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RESEARCH PAPER

Impact of foliar application of aminoethoxyvinylglycine on pre-harvest fruit drop and quality in mandarin cv. kinnow (*Citrus reticulata* L. Blanco)

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Key Message: The current study proved that foliar application of AVG 300 mg L^{-1} is the most effective in minimizing pre-harvest fruit drop and improving fruit quality of kinnow.

Abstract: Citrus fruit drop is a serious issue in citrus producing countries of the world as well as in Pakistan. The pre-harvest foliar application of aminoethoxyvinylglycine (AVG) @ 150, 300 and 600 mg L^{-1} were applied at mature and color break stage to evaluate its influence on fruit drop and quality of kinnow. Exogenous application of AVG (300 and 600 mg L^{-1}) at both mature and color break stage significantly reduce fruit drop in kinnow as well as improve the fruit quality. However, exogenous application of AVG with 300 mg L^{-1} at color break stage was the most effective in reducing fruit drop (22.64%) as compared to mature stage (24.19%). Foliar application of AVG had insignificant effects on rind thickness and highest fruit rind thickness (3.53 mm) was observed at higher level of AVG @ 600 mg L^{-1}. In the case of juice (%) foliar application of AVG 300 mg L^{-1} had the most profound effect on kinnow fruit. The Foliar application of AVG (150, 300 mg L^{-1}) applied at both mature fruit and color break stage in kinnow had significant effects on fruit weight, diameter and juice (%) and total soluble solids. It is concluded that foliar application of AVG 300 mg L^{-1} is the most effective in minimizing pre-harvest fruit drop of kinnow. © 2021 Department of Agricultural Sciences, AIOU

Keywords: Aminoethoxyvinylglycine (AVG), Color break, Ethylene, Fruit drop, Kinnow, Mature stage

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Introduction

Mandarin cv. kinnow is one of the important group of citrus, which is the main fruit crop of Pakistan (Altaf, 2006). It has prime importance in Pakistan's economy. It is cultivated for exotic taste, process ability, fresh consumption and it is well adapted to agro environmental conditions of Punjab in Pakistan (Ahmed et al., 2006). About 2 million metric tons of citrus fruits are produced in Pakistan annually and kinnow is at top among citrus (Naeem et al., 2010). China is the leading producer of citrus, while Pakistan is ranked at 16th position in the world with production of 2.28 million metric tons annually (Food and Agriculture Organization [FAO], 2009). It is estimated Pakistan produces 70 % of total world kinnow (Qureshi et al., 2014). In Pakistan, citrus yield is 10-tons per hectare which is one third the rest of the world (Saleem et al., 2005). Like other citrus species, fruit drop is a serious issue in kinnow which starts from flowering and continues till harvesting, especially pre-harvest drop. According to a study, kinnow produce forty to eighty thousand flowers out of which few hundred reached maturity (Ashraf et al., 2010). The deficiency of essential elements is also a reason for fruit drop in kinnow (Ibrahim et al., 2007).

It has been reported that enhancement in the level of abscisic acid (ABA) and reduction of auxins concentration, fruit drop occurred due to the hormonal imbalance (Marinho et al., 2005). Modise et al. (2009) have revealed a remarkable reduction of fruit drop by the application of numerous plant growth regulators. Among various plant growth regulators (PGRs) 2,4-dichlorophenoxyacetic acid (2,4-D) and salicylic acid (SA) have been found to play a key role for reduction of premature fruit drop in citrus (Ashraf et al., 2012). Some supplementary factors like pH and EC of soil also play a significant role in quality enhancement of citrus fruit.

Ethylene (C_2H_4) is a simple PGR which has a vital role in the fruit ripening, improving plant immunity and abscission (Dupille et al., 1993). Ethylene is also involved in organ abscission (DalCin et al., 2005) tissue softening (Masia et al.,

1998) and chlorophyll loss (Matilla, 2000). The negative effects of ethylene on plants can be controlled by using ethylene inhibitors such as aminoethoxyvinylglycine (AVG) as an ethylene biosynthesis inhibitor. The ethylene biosynthesis pathway is mostly initiated by methionine production followed by Sadenosyl methionine (SAM), 1-aminocyclopropane- 1-carboxylic acid (ACC) ultimately results in ethylene protection (Adams & Yang, 1979). ACC oxidase belongs to the ferrous ion-dependent family of non-heme oxygenases (Brown et al., 1997).

