray pump' until the entire plant was completely wet. Fruits were harvested when they were mature, when the colour of the fruits changed from green to a pale green. Each treatment resulted in healthy, pest- and disease- free animals, as well as injuries, bruises, and blemishes. All observations regarding yield and quality parameters of fruits were recorded at first picking (in June) from each replication treatment and analysed in the P.G. laboratory, Department of Horticulture, BACA, AAU, Anand. Under normal storage conditions.

Parameters to be recorded

For counting physiological weight loss, the 10 fruits of each treatment were harvested and the weight of each fruit was taken every day for 10 days, and weight loss was expressed as a percentage of weight loss compared to the initial weight. The ten fruits from each treatment were harvested and stored separately at room temperature. The data was collected every day after harvest, and the average data days from harvest to consumable quality were used to determine the shelf life of the fruits. The stored fruits from each treatment were thoroughly examined at harvest and every day after harvest for visible signs of spoilage for up to 10 days and expressed as a percentage.

A lemon squeezer was used to extract the juice from ten different fruits. For each treatment, the percentage of juice content was calculated in relation to the weight of the fruit. The total soluble solids were measured using an Erma Hand refractometer (0-32 °Brix). Ten fruits from each treatment were used to calculate the TA value by exposing the juice to a sodium hydroxide solution. Phenolphthalein was used as an indicator (Ranganna, 14). The ascorbic acid content was determined using the 2,6-chlorophenol indophenols visual titration method (AOAC.1965) and ascorbic acid content was measured in milligrams of ascorbic acid equivalents per milliliter of fresh weight basis (mg/ml). For each treatment, three replications were completed, with ten fruits in each replication.

Results and Methods

Effect of humic acid and zinc sulphate on postharvest life fruit acid lime

The foliar application of individual humic acid and zinc sulphate, as well as their combinations, resulted in a significant effect on physiological weight loss (%) in acid lime, as shown in Table 1.0. Treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) achieved the lowest physiological weight loss (8.36%), and it was statistically comparable to T2 (Humic acid 20 ml/l), T3 (Humic acid 20 ml/l + $ZnSO_4$ 0.5%) and T4 (Humic acid 20 ml/l + $ZnSO_4$ 1.0%). T5 (Humic acid 40 ml/l) and T7 (Humic acid 40 ml/l + $ZnSO_4$ 1.0%) were found to be non- significant in comparison to T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%). While treatment T1 (water spray) resulted in the greatest physiological weight loss (11.21%). The reduction in physiological weight loss caused by humic acid application could be attributed to thickening of the cell wall in fruit, which leads to a slower respiratory rate and delayed senescence. Shaaban *et al*. (2015) [34] found a similar result in "Canino" apricot fruits.

The results obtained regarding the shelf life of fruits under ambient storage condition as significantly influenced due to foliar application of humic acid and zinc sulphate are furnished in Table 1.0 The treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest shelf life (16.14 days) and was statistically equal to T4 (Humic acid 20 ml/l + $ZnSO_4$ 1.0 percent) and T5 (Humic acid 40 mL/L). T7 (Humic acid 40 mL/L + $ZnSO_4$ 1.0%), on the other hand, was found to be non-significant in comparison to T6 (Humic acid 40 mL/L + $ZnSO_4$ 0.5%). Treatment T13 (water spray), on the other hand, had the shortest fruit shelf life (12.56 days). Increased shelf life may be due to humic acid stimulating plant enzyme activity and cell wall firmness in fruits, thereby extending shelf life. Farahi *et al.* (2013) [10] reported similar results in strawberry, and Sindha *et al.* (2018) [36] reported similar results in custard apple.

The data pertaining to the number of seeds per fruit and spoilage (%) influenced by different treatments of humic acid and zinc sulphate are presented in Table 1.0. The foliar application of humic acid and zinc sulphate and their combinations were found to produce a significant effect on the number of seeds/per fruit spoilage (%). However, no possible reason or reference was found this result of humic acid and zinc sulphate.

Effect of humic acid and zinc sulphate on postharvest fruit quality of acid lime

The data of fruit quality, namely total soluble solids, ascorbic acid content, and juice content, were significantly influenced by increasing levels of humic acid and zinc sulphate, but the level of acidity was slightly decreased, as shown in Table 2.0. Treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest TSS (8.27 °Brix) at harvest, and it was statistically equal to treatments T4 (Humic acid 20 ml/l + $ZnSO_4$ 1.0%), T5 (Humic acid 40 ml/l), and T7 (Humic acid 40 ml/l + $ZnSO_4$ 1%). Under treatment T1 (water spray), the lowest TSS (7.43 °Brix) was recorded. After 10 days, the highest TSS (8.50 °Brix) was retained in treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) and was statistically comparable to treatment T4 (Humic acid 40 mg/l). However, T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%), T5 (Humic acid 40 ml/l), and T7 (Humic acid 40 ml/l + $ZnSO_4$ 1%) were statistically insignificant in comparison to the other treatments. Treatment T1 (water spray), on the other hand, yielded the lowest TSS (7.60 °Brix).

