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Impact of humic acid and zinc sulphate on pre-harvest fruit drop and fruit growth of acid lime (*Citrus aurantifolia* Swingle)

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Abstract
The present investigation was undertaken with the view of determining the impact of humic acid and zinc sulphate on preharvest fruit drop and fruit growth of 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. The foliar application of humic acid and zinc sulphate had a significant effect on preharvest fruit drop and fruit growth of acid lime. Among all the treatments, T_6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) was the most effective, and it recorded significantly lowest fruit drop (16.16%), the maximum fruit volume (33.55 cc), fruit weight (34.20 g), fruit diameter (4.34 cm), number of fruits per plant (1641.33) and fruit yield (56.13 kg/plant).

Keywords: *Citrus aurantifolia* Swingle, humic acid $ZnSO_4$, preharvest fruit drop and fruit growth

Introduction
Acid lime has a lovely appearance with its lovely evergreen foliage and blossoms, as well as a wonderful scent that adds to its aesthetic and flavoured value. The fruits are also highly valued for their exceptional nutritional properties. Because of its balanced ratio and precise combination of acidity and sweetness, acid lime juice is an excellent food source that is high in vitamins and other nutritional qualities. It has a high concentration of 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).

Acid lime is a thorny, polyembryonic shrub. Petiole wings are present on the leaves. The flowers are small and white, and they grow in clusters. The fruits are round or oval, smooth, and have a thin rind (paper) attached lightly. The juice is greenish-white in colour and very acidic.

From the fourth year after planting, acid lime begins to bear flowers and fruits. Under natural conditions, the trees bloom all year, and each flush produces new blossoms. Six months after flowering, the fruits mature. The harvesting of acid lime is dependent on the species, varieties, and cultivation regions. A good acid lime plant (7 years old) can produce 600-800 fruits per plant on average. The acid lime plant produces throughout the year, but the main season is from July to September.

When applied in small amounts, humic acid is one of the bio-stimulants, which are organic materials that promote plant growth and help plants to withstand harsh environments. It is extremely beneficial to both plants and soil; 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, particularly in alkaline soils with low organic matter. Humic acid stimulates and increases the production of plant enzymes. It is known to thicken the cell wall in fruit, extending storage and shelf life. Humic acid also promotes plant growth (increased biomass production) by speeding up cell division, increasing the rate of development in root systems, and increasing dry matter yield. As a result, the use of humic acid improves nutrient availability, particularly microelement availability, in calcareous soil because it promotes nutrient uptake as a chelating agent.

Materials and Methods
During the academic year 2017-18, an experiment was conducted 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. A thirteen-year-old acid lime orchard with well-maintained trees of comparable heights and canopy were photographed. The experiment was set up in a completely randomized design, with 7 treatments and 3 replications of 1 plant each. T_1) Control was one of the treatments considered. T_2) Humic acid 20 mg/l, T_3) Humic acid 20 mg/l + $ZnSO_4$ 0.5%, T_4) Humic acid 20 mg/l + $ZnSO_4$ 1.0%, T_5) Humic acid 40 mg/l, T_6) Humic acid 40 mg/l + $ZnSO_4$ 0.5%, and T_7) Humic acid 40 mg/l + $ZnSO_4$ 1.0%.

Application was given as a foliar spray at pea stage and 2nd spray was given 30 days after 1st spray. The foliar spray of humic acid was applied at pea stage (3rd week of March) in the morning hour and $ZnSO_4$ was sprayed after 4 days and 2nd spray was done after 30 days of the first spray with the help of 'foot spray pump' till the whole plant was completely wet. Fruits were harvested at a mature stage, when the colour of the fruits changed from green to a pale green colour. Healthy, free from pests and diseases, injuries, bruises and blemishes were collected from each treatment. All observations regarding yield and quality parameters of fruits were recorded at first picking (in the month of June) from each treatment of replications and analysed in P.G. laboratory, Department of Horticulture, BACA, AAU, Anand. Under ambient storage conditions.