During ripening, kinnow produce enough ethylene to stimulate the softening of fruits and the formation of an abscission layer in the calyx and pedicel of fruit and stimulate production of enzymes that break down the complex sugars that hold cell walls together in the abscission zone. Abscission layer in the calyx and pedicel of fruit and stimulate production of enzymes that break down the complex sugars that hold cell walls together in the abscission zone. Keeping in view previous findings, a study was designed to overcome fruit drop and to improve quality of citrus fruit by spray of AVG as ethylene biosynthesis inhibitor.

Materials and Methods

Uniform size and age plants of kinnow mandarin (*Citrus reticulata* Blanco*)* were selected and were growing on sandy loam soil. AVG was applied to evaluate the effect on pre-harvest fruit drop and quality of the fruit. The experiment consisted of 4 treatments including control, replicated four times and a single tree was taken as an experimental unit. Different concentrations of ethylene inhibitor AVG (150, 300 and 600 mg L^{-1}) were applied at mature and color break stage and same concentrations were used to control fruit drop in apple. The data for the following parameters were collected.

Fruit drop % age

4-branche on each side of the tree were tagged before spraying and Number of fruits per plant at the time of spray and after 20 days of spray was counted. To calculate fruit drop %age from tagged branches of the experimental tree, number of fruits was counted, and fruit drop percentage was calculated using the following formula:

$$\text{Fruit drop \%age} = \frac{\text{Total number of fruits dropped}}{\text{Total number of fruits before applicatiom}} \times 100$$

Fruit weight, fruit diameter and rind thickness

The kinnow fruits were harvested at the ripening stage. Ten fruits per replication were placed on digital balance (A and D Limited, Tokyo, Japan) to measure the fruit weight (g) and average fruit weight per treatment was calculated. Similarly, selected fruits were cut into two halves and fruit diameter (mm) and rind thickness (mm) was also measured using a digital Vernier-calliper.

Total soluble solids (TSS)

To calculate TSS, the one drop of fruit juice was placed on the refractometer and TSS (%) was recorded by using a digital refractometer (Atago-Palette PR 101, Atago CO. Ltd, Itabashi-Ku, Tokyo, Japan).

Titratable acidity (TA)

TA was measured by using the method of Hussain (2014) and TA was expressed as percent citric acid as given below.

$$\text{Titratable acidity} = \frac{(\text{Miliequivalent factor}) \times \text{Vol. of titrant} \times \text{Vol} * 0.1(\text{NaOH})}{[\text{ml of juice} \times \text{Vol.of aliquot}]} \times 100$$

Mili equivalent factor for citric acid = 0.0064

Fresh Juice % age

Juice of each of 10 harvested fruits was extracted and weighed; average juice weight was calculated separately for each treatment. The average juice percentage per fruit was obtained from the following formula:

$$\text{Juice \%age} = \frac{\text{juice weight per fruit}}{\text{Average fruit weight}} \times 100$$

Number of seeds per fruit

Similarly, the number of seeds per fruit viable and aborted seeds were carefully collected and counted.

Statistical analysis

The statistix 8.1 was used to analysis of data by using least significant difference (LSD) test at 5 percent probability level (Steel et al., 1997).

Results and Discussion

Fruit drop (%)

A significant reduction in fruit drop was observed as concentrations of AVG increased whether it was applied at mature or color break stage of kinnow. However, the Foliar application of an aqueous solution containing AVG (300 mg L^{-1}) have considerably ($p \leq 0.05$) decreased drop (%) than 150 mg

L^{-1}, 600 mg L^{-1} and control (Table 1). All the concentrations of AVG (150, 300 and 600 mg L^{-1}) at mature and color break stage reduced fruit drop in mandarins cv. 'Kinnow'. In general, the AVG application at color break stage was more effective in decreasing fruit drop compared to mature stage. The treatment of AVG (300 mg L^{-1}) resulted in lowest fruit drop (24.19 and 22.64%) as compared to the control (47.87 and 45.44%) at both stages of foliar application.

