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Effect of Foliar Application of Salicylic Acid and Zinc Levels on the Growth Quality and Yield of Muskmelon

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Abstract. The use of foliar applications to enhance crop growth and yield has become an important strategy in modern agriculture, particularly for fruit crops like muskmelon (*Cucumis melo* L.) known for its nutritional value and economic significance. This research focus on the growth, quality and yield of muskmelon was conducted at platoo Mardan, during 2018. The research was laid out in two factor Randomized complete block design (RCBD). Factor “A” consists of different zinc levels (0, 25, 50 and 75 ppm) while Factor “B” consist of different salicylic acid (SA) concentrations (0, 50, 100 and 150 ppm) which were applied as foliar application 40 days after sowing. The maximum fruit volume (12.40 cm^3), rind thickness (0.28 mm) and total soluble solid (11.73 $^{\circ}$Brix) were significantly affected by 75 ppm of zinc concentration. Whereas, the maximum number of branches (6.83), total yield/ha (12.61 tons) and fruit firmness (9.00 cm^3) were recorded in plants treated with 50 ppm of zinc concentration. While salicylic acid the maximum yield/he (12.82 tons), fruit volume (13.18 cm^3), rind thickness (0.28 mm), total soluble solid (10.62 °Brix) and fruit firmness (9.26 N) were recorded in plant treated with 150 ppm of salicylic acid. It can be concluded from the present results that the treatment of 75 ppm of zinc levels and 150 ppm of salicylic acid can improve the growth and production of muskmelon Cv. kandyalay under the agro. climatic condition of Mardan.

Keywords: salicylic acid, zinc, foliar application, fruit volume, total soluble solid, fruit firmness

Introduction

Muskmelon (*Cucumis melo* L.) know as cantaloupe, is a highly valued crop from the cucurbitaceae family. It is widely cultivated for its sweet flavor, rich nutritional content, significant health benefits, being a good sources of Calcium, Phosphorus and Vitamin A (Sensory *et al*., 2007). Fruit of muskmelon is important for its sweet taste (Villanueva *et al*., 2004). Muskmelon locally known as khatakey. It is juicy and important for nutritive and medicinal properties and is native to Africa and India (Wikipedia, 2005). Muskmelons have been cultivated in East and can be found in China, Turkey, North-west India, Pakistan and Afghanistan. And some varieties of cantaloupe were grown in East and West Indies (McCullum *et al*., 1992).

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Muskmelon is an important horticultural crop around the world, having an annual production of about 27.8 million tones and cultivated on an area of almost 1.4 million hectare (FAO, 2007). The total production of cantaloupe in Pakistan was about 544,966 tons (Ihsan *et al*., 2013). While in Khyber Pakhtunkhwa the total cultivated area for muskmelon cultivation was (3,147 ha) with the total production of 26,760 tons (MNFSR, 2014-2015).

Muskmelons are warm-season crops grow well in range of 18 to 24°C temperature. The best temperature for muskmelon plantation is 15 to 18 °C. While when temperatures exceed from 30 to 36 °C below 10 to 8 °C, it an effect the plant growth and cause maturation of the plants. Muskmelon cannot tolerate cold temperature even a mild frost is enough to damage the plant. Muskmelons should be planted after the frost goes to end (Coleman, 1995). Muskmelon can be cultivated on sandy loam, silt loam and well-drained soil. Loams type soils are generally for good yields and better-quality melons which may be feasible with absorbents in soils contaminated by heavy hydrocarbon (Ramírez *et al*., 2023). Crop rotation is important to reduce disease, pest and pathogens. Muskmelon is also, adapted to those areas where watermelon, pumpkin and squashes are grown (Rubatzky and Yamaguchi, 1997). Good internal and surface drainage of soil should be ensured before planting. The pH should be kept near to 6. Ridges should be raised from 15 to 20 cm above the surface to ease soil drainage (Van, 2005).

Its major problem is blossom drop off and fruit does not develop properly due to stress condition. Fruit size is small, flattened, less number of vine, branches and flowers which directly affects yield and quality of muskmelon.

For this purpose, zinc (Zn) and salicylic acid (SA) can be used. Salicylic acid is secondary plant hormones which can be used for stress condition and its essential role in plant growth, development & maturation. While zinc is effective for formation of flower, fruit and seed ultimately enhance production of the crop (Solamani *et al*., 2001). While zinc important role in Muskmelon plants was metal activator of enzymes.