Parameters to be recorded

Each tree's percentage of fruit drops was calculated, and the total number of fruit drops was counted at each harvest. Using the following formula, data was used to calculate the pre-harvest fruit drop percent.

$$\text{Fruit drop (\%)} = \frac{\text{Total number of harvested fruits-Total number of dropped fruits}}{\text{Total number of harvested fruits}} \times 100$$

The number of fruits was counted at each harvest and then totaled, which was expressed as the number of fruits per tree. Ten marketable fruits were randomly selected from each treatment, their total weight was recorded, and the average fruit weight in grammes was calculated. Five matured, harvested acid lime fruits were randomly selected from each treatment, and the diameters of the selected fruits were measured with a Vernier Caliper, and the average value was calculated in centimeters. The volume of acid lime fruit was measured using the water displacement method. Fruit was placed in a 250 ml measuring beaker filled with water. The fruit was placed in a cylinder, the replaced water was measured in volume, and data were recorded as volume of fruits in (cc), after which the average value of five acid lime fruits was calculated. The fruits harvested from each tree were weighed in kilograms throughout the picking process, and the total was expressed as yield (kg/tree).

Results and Methods

Effect of humic acid and zinc sulphate on fruit growth and yield potential of acid lime. The effect of different humic acid, and zinc sulphate treatments on fruit drop (%) and total number of fruits per tree were presented in Table 1. The lowest fruit drop (16.16 percent) was recorded in treatment T_6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%), which was statistically comparable to treatments T_4 (Humic acid 40 mg/l), T_5 (Humic acid 40 mg/l + $ZnSO_4$ 0.5%) and T_7 (Humic acid 40 mg/l + $ZnSO_4$ 1.0%), on the other hand, Treatment T_1 (water spray) had the highest fruit drop (26.72%). In terms of total number of fruits per tree, treatment T_6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest number of fruits/tree (1641.33), which was statistically comparable to treatments T_3 (Humic acid 20 ml/l + $ZnSO_4$ 0.5%), T_4 (Humic acid 20 mg/l $ZnSO_4$ 1%), T_5 (Humic acid 40 mg/l) and T_7 (Humic acid 40 mg/l + $ZnSO_4$ 1.0%). The reduction in fruit drop might be due to the humic acid stimulate the synthesis of endogenous auxin, which prevent the abscission and facilitated the fruits to remain the attached with shoot, resulting in reduced fruit drop. Similar result was reported by Razzaq *et al.* (2013) [33] in Kinnow mandarin and Venu *et al.* (2016) [39] in acid lime. Shaaban *et al.* (2015) [34] in apricot, Ennab (2016) [9] in Egyptian lime, Iftikhar *et al.* (2017) [14] in Kinnow mandarin, Table 1.0 shows the data for fruit weight (g), fruit diameter (cm), and fruit volume (cc) that were significantly influenced by different humic acid and zinc sulphate treatments. Treatment T_6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) had the highest fruit weight (34.20 g), fruit volume (4.34 cm), and fruit volume (33.55 cc), which was statistically equal to treatments T_2 (Humic acid 20 ml/l), T_3 (Humic acid 20 ml/l + $ZnSO_4$ 0.5%), and T_4 (Humic acid 20 mg/l $ZnSO_4$ 1%). Fruit weight, with the exception of T_2 (Humic acid 20 ml/l), fruit diameter, with the exception of T_2 (Humic acid 20 ml/l), T_3 (Humic acid 20 ml/l), and fruit volume, with the exception of T_1 (water), were not statistically comparable to treatments. Increased fruit weight, diameter, and volume may be due to humic acid activating hormones like auxin and cytokinin, resulting in higher mobilization of foods and minerals from other parts of the plant towards the developing fruits, which are extremely active metabolic sinks, resulting in increased fruit weight. Meena *et al.* (2017) [20] found similar results in Nagpur mandarin, Mohammed *et al.* (2018) [23] in lemon, Eman *et al.* (2007) [8] in Washington novel orange, and Amro and Salama (2015) [4] in orange.