AVG which is an ethylene inhibitor was more effective in minimizing fruit drop at color break stage as compared to mature stage. This significant reduction in pre-harvest fruit drop can be attributed to the ethylene bio-synthesis inhibiting abilities of AVG applied on the fruit. Burns et al. (1999) found that higher levels of endogenous ethylene causes fruit drop in Valencia sweet orange. Brown (1997) reported there is a strong relationship among increased ethylene biosynthesis and abscission in plants. Hartmond et al. (2000) studied that the fruit drop in Hamlin oranges was amplified due to mounting the levels of internal ethylene in fruit. AVG is a reversible inhibitor of ACC synthase (Boller et al., 1979) and ethylene biosynthesis. Incubation of grapefruit flavedo discs with AVG at various concentrations inhibited ethylene formation at lower concentrations but induced ACC synthase activity at higher concentrations (Mullins et al., 1999). AVG holds back the activity of ACC oxidase as a result inhibits the alteration of 1-Aminocyclopropane-1-carboxylic acid (ACC) to ethylene (Yang & Hoffman, 1984). The ethylene biosynthesis inhibitors such as AVG inhibit the fatal step of ethylene biosynthesis through blocking the transformation of ACC to ethylene (Even-chen et al., 1982).

Similarly, Anthony and Coggins (2001) have studied and confirmed that preharvest application of AVG reduced citrus fruit drop both in California and Florida. The foliar application of AVG 200 ppm at flowering in Satsuma mandarin reduced preharvest drop (Ogata et al., 2002) and in different cultivars of apple (Amarante et al., 2002). The foliar application of AVG twenty to thirty days before expected harvest date in peaches (*Prunus persica* cv. Mibaekdo) brings less pre-harvest fruit drop (Kim et al., 2004). Similarly, Lafer (2008) conducted another study on pears cv. Williams and controlled the fruit drop by pre-harvest treatment of AVG (125 mg L^{-1}). The pre-harvest application of AVG also used to control fruit drop in different cultivars of apple such as McIntosh apple (Greene, 2005), Kogetsu apple (Rath et al., 2006) as well as Anna apple (Hatem, 2019).

Table 1 Effect of various levels of AVG sprayed at mature or color break stage on fruit drop and weight of mandarins cv. kinnow

	Fruit drop (%)			Fruit weight (g)		
Treatments	Mature (S)	Color break (S)	Means (T)	Mature (S)	Color break (S)	Means (T)
Control	47.87^{a}	45.44^{a}	46.65^{a}	136.13^{b}	137.19^{b}	136.66^{b}
AVG150 mg L^{-1}	31.72^{b}	30.31^{b}	31.01a	158.81^{ab}	166.31^{ab}	162.56^{a}
AVG 300 mg L^{-1}	24.19^{b}	22.64^{b}	23.41^{c}	168.88^{ab}	182.56^{a}	175.72^{a}
AVG 600 mg L^{-1}	27.06^{b}	24.57^{b}	25.82^{bc}	146.81^{b}	157.94^{ab}	152.38^{ab}
Means (Stage)	32.71^{a}	30.74^{a}		152.66^{a}	161.00^{a}	
LSD ($p \leq 0.05$)						
Treatments (T)	0.00			0.02		
Stage (S)	Ns			Ns		
T×S	Ns			Ns		

n = 4 replications (10 fruits per replications) any two means in column or a row followed by different letters are significantly different, NS = not significant, T=Treatment

Fruit weight (g)

Significantly increased fruit weight was observed by the treatments of AVG (150, 300, 600 mg L^{-1}) were applied either at mature or color break stage in kinnow (Table 1). In case of treatments the mean fruit weight was significantly increased as compared to control treatment. Maximum average fruit weight (182.56 g) was obtained with the application of AVG at 300 mg L^{-1} than other levels and control. AVG showed significant results in reducing preharvest fruit drop and increasing fruit weight as well as diameter in sweet orange (Al- Husseini, 2012). Cetinbas and Koyuncu (2011) reported that AVG was found to be effective in inhibiting ethylene biosynthesis, delaying fruit maturity while enhancing fruit weight along with its diameter. It was also previously reported that $CuSO_4$ has been found to decrease fruit drop and increase average fruit weight and diameter in sweet orange (Al-Husseini, 2012; Hayat et al., 2019). Hussain and Singh (2020) also reported that AVG significantly improved rind properties of sweet oranges. Similar findings have been observed in present study that application of AVG has significantly improved the weight and size of kinnow by letting the fruit spend more time on the tree due to ethylene biosynthesis inhibiting properties.