The salicylic acid is the most important component of the cell wall as well as phenolic compounds, especially phytoalexin phenolic compounds that are necessary in the biosynthesis of Lignin. It plays vital role in chemical protection of the plant against germs and insects (AL-Khafaji *et al*., 2014). Crop residues can be an alternative for energy generation (Ramirez *et al*., 2024). It also play important role in secondary metabolism, which enhance root growth, gives resistance against infection by pathogens of the plant, prevent the biosynthesis of ethylene and increase the quantity of protein (Canakci and Munzuroglu 2007). Salicylic acid (SA) application in plants shows a number of responses. It activates enzyme amylase and nitrate reductase (Chen *et al*., 1993). Salicylic acid also showed synergistic impact with gibberellins and auxin (Sanaa *et al*., 2006). Salicylic acid more improve flowering as compared to other PGR such as IAA & GA3 (Shehata *et al*., 2000).

Zinc is essential micro nutrient for plant development and growth. It is involved in composition of the essential amino acids and plays essential function in metabolism by influence the actions of carbonic anhydrate, synthesis of cytochrome and stabilization of ribosomal fractions. Zinc activated some enzymes which are concerned in preservation of the integrity of protein production, cellular membranes, carbohydrate metabolism and pollen formation (Marschner *et al*., 1995). Gene expressions responsible for ecological stresses in plants are Zinc dependent (Cakmak *et al*., 2000). Zinc is needed for the synthesis of tryptophane that could be a herald of IAA (Indole acetic acid) (Sariñana-Aldaco *et al*., 2023). It also has an active function within the formation of an important growth hormone auxin (Alloway *et al*., 2004).

Considering the above function of SA and Zn which can improve the growth, yield and quality on muskmelon. The present experiment was designed with the below following objectives.

To determine the best level of SA on fruit development and growth of muskmelon; To study the suitable concentration of zinc for improving fruit quality of muskmelon; To find the interactive effect between SA and Zn on the plant growth, quality and yield of muskmelon.

Materials and Methods

A research study "Effect of foliar application of salicylic acid (SA) and zinc (Zn) on growth, quality and yield of muskmelon" was performed at Amir Muhammad Khan Research Farm Mardan Plaatoo in April 2018.

Experimental design. The field experiment was laid out in randomized complete block design (RCBD) with two (2) factors arrangement. Each treatment was replicated three times while each replication contains sixteen (16) plots, so the total plots units were forty-eight (48) Nos. Each plot area was 2m x 3m ($6m^2$) with spacing between row to row (R to R) 150 cm and plant to plant (P to P) distance was 60 cm. Each plot was having 2 rows and each row had 5 plants. The total experiment plot area was ($6m^2$ X 48) = ($288m^2$). The concentration of SA and Zn were applied as a foliar spray after 40 day of seed sowing. Zinc sulphate was used as a Zn source. While the seed was sown on 22th March 2018. The muskmelon cv. Kandyalay was used for this experiment. Normal culture practices i.e weeding, irrigation, hoeing and chemical sprays against insect and diseases were managed accordingly.

Factor and their levels; ***Factor A: Zinc levels***. Zn0:Control; Zn1:25ppm; Zn2:50ppm; Zn3:75ppm;

Factor B. Salicylic acid levels; SA0: Control; SA1:50ppm; SA2: 100ppm; SA3:150ppm

Preparation of stock solution (Zinc). 25 ppm = 78 mg of zinc sulphate ($ZnSO_4$) in one liter of water (H_2O); 50 ppm = 156 mg of zinc sulphate ($ZnSO_4$) in one liter of water (H_2O); 75ppm = 234 mg of zinc sulphate ($ZnSO_4$) in one liter of water (H_2O)

Preparation of stock solution (Salicylic acid). 50 ppm = 50 mg of salicylic acid (SA) in one Liter of water (H_2O); 100 ppm = 100 mg of salicylic acid (SA) in one liter of water (H_2O); 150 ppm = 150 mg of salicylic acid (SA) in one liter of water (H_2O)

Soil analysis. Before experiment sowing, soil collect different locations from the field and were analyzed for the below chemicals and Physio-chemical analysis was done at soil department, University of Agriculture Peshawar.