The data on acid lime yield significantly influenced by the effects of humic acid and zinc sulphate are presented in Table 1.0 and graphically in Fig. 4. Treatment T_6 (Humic acid 40 ml/l + $ZnSO_4$ 0.5%) produced the highest fruit yield (56.13 kg per plant), which was statistically comparable to treatments T_3 (Humic acid 20 ml/l + $ZnSO_4$ 0.5%), T_4 (Humic acid 20 ml/l + $ZnSO_4$ 1.0%), T_5 (Humic acid 40 ml/l), and T_7 (Humic acid 40 ml/l + $ZnSO_4$ 1%) However, treatment T_1 (water spray) produced the lowest fruit yield (37.47 kg/plant). Humic acid improves mineral nutrient uptake and translocation, as well as cation exchange in soil. It also acts as a plant hormone-like activity of humic substances, responsible for increased cell division and cell enlargement, as well as regulating the semi-permeability of cell walls, mobilizing more water into the fruits and thus increasing fruit diameter. Increased metabolic activities resulted in increased stored food material in tissue, resulting in increased fruit volume and, possibly, increased fruit yield. lime Serenella *et al.* (2002) discovered similar results in grapes, Asgharzade and Babaeian *et al.* (2012) [6] discovered similar results in pomegranates, and Khattab *et al.* (2012) [17] discovered similar results in pomegranates.