Fruit diameter (mm)

Fruit diameter was significantly increased with increased concentration of AVG (150, 300, 600 mg L^{-1}) when applied at mature or color break stage of kinnow (Table 2). With AVG applications, average fruit diameter was significantly increased than control. Maximum average fruit diameter (73.42 mm) was observed at AVG 600 mg L^{-1} than control (62.75 mm) and all other treatments. Citrus fruit size is important for the world market (Guardiola & García-Luis, 2000). Due to time constraints and labor shortages some fruit varieties are harvested earlier than proper maturity and ripening which deteriorates fruit quality and causes economic loss. Chemical sprays that are used in agriculture that can retard preharvest fruit drop and ripening for another 15 to 20 days may increase profit through increase in fruit size and consequently price by as much as 20% (Byers & Eno, 2002). It is a well-known fact that AVG is a firm and capable inhibitor of ethylene biosynthesis in plant tissue and commercially used by farmers to improve end yield and quality of fruits. AVG has been used to evaluate ethylene impact on plant growth, developmental process and behavior toward stress tolerance (Abeles et al., 1992). By employing AVG final yield can increase due to reduction in preharvest fruit drop and increment in size of fruit due to belated ripening and harvesting (Byers et al., 2005). The results showed that different concentrations of AVG (150, 300, 600 mg L^{-1}) significantly enhanced the fruit rind thickness either at mature or color break stage (Table 2). The treatments of AVG @ (300 and 600 mg L^{-1}) significantly increased the fruit rind thickness (3.51 and 3.53 mm), respectively as compared to control (3.09 mm) and treatment AVG @ (150 mg L^{-1}). The stage of application and interaction between treatments and the stages of application revealed non-significant results for fruit diameter for kinnow.

Rind thickness (mm)

Citrus rind is constituted by two distinct layers exocarp which is a colored portion of rind known as flavedo and mesocarp which is white inner portion of the rind known as albedo (Iglesias et al., 2007; Ladaniya, 2007). It has also been revealed that generally citrus fruit does not produce much of ethylene, but it is accentuated in case of biotic or abiotic stress (Alfe´rez et al., 2003). In another study, it was revealed that exposure to high levels of ethylene restricts the activity of most genes involved in cell wall modification in mandarins (Fujii et al., 2007). Noteworthy observation made by Hatfield and Vermerris (2001) that ethylene can stimulate biosynthesis of lignin materials which are essential for strengthening of plant cell walls. However, if ethephone is applied 7-day before harvest date up to 250 mg L^{-1} it increases peel puffing in Satsuma mandarin (Ladaniya, 2007). Peel puffing is directly associated with peel aging (Baez-sanudo et al., 1992). It is also well known that inhibition of peel aging by GA_3 application is directly related to prevention of peel puffing in citrus (Garcia-Luis et al., 1985). GA_3 is a well-known ethylene-antagonist (Weiss & Ori, 2007). Similarly, AVG is also a renowned inhibitor of ethylene biosynthesis. AVG might have restricted the production of ethylene in albedo tissue of citrus peel and restrained the aging process of albedo tissue which helped to increase albedo and rind thickness.

Table 2 Effect of various AVG levels sprayed at mature or color break stage on fruit diameter and rind thickness of mandarins cv. kinnow

	Fruit diameter (mm)			Fruit rind thickness (mm)		
Treatments	Mature (S)	Color break (S)	Means (T)	Mature (S)	Color break (S)	Means (T)
Control	61.05^{c}	64.46^{bc}	62.75^{b}	2.94^{b}	3.23^{ab}	3.09^{b}
AVG150 mg L^{-1}	69.69^{abc}	66.87^{abc}	68.28^{b}	3.29^{ab}	3.47^{a}	3.38^{ab}
AVG 300 mg L^{-1}	71.84^{ab}	71.63^{ab}	71.74^{a}	3.42^{a}	3.60^{a}	3.51^{a}
AVG 600 mg L^{-1}	72.55^{ab}	74.29^{a}	73.42^{a}	3.45^{a}	3.62^{a}	3.53^{a}
Means (Stage)	68.78^{a}	69.31^{a}		3.28^{a}	3.48^{a}	
LSD ($p \leq 0.05$)						
Treatments (T)	0.01			0.30		
Stage (S)	Ns			Ns		
T×S	Ns			Ns		

n = 4 replications (10 fruits per replications) any two means in column or a row followed by different letters are significantly different; NS = Not significant; T = Treatment

Table 3 Effect of various levels of AVG sprayed at mature or color break stage on fruit juice and Total soluble solids (TSS) of mandarins cv. kinnow