Property	Unit	Depth (cm)	Min	Max
AB-DTPA extractable zinc	mg/kg	0-15	0.08	0.012
Organic matter	%	0-15	0.40	0.55
Soil pH	-	0-15	7.00	9.20
Soil E.C	d/sm	0-15	1.4	6.7

Parameters were studied. *Fruit volume (cm^3).* The fruit volume was measured with water displacement method with following formula.

Fruit volume (cm^3) = Final reading (mL) – initial reading (mL).

Rind thickness (cm). Rind thickness was measured at the middle portion of 10 randomly selected fruits from each plot by using Venire calipers and their average was calculated.

Total yield/hacter (tons). It was measured by the below formula

$$\text{Yield/hectare (ton)} = \frac{\text{Yield/plot kg xI0000 m}^2}{\text{Area of pIot (m}^2\text{) x I000 kg}}$$

Total soluble solids (°brix). The TSS (°Brix) was measure in 10 randomly selected fruits was determined with refractometer. The means was calculated.

Fruit firmness. The fruit firmness was measure in ten (10) randomly selected fruits was determined with penetrometer. The means was calculated.

Statistical analysis. The mean data was analyzed for analysis of variance (ANOVA) and mean differences. Mean differences was analyzed by using (LSD) according to Steel and Torrie (1980).

Results and Discussion

The research “effect of foliar application of salicylic acid (SA) and zinc (Zn) on growth, quality & yield of muskmelon/cantaloupe was performed at platoo research farm of AMK campus Mardan, in April 2018. The data were recorded of all parameter are shown in table 1-5 while table 1a-4.5a showing ANOVA for all parameter. The result appertains to different growth, quality and yield parameter are described below.

Fruit volume (cm^3). Data regarding on fruit volume are present in Table 1, while the ANOVA table are shown in Table 1a.The ANOVA point out that there was significant variation exists between different salicylic acid, zinc concentration and while their interaction was found non-significant affected.

Mean value presented (4.1) that highest fruit volume (12.40 cm^3) were obtained by 75 ppm zinc, followed

Table 1. Effect of foliar application of salicylic acid (SA) and zinc (Zn) on the fruit volume (cm^3) of muskmelon

	Salicylic acid levels				
Zinc levels	0 (ppm)	50 (ppm)	100 (ppm)	150 (ppm)	Mean
0 (ppm)	9.13	9.91	9.23	12.46	10.18c
25 (ppm)	9.75	8.80	11.03	12.20	10.44bc
50 (ppm)	9.70	9.83	12.00	13.63	11.29b
75 (ppm)	9.93	11.96	13.30	14.43	12.40a
Mean	9.63c	10.12c	11.39b	13.18a	

Different letters with mean value show significant difference at 5% significance level

LSD for zinc at 5% = 1.0612; LSD for Salicylic acid at 5% = 1.0612.

Table 1a. ANOVA for fruit volume (cm^3) of muskmelon as affected by foliar application of SA and Zn

SOV	D.F	S.S	M.S	F-value	P-value
Block	2	12.652	6.3259		
SA	3	90.370	30.1235	18.60	0.0000
Zn	3	36.119	12.0395	7.43	0.0007
SA x Zn	9	16.926	1.8807	1.16	0.3540
Error	30	48.598	1.6199		
Total	47	204.665			

Coefficient of variance = 11.48%.

by fruit volume (11.29 cm^3) recorded in 50 ppm zinc application, while, the lowest fruit volume (10.18 cm^3) were found untreated plants. As concerned salicylic acid application the highest fruit volume (13.18 cm^3) were obtained in 150 ppm of salicylic acid concentration, followed by fruit volume (11.39 cm^3) recorded in 100 ppm, while the lowest fruit volume (9.63 cm^3) was gives by untreated plants.

Zinc enhance in the growth characters might be Impute to synthesis of tryptophan which enhance intensity of auxins which are increase fruit volume and fruit weight. Zinc increased rate of cell enlargement and cell division important to more increase of metabolites in the fruit. Same finding was also reported by Khan *et al*. (2012), in citrus. The rapid growth of the fruit synchronized with the maximum amount of auxin present therein. The results regarding weight and volume of the fruit are increased due to augmentation of the native supply of hormones. Similar findings were found by Shinde *et al*. (2008) in acid lime and Choudhary *et al*., (2013) in Nagpur mandarin. Our finding also get support from the work done by Shinde *et al*. (2008) who recommend that a high level of SA and Zn treatment increased the fruit volume, fruit yield and fruit quality.