The increase in total soluble solids with storage period advancement could be attributed to a variety of catabolic processes that occur in fruits during ripening and senescence. TSS levels may have risen due to water loss and the hydrolysis of starch and other polysaccharides to soluble sugars. Furthermore, El-Mohamedy *et al*. (2009) [22] found a similar effect in mandarin, and Shehata *et al.* (2011) [35] found a similar effect in strawberry. The decrease in titratable acidity during storage may be attributed to the use of organic acids in the pyruvate decarboxylation reaction that occurs during the fruit ripening process. Ennab (2016) [9] In Egyptian lime. The data presented in Table 2.0 show that treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest ascorbic acid content (37.70 mg/100 ml) and juice content (46.73%) and remained statistically equal to treatments T4 (Humic acid 20 ml/l + $ZnSO_4$ 1.0%), T5 (Humic acid 40 ml/l), and T7 (Humic acid 40 ml/l). Under treatment T1 (water spray), however, the minimum ascorbic acid content (30.24 mg/100 ml) and juice content (39.38 percent) were recorded. Similarly, after 10 days of harvest, treatment T6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest ascorbic acid content (34.37 mg/100 ml) and the highest juice retention %). Under treatment T1 (water spray), the minimum ascorbic acid content (27.14 mg/100 ml) and minimum juice content (28.17 percent) were recorded.

It is possible that humic acid increased the permeability of bio membranes for electrolytes, resulting in increased phosphorus and potassium uptake, which increases the ascorbic acid percentage of the fruits. Abbas *et al.* (2013) [1] reported similar results in Kinnow mandarin and Ahmed *et al.* (2014) [2] in Valencia orange. The increased juice content could be attributed to humic acid, which increased the mobilization and accumulation of foods and minerals from other parts of the plant towards the developing fruits, resulting in an increased source to sink ratio and increased juice content of the fruits. In Egyptian lime, Ennab (2016) [9] obtained similar results, as did Meena *et al.* (2017) [20] in Nagpur mandarin.