	Fresh juice (%)			TSS (%)		
Treatments	Mature stage	Color break stage	Mean	Mature stage	Color break stage	Mean (Treatments)
Control	41.33^{bc}	36.40^{c}	38.87^{c}	9.50^{b}	9.25^{b}	9.38^{b}
AVG150 mg L^{-1}	44.76^{b}	46.02^{ab}	45.39^{bc}	10.25^{ab}	10.25^{ab}	10.25^{ab}
AVG 300 mg L^{-1}	48.44^{ab}	52.34^{a}	50.39^{a}	10.50^{ab}	11.25^{a}	10.86^{a}
AVG 600 mg L^{-1}	42.58^{bc}	46.86^{ab}	44.72^{b}	11.00^{a}	11.50^{a}	11.25^{a}
Means (Stage)	44.28^{a}	45.40^{a}		10.31^{a}	10.56^{a}	
LSD ($p \leq 0.05$)						
Treatments	0.02			0.01		
Stage	Ns			Ns		
Treatments*stage	Ns			Ns		

n = 4 replications (10 fruits per replications) any two means in column or a row followed by different letters are significantly different; NS = Not significant; T = Treatment

Fruit juice (%)

All the applied treatments of AVG (150, 300 and 600 mg L^{-1}) on mature and color break stage increased the fruit juice % (Table 3). Results were significant as improvement was observed in fruit juice (%) as per increasing levels of AVG on both mature and color break stages. Among all the treatments of AVG applied (150, 300 and 600 mg L^{-1}) at mature and color break stage, AVG 300 mg L^{-1} resulted in highest fruit juice (48.44 and 52.34 %). In general, the color break stage was more effective in increasing fruit juice (45.40 %) as compared to the mature stage (44.28 %). There was non-significant interaction for application of stages and treatment for fruit juice. Fidelibus et al. (2002) reported that GA_3 increased juice yield in Valencia oranges when applied 5 months before harvest. Studies in the past have shown that GA_3 improves the juice content in Satsuma mandarin (Garcia-Luis et al., 1985). Davies et al. (1997) have shown that GA_3 increases juice content by 4% as compared to control. Autumn application of GA_3 increased juice yield in late season in Satsuma mandarin and sunburst tangerine (Garcia-Luis et al., 1985; Pozo et al., 2000). Ashraf et al. (2013) also found that plant growth regulators 2, 4 dichlorophenoxyacetic acid and salicylic acid combined with nutrients zinc and potassium improved fruit juice % in kinnow.

Total soluble solid (%)

All the treatments of AVG applied at mature and color break stage significantly improved TSS when AVG was applied @ (600 mg L^{-1}) than control (9.38%) in kinnow mandarin (Table 3). Khalid et al. (2012) studied that the TSS increased in kinnow fruit by using plant growth regulators GA_3 and Benzyl adenine. The growth regulators treatments had an increasing trend towards TSS, total sugars and reducing sugars (Saleem et al., 2007). Haque et al. (2020) TSS and acidity showed conversely increasing and decreasing trends respectively in mandarin fruits with extension of storage period. Similarly, TSS in sweet orange was reported to be increased by foliar application of AVG (Al-Husseini, 2012). It is also reported that AVG application improves fruit TSS in apple (Wargo et al., 2004; Greene, 2005). It has been previously reported that ethylene inhibitor significantly improved the quality properties of papaya (Hanif et al., 2020), mango (Zahedi et al., 2019), Kanzi apples (Gwanpua et al., 2016), strawberry (Paniagua et al., 2016), blueberries (Chen et al., 2015), Murcott mandarin (Enab et al., 2020) and sweet orange (Hussain & Singh, 2020).

Titratable acidity (%)

Different concentrations of AVG (150, 300 and 600 mg L^{-1}) significantly effect on the titratable acidity (TA) irrespective of stages of application of kinnow (Table 4). The results showed that the significantly higher TA was observed at control (1.07%) compared to all treatment of AVG. Similarly, Average over the stage of application, the mature stage of foliar application was more effective (0.99%) compared to color break stage (9.87%). However, the interaction was non-significant for fruit titratable acidity. Quality attributes like acidity are not affected substantially by plant growth regulators (PGRs). Similar findings were observed by Al-Hussaini (2012); Hussain (2014) who observed non-significant influence of AVG and $CuSO_4$ on sweet orange cv. Washington naval and Lane late.