Rind thickness (cm). The mean data pertaining rind thickness are point out in Table 2, while the ANOVA table are shown in Table 2a. The ANOVA point out that various concentration of salicylic acid (SA) and zinc (Zn) significantly affected and while their interaction was obtained non-significant.

Table of mean (4.2) present that maximum rind thickness (0.21cm) was found in 75ppm zinc, followed by rind thickness (0.27cm) obtained in 25ppm of zinc application, while minimum Rind thickness (0.21cm) was obtained at control treatment.

Table 2. Effect of foliar application of salicylic acid (SA) and zinc (Zn) on the rind thickness of muskmelon

Zinc levels	Salicylic acid levels 0 (ppm)	50 (ppm)	100 (ppm)	150 (ppm)	Mean
	0.20	0.23	0.22	0.27	0.21b
25 (ppm)	0.22	0.30	0.26	0.26	0.27a
50 (ppm)	0.23	0.30	0.26	0.30	0.25a
75 (ppm)	0.20	0.30	0.26	0.31	0.28a
Mean	0.23	0.26ab	0.27a	0.28a	

Different letters with mean value show significant difference at 5% significance level

LSD for Zinc at 5% = 0.0325; LSD for Salicylic acid at 5% = 0.0325.

Table 2a. ANOVA for rind thickness of muskmelon as affected by foliar application of SA and Zn

SOV	D.F	S.S	M.S	F-value	P-value
Block	2	0.00271	0.00136		
SA	3	0.041429	0.01383	9.09	0.0002
Zn	3	0.01394	0.00465	3.06	0.0434
SA x Zn	9	0.00896	0.00100	0.65	0.7420
Error	30	0.04562	0.00152		
Total	47	0.11272			

Coefficient of variance = 14.93%.

As concerned salicylic acid application the maximum rind thickness (0.28cm) was recorded in 150 ppm of salicylic acid concentration, followed by rind thickness (0.27 cm) recorded in 100ppm, while the minimum rind thickness (0.23cm) was recorded at control treatment.

Rind thickness is one of important quality parameter in muskmelon. Zn is an important nutrient for plant growth and that activate a different enzyme such as synthesis of auxin, functional structural, photosynthesis, regulatory cofactor protein synthesis, cell division, maintenance of cell membrane structure and cell function, (Marschner *et al*., 1995). Plant growth regulators (PGR) have been reported to affect quality in many vegetables and fruits. Salicylic acid (SA) can enhance colony formation in protoplasts and directive of the cell cycle. Xyloglucan endotransglucosylase/hydrolase (XTH) genes encode enzymes and cell expansion and enlargment (Rose *et al*., 2002). Our findings are in accordance with the previous result of Rose *et al*. (2002), who observed maximum rind thickness with the application of SA and Zn.

Yield/hacter (tons). The mean data regarding Yield/hacter are present in Table 4.3, while the analysis of variance table is mention in Table 4.3a.The ANOVA point out that there were significantly affected among different concentrations of salicylic acid (SA), zinc (Zn) and their interaction.

Table of mean (4.3) shows that maximum Yield/hacter (12.61 ton) were recorded in 50 ppm of zinc, followed by Yield/hacter (12.21 ton) recorded in 75 ppm of zinc application, while the minimum Yield/hacter (10.99 ton) were recorded in control treatment.

Table 3. Effect of foliar application of salicylic acid (SA) and zinc (Zn) on the yield/hacter (tons) of muskmelon

Zinc levels	Salicylic acid levels 0 (ppm)	50 (ppm)	100 (ppm)	150 (ppm)	Mean
0 (ppm)	9.62	9.59	12.08	12.68	10.99b
25 (ppm)	10.93	11.05	11.51	12.33	11.45ab
50 (ppm)	10.58	10.90	12.75	11.80	12.61a
75 (ppm)	12.75	12.66	11.53	14.40	12.21a
Mean	10.97c	11.05bc	11.97ab	12.82a	

Different letters with mean value shows significant difference at 5% significance level
LSD for Zinc at 5% = 0.9498; LSD for Salicylic acid at 5% = 0.9498; LSD for interaction of SA and Zn at 5% = 1.8996.