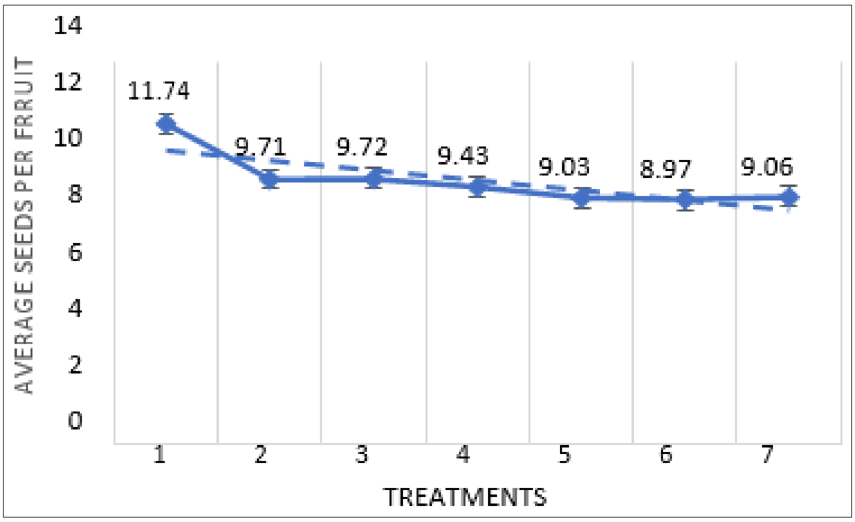

Fig 1: Average seeds per fruit

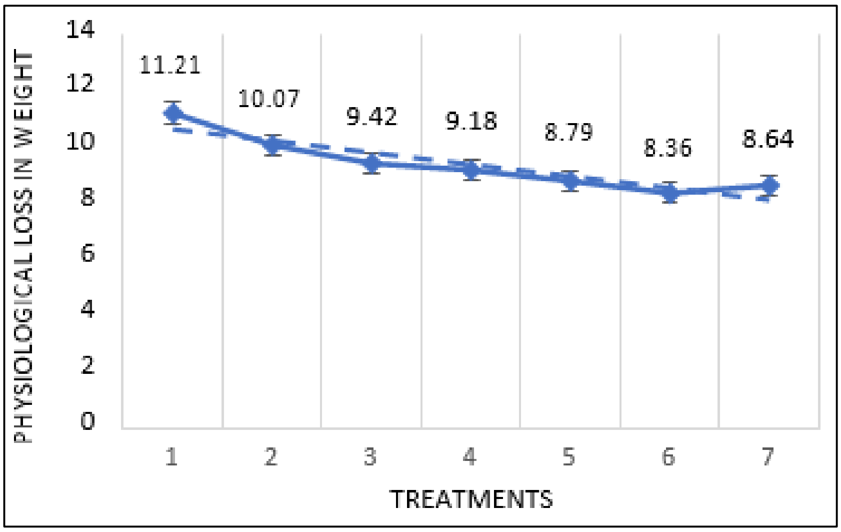

Fig 2: Physiological loss in weight

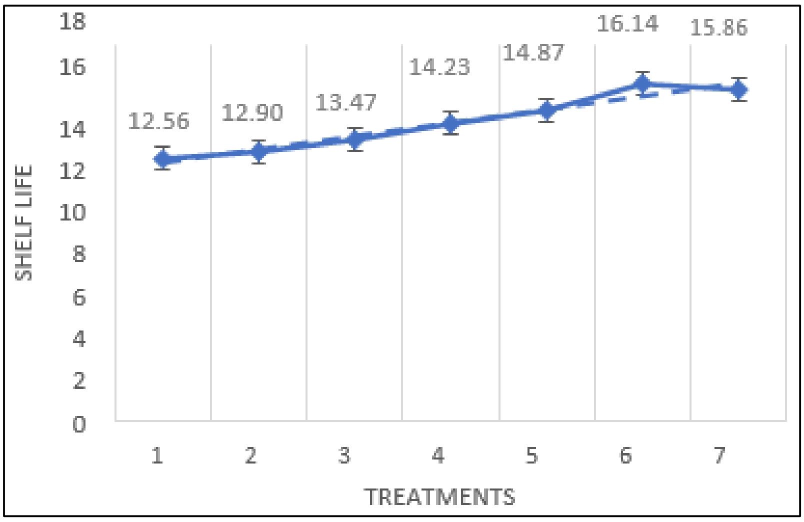

Fig 3: Shelf life

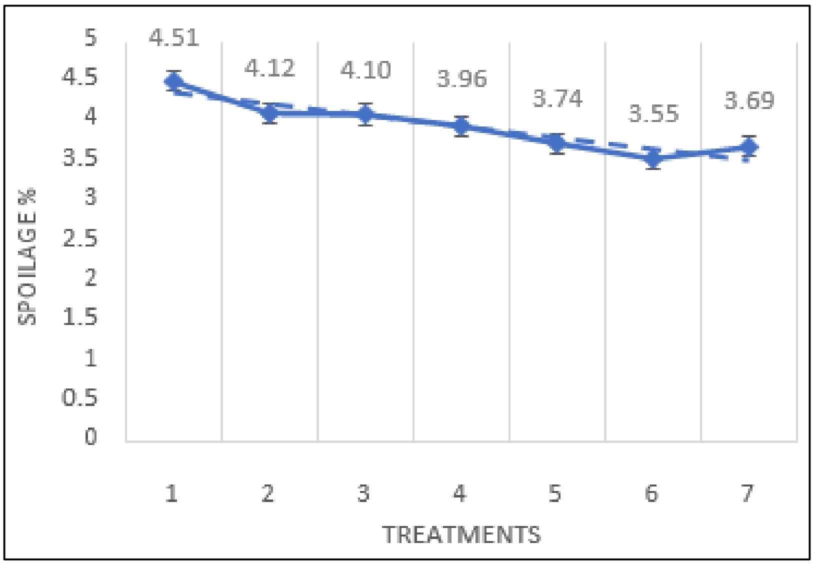

Fig 4: Spoilage %

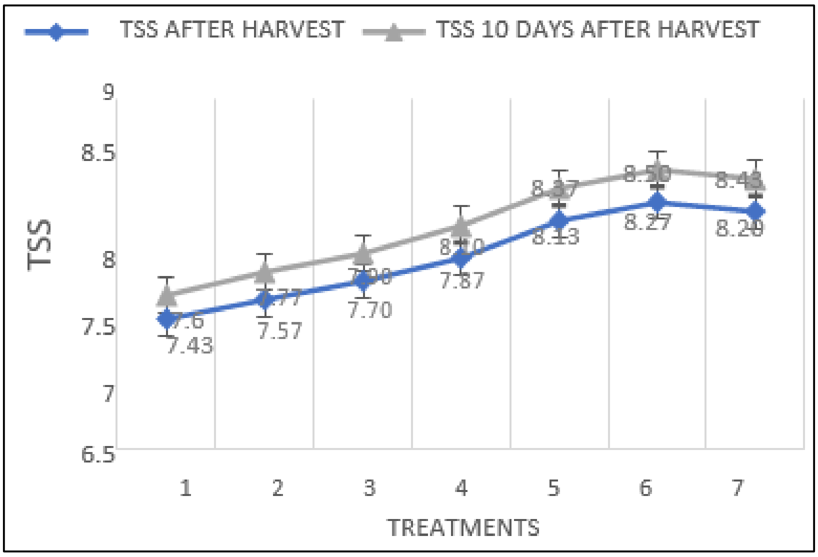

Fig 5: TSS

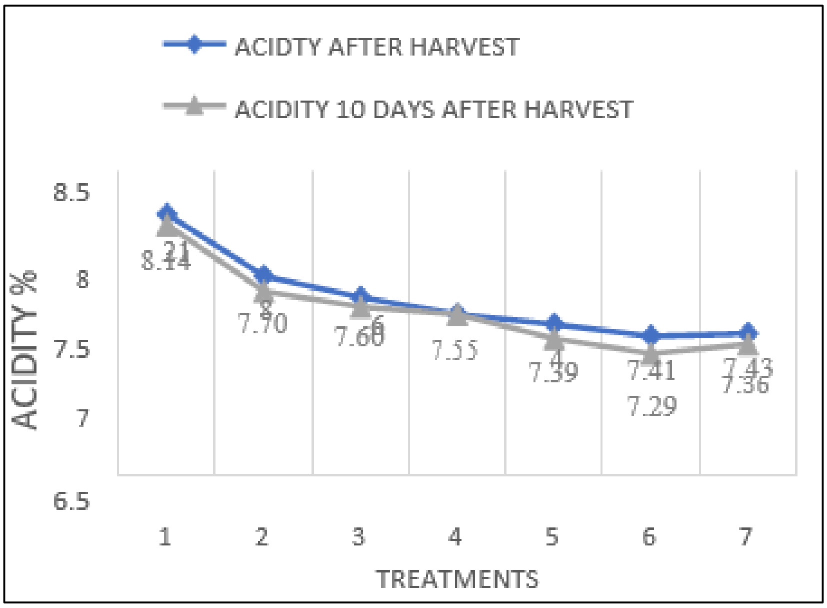

Fig 6: Acidity %

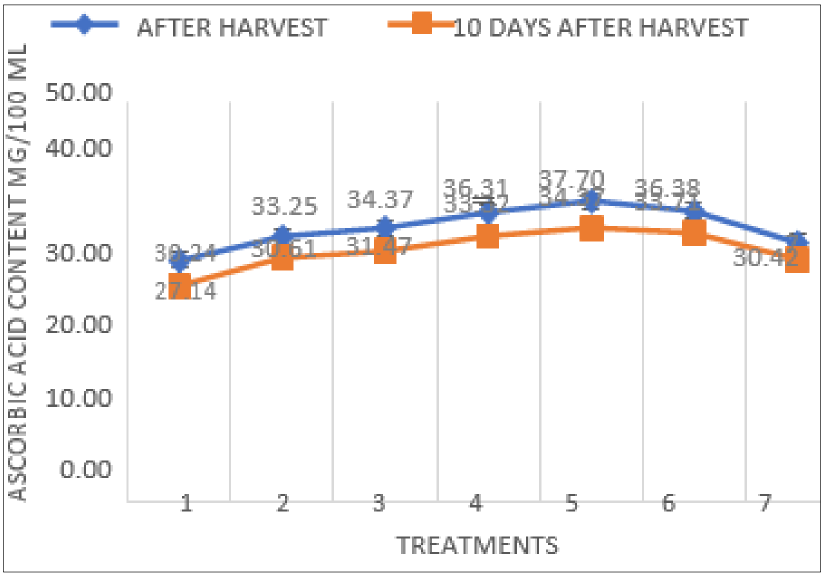

Fig 7: Ascorbic acid content mg/100 ml

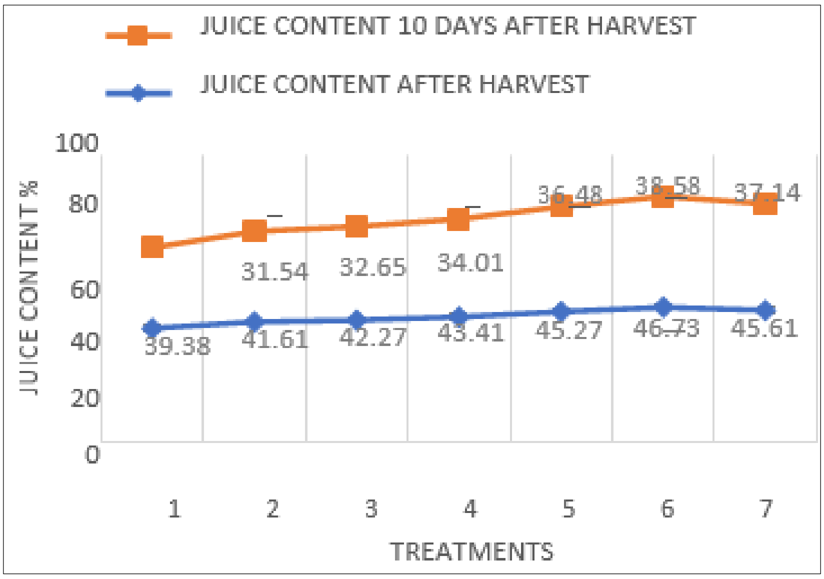

Fig 8: Juice content %

Table 1: Effect of humic acid and $ZnSO_4$ on fruit growth, yield and pre-harvest fruit drop of acid lime.

S. No	Treatments	No. of seeds/fruit	Shelf life (days)	PLW (%)	Spoilage (%)
T1	Control	11.73b	12.56 c	11.21 c	4.51b
T2	Humic acid 20 ml/l	9.71 a	12.90 bc	10.07ab	4.12 ab
T3	Humic acid 20 ml/l + $ZnSO_4$ 0.5%	9.72 a	13.47 bc	9.42 ab	4.10 ab
T4	Humic acid 20 ml/l + $ZnSO_4$ 1.0%	9.43 a	14.23abc	9.18 ab	3.96 ab
T5	Humic acid 40 ml/l	9.03 a	14.87 abc	8.79 a	3.74 a