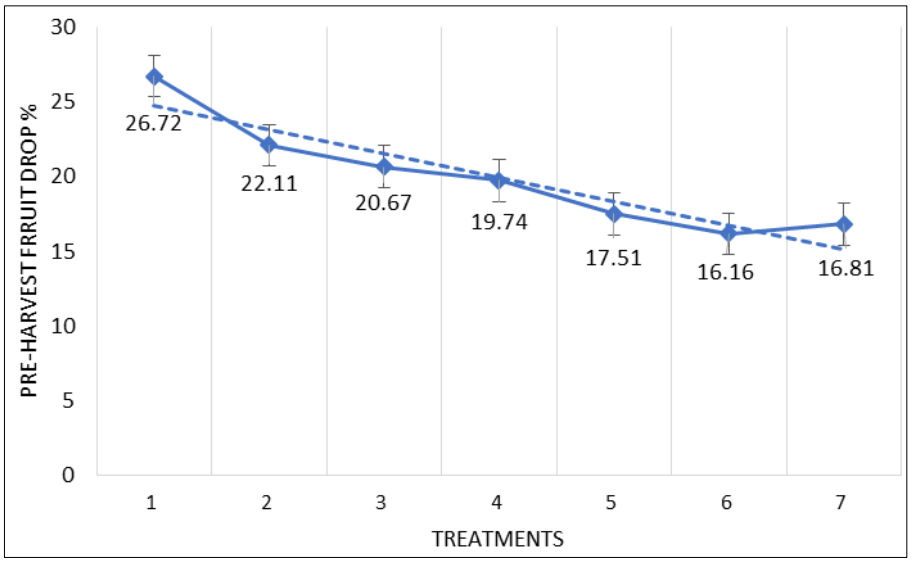

Fig 1: Pre-harvest fruit drop %

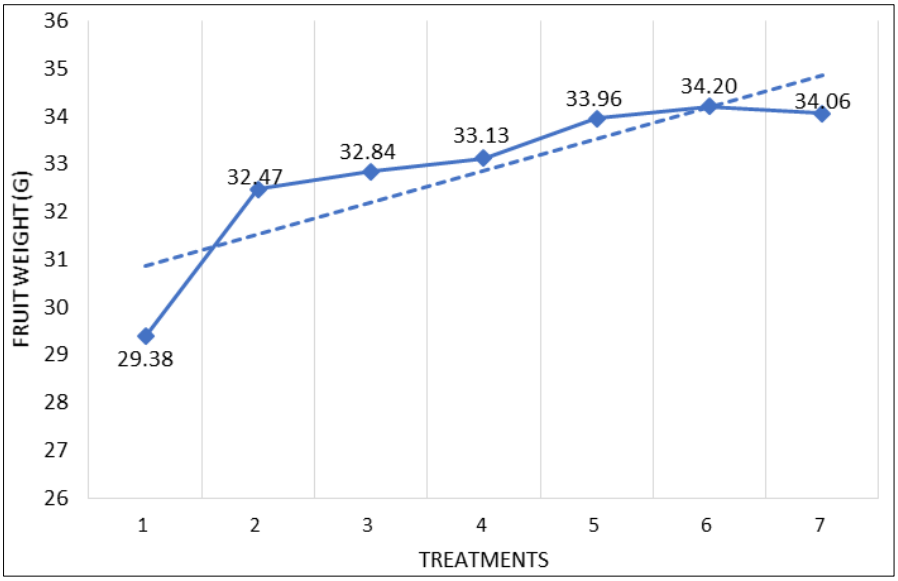

Fig 2: Fruit weight

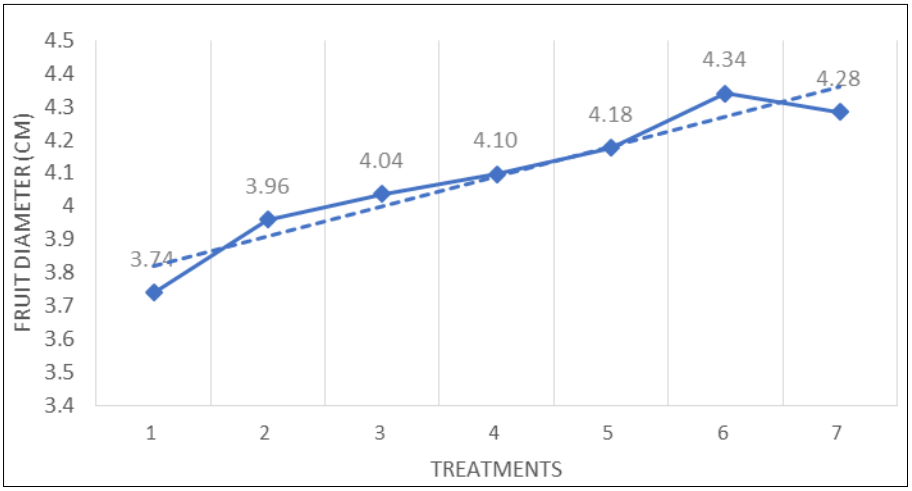

Fig 3: Fruit diameter

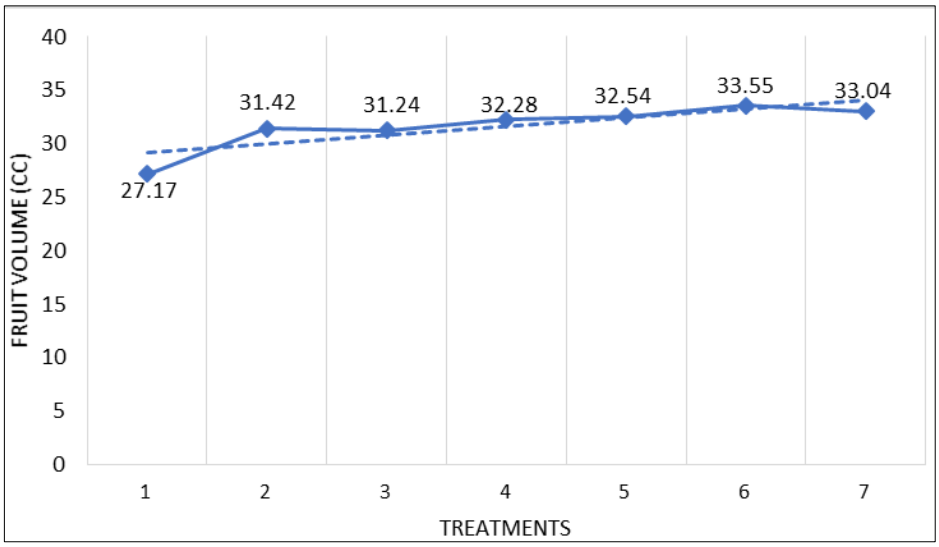

Fig 4: Fruit volume

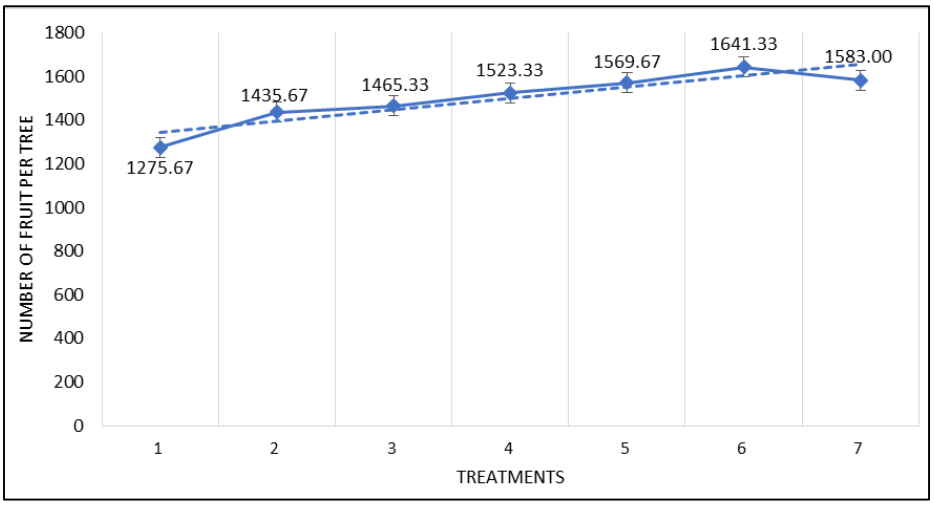

Fig 5: Number of fruits per tree

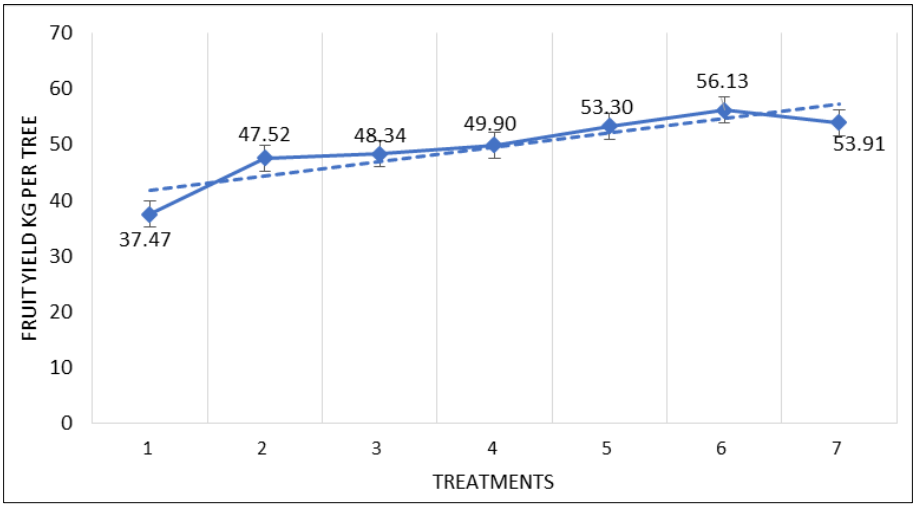

Fig 6: Fruit yield

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

S. No	Treatments	Pre-harvest fruit drop (%)	No. of fruits/tree	Fruit weight (gm)	Fruit diameter (cm)	Fruit volume (cc)	Fruit yield (kg/tree)
T_1	Control	26.72 d	1275.66 c	29.38 b	3.74 b	27.17 b	37.47 c
T_2	Humic acid 20 ml/l	22.11 bc	1435.67 bc	32.47ab	3.96 ab	31.42 a	47.52 b
T_3	Humic acid 20 ml/l + $ZnSO_4$ 0.5%	20.67 bc	1465.33 ab	32.84 a	4.04 ab	31.24 a	48.34 ab
T_4	Humic acid 20 ml/l + $ZnSO_4$ 1.0%	19.74 abc	1523.33 ab	33.13 a	4.10 ab	32.28 a	49.90 ab
T_5	Humic acid 40 ml/l	17.51 ab	1569.67 ab	33.96 a	4.18 a	32.54 a	53.30 ab
T_6	Humic acid 40 ml/l + $ZnSO_4$ 0.5%	16.16 a	1641.33 a	34.20 a	4.34 a	33.55 a	56.13 a
T_7	Humic acid 40 ml/l + $ZnSO_4$ 1.0%	16.81 ab	1583.00 ab	34.06 a	4.28 a	33.04 a	53.91 ab
F test at 5% level of significance		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

On the basis of finding of the present study, it can be concluded that foliar spray of humic acid 40 ml/l + $ZnSO_4$ 0.5% at pea stage (dated on 15th March) and 2nd spray 30 days after 1st spray was most effective for increasing number of fruit/trees, fruit yield, fruit weight, fruit diameter, fruit volume and reducing the fruit drop of acid lime.

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