Table 3a. ANOVA for yield/hacter (tons) of muskmelon as affected by foliar application of salicylic acid and zinc

SOV	D.F	S.S	M.S	F-value	P-value
Block	2	0.366	0.18283		
SA	3	27.363	9.12115	7.03	0.0010
Zn	3	12.379	4.12648	3.18	0.0381
SA x Zn	9	31.289	3.47657	2.68	0.0207
Error	30	38.931	1.29769		
Total	47	110.328			

Coefficient of variance = 14.78%.

As concerned salicylic acid application the maximum yield/hacter (12.82 ton) were recorded in 150ppm of salicylic acid concentration, followed by Yield/hacter (11.97 ton) recorded in 100 ppm, while the minimum Yield/hacter (10.97 ton) were recorded untreated plants. As concerned the interaction between salicylic acid and zinc, So the maximum yield/hacter (12.75 ton) were recorded in 50 ppm of zinc and 100 ppm of SA, while the minimum Yield/ha (9.59 ton) were recorded in zinc at the control treatment and salicylic acid at 50ppm.

Zinc (Zn) is an importance mechanism in the synthesis of tryptophan which confident the auxin biosynthesis in the active sinks which would have led to increase transport and accumulation of photosynthetic in fruits and hence, improving yield (Guerrero-Martin *et al*., 2023). SA increasing plant development, growth and fruit yield due to SA. SA is causing plant defense mechanisms against virus disease by Prohibition or energizing of some antioxidant enzymes, reduction of lipid peroxidation or induction of H_2O_2 accumulation in summer squash (Radwan *et al*., 2006). SA is naturally plant hormone occurring in plant acts as an essential signaling molecule (Khan *et al*., 2012). Similar finding is in conformity with those of Dongre *et al*., (2000) for yield/plant, yield/plot and yield/hectare in chilli. (Radwan *et al*. 2006) observed that the foliar spray of SA plays a significant role in improve the productivity of sweet pepper plant. Our obtained are closely related with those reported by Dongre *et al*. (2000), reported that the fruit set percentage was significantly improved with foliar applications of SA with combination zinc.

Total soluble solid (°Brix). The mean data pertaining TSS are point out in Table 4.4 and analysis of variances are shown in Table 4.4a. The ANOVA shown that there was significant variation exist different levels of zinc and salicylic acid concentrations while their interaction was found non significant.

Table 4. Effect of foliar application of salicylic acid (SA) and zinc (Zn) on the total soluble solid (TSS) of muskmelon

Zinc levels	Salicylic acid levels 0 (ppm)	50 (ppm)	100 (ppm)	150 (ppm)	Mean
0 (ppm)	8.44	8.09	8.31	8.16	8.25c
25 (ppm)	8.79	9.05	9.60	9.56	9.25c
50 (ppm)	9.69	10.29	10.13	11.18	10.32b
75 (ppm)	11.25	10.58	11.54	13.58	11.73a
Mean	9.54b	9.50b	9.88b	10.62a	

Different letters with mean value show significant difference at 5% significance level; LSD for Zinc at 5% = 0.7521; LSD for Salicylic acid at 5% = 0.7521.

Table 4a. ANOVA for TSS of muskmelon as affected by foliar application of Salicylic acid and zinc

SOV	D.F	S.S	M.S	F-value	P-value
Block	2	14.234	7.1169		
SA	3	9.673	3.2242	4.29	0.0124
Zn	3	80.438	26.8127	35.68	0.0000
SA x Zn	9	10.529	1.1699	1.56	0.1738
Error	30	22.543	0.7514		
Total	47	137.416			

Coefficient of variance = 8.76%.

Table of mean (4.4) observed that maximum total soluble solid (11.73 °Brix) were obtained in 75ppm zinc, followed by TSS (10.32 °Brix) obtained in 50 ppm of zinc concentration, while the minimum TSS (8.25 °Brix) were recorded in control treatment.