T6	Humic acid 40 ml/l + $ZnSO_4$ 0.5%	8.97 a	16.14 a	8.36 a	3.55 a
T7	Humic acid 40 ml/l + $ZnSO_4$ 1.0%	9.06 a	15.86 a	8.64 a	3.69 a
	F test at 5 % level of significance	Sig.	Sig	Sig	Sig.

Note: Treatment means with the letter / letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

Table 3: Effect of humic acid and $ZnSO_4$ on quality after harvest and 10 days after harvest of Acid lime.

S. No	Treatments	TSS (Brix)		Acidity (%)		Ascorbic acid (mg/ml)		Juice (%)	
		At harvest	10 days after harvest	At harvest	10 days after harvest	At harvest	10 days after harvest	At harvest	10 days after harvest
T1	Control	7.43 c	7.63 b	7.88 b	7.69 b	30.24 b	27.14 c	39.38 c	28.17 c
T2	Humic acid 20 ml/l	7.57 c	7.77 bc	7.80 ab	7.70 ab	32.47 bc	30.42 b	41.61 bc	31.54 de
T3	Humic acid 20 ml/l + $ZnSO_4$ 0.5%	7.70 bc	7.90 bc	7.66 ab	7.60 ab	33.25 bc	30.61 b	42.27 abc	32.65 cd
T4	Humic acid 20 ml/l + $ZnSO_4$ 1.0%	7.87 abc	8.10 ab	7.55 ab	7.55 ab	34.37 ab	31.47 ab	43.41 abc	34.01 bcd
T5	Humic acid 40 ml/l	8.13 abc	8.37 a	7.49 a	7.39 a	36.31 ab	33.32 ab	45.27 ab	36.48 abc
T6	Humic acid 40 ml/l + $ZnSO_4$ 0.5%	8.27 a	8.50 a	7.41 a	7.29 a	37.70 a	34.37 a	46.73 a	38.58 a
T7	Humic acid 40 ml/l + $ZnSO_4$ 1.0%	8.20 ab	8.43 a	7.43 a	7.36 a	36.38 ab	33.71 ab	45.61 ab	37.14 ab
	F test at 5% level of significance	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Note: Treatment means with the letter / letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Conclusion

Based on the findings of this study, it can be concluded that foliar spraying with humic acid 40 ml/l + $ZnSO_4$ 0.5 percent at pea stage (March 15th) and a second spray 30 days later was the most effective for extending shelf life and reducing spoilage percent as well as physiological weight loss during storage. It also improves quality parameters such as TSS, ascorbic acid, and juice content of fruits and keeps them stable during storage.

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