As concerned salicylic acid the maximum TSS (10.62 °Brix) were obtained in 150 ppm of salicylic acid concentration, followed by TSS (9.88 °Brix) recorded in 100 ppm, while the minimum TSS (9.54 °Brix) were obtained in control treatment.

The total soluble solids (TSS) are considered as important quality parameter in muskmelon. Sayyari *et al*. (2009) observed that the amount of T.S.S and acidity were influenced by salicylic acid treatment in pomegranate. Loreti *et al*. (2001) reported that soluble sugars (TSS) function as metabolic resources, structural of cells and also act as signals regulating different processes related with plant development and growth under abiotic stresses. Similarly, Chandra *et al*. (2007) was also observed that SA increased TSS and TSP in cowpea plants. Babalar *et al*. (2007) studied that SA at all concentrations effectively reduced fruit ethylene production and retained overall quality. Our findings were closely related to finding of Hayata *et al*. (2000) who reported that the total soluble solid was significantly increases by the optimum levels of SA and Zn in muskmelon.

Fruit firmness. The mean data regarding fruit firmness are shown in Table 4.5, ANOVA is shown in Table 4.5a. Analysis of variance shows that there was significant variation exist among different zinc and salicylic acid concentrations while their interaction was obtained non-significant.

Mean data table (4.9) shows that highest fruit firmness (11.73 kg) was obtained by 75 ppm zinc, followed by fruit firmness (10.32 kg) obtained in 50 ppm of zinc application, while the lowest fruit firmness (8.25 kg) was found untreated plants.

As concerned salicylic acid application the highest fruit firmness (10.62 kg) were recorded in 150 ppm of salicylic acid concentration, followed fruit firmness (9.88 kg) recorded in 100 ppm, while the lowest fruit firmness (9.54 kg) was found untreated plants. The improvement in quality of fruit is might be due to the fact that nutrients directly play as an essential role in plant metabolism. Zinc needed in enzymatic reaction like hexokinase, formation of carbohydrate and protein synthesis (Pamila *et al*., 1992). recorded that rate of fruit ripening related to internal SA concentration. Salicylic acid gave positive effects on these parameters might account for enhanced physical properties of cluster and berries SA preserves berry firmness by impacting actions of prime cell wall mortifying enzymes such as xylanase, cellulose, polygalacturonase and promotes cell enlargement and cell division (Hayat *et al*., 2005). SA Suppress ethylene biosynthesis in pear cell suspension culture by blocking the conversion of I-aminocyclopropane I-carboxylic acid to ethylene (Raskin, 1992). Enzyme activities such as nitrate reductase and amylase were increased by SA concentration (Chen *et al*., 1993). Our results suggested that the fruit firmness caused by maximum concentration of Zn and SA in watermelon.

Table 5. Effect of foliar application of salicylic acid SA and zinc Zn on the fruit firmness of muskmelon

Zinc levels	Salicylic acid levels 0 (ppm)	50 (ppm)	100 (ppm)	150 (ppm)	Mean
0 (ppm)	7.40	7.33	8.80	8.43	7.99b
25 (ppm)	8.26	8.13	8.46	9.50	8.59ab
50 (ppm)	9.16	9.20	8.83	8.83	9.00a
75 (ppm)	8.10	8.26	9.20	10.30	8.96a
Mean	8.23b	8.23b	8.82ab	9.26a	

Different letters with mean value show significant difference at 5% significance level

LSD for Zinc at 5% = 0.6421; LSD for Salicylic acid at 5% =0.6421.

Table 5a. ANOVA for fruit firmness of muskmelon as influences by foliar application of SA and Zn

SOV	D.F	S.S	M.S	F-value	P-value
Block	2	0.1079	0.05396		
SA	3	9.0923	3.03076	5.11	0.0056
Zn	3	7.9806	2.66021	4.49	0.0102
SA x Zn	9	8.8619	0.98465	1.66	0.1431
Error	30	17.7921	0.59307		
Total	47	43.8348			

Coefficient of variance = 8.91%.

Conclusion

Salicylic acid at 150 ppm had highest/yield ha (tons), TSS content, fruit volume, fruit firmness, rind thickness and Zinc at 75 ppm had highest fruit volume, TSS content, rind thickness, while Zinc at 50 ppm had highest number of branches, yield/ha and fruit firmness.

Conflict of Interest. The authors declare that they have no conflict of interest.

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