Table 4 Effect of various levels of AVG sprayed at mature or color break stage on fruit juice acidity and TA/TSS ratio mandarin cv. kinnow

Treatments	TA (%)			TA/TSS ratio (%)		
	Mature stage	Color break stage	Mean	Mature stage	Color break stage	Mean (Treatments)
Control	1.21^{a}	0.93^{bc}	1.07^{a}	11.72^{bc}	10.04^{c}	10.88^{b}
AVG150 mg L^{-1}	0.96^{b}	0.86^{bc}	0.91^{b}	12.08^{abc}	12.13^{abc}	12.10^{ab}
AVG 300 mg L^{-1}	0.92^{bc}	0.91^{bc}	0.91^{b}	11.50^{bc}	12.56^{abc}	12.03^{ab}
AVG 600 mg L^{-1}	0.89^{bc}	0.78^{c}	0.84^{b}	13.08^{ab}	14.82^{a}	13.95^{a}
Means (Stage)	0.99^{a}	0.87^{b}		12.09^{a}	12.39^{a}	
LSD ($p \leq 0.05$)						
Treatments	0.11			2.09		
stage	0.08			Ns		
Treatments*stage	Ns			Ns		

n = 4 replications (10 fruits per replications) any two means in column or a row followed by different letters are significantly different; NS = Not significant; T = Treatment

TA/TSS ratio (%)

All the applied treatments of AVG (150, 300 and 600 mg L^{-1}) on mature or color break stage increased the TA/TSS ratio (Table 4). Results were significant as improvement was observed in TA/TSS ratio (%) as per increasing levels AVG on both mature and color break stages. The results showed that the significantly higher TA/TSS ratio (13.95%) was observed at treatment of AVG (600 mg L^{-1}) compared with control (10.88%) and AVG (300 mg L^{-1}) as well as AVG

(150 mg L^{-1}). The stage and interaction of treatment and stage were observed as non-significant for fruit juice TA/TSS ratio in kinnow. The current study was also supported by Al-Hussaini (2012); Hussain (2014) as well as Aziz et al. (2020).

Number of viable seeds per fruit

The number of seeds per fruit have shown no specific pattern of decrease or increase with any concentration of AVG applied weather at the mature or color break stage in Mandarins cv. Kinnow. Number of seeds showed non-significant results by the application of both treatments and stage of application (Table 5). Ovary of the seeded citrus flower must be pollinated and fertilized to develop into fruit otherwise ovary development is arrested, and flower abscises (Iglesias et al., 2007). Studies have shown that in plants ethylene plays a vital role in seed sets. Ethylene produced during pollination is associated with ovary growth and fruit set. In many studies when tomato ovaries were analyzed it revealed that high levels of ethylene related genes played their part in transformation of flower into fruit (Vriezen et al., 2008; Pascual et al, 2009; Wang et al, 2009). It clearly shows that ethylene has a key role to play in seed setting but that is not set at mature stage or color break stage. Seed count of citrus fruit can be affected if ethylene biosynthesis inhibitors can be applied at the fruit set stage.

Number of aborted seeds

The number of aborted seeds per fruit have shown a specific pattern of increase as AVG applied levels enhanced, regardless of fruit developmental stages in mandarins cv. Kinnow. Treatments and the interaction between treatment and stage were found to be significant ($P \leq 0.05$) for the number of aborted seeds (Table 5). Consumers appreciate and demand both in fresh and processed form of fruits. It is perceived as an improvement in fruit quality as seeds are commonly bitter in taste and are quite hard. When seedlessness was induced in eggplant it prevented discoloration of pulp and reduction in texture (Maestrelli et al., 2003). It is proved that GAs application can induce parthenocarpy in fruits. When GAs are supplied from external sources it fulfills the requirement that is needed by the ovary of seeded sweet orange to develop into fruit normally these hormones are provided by developing seeds endogenously (Iglesias et al., 2007). Because of many researches data that have been produced on embryonic development submits a conclusion that ethylene biosynthesis pathway and seed maturation are linked together. It shows that along the terminal stages of embryonic development especially during development of desiccation tolerance chlorophyll loss is observed this process may be triggered by ethylene biosynthesis (Matilla, 2000). Looking at above mentioned facts as gibberellic acid induce seedlessness in citrus and it also inhibits ethylene and seeds require high amount of ethylene in final stages of seed development so in my work AVG with ethylene inhibiting properties may have induced seed abortion at mature and color break stages.

Table 5 Effect of various levels of AVG sprayed at mature or color break stage on number of viable and aborted seeds in mandarin cv. kinnow

	Number of viable seeds			Number of aborted seed		
Treatments	Mature stage	Color break stage	Mean	Mature stage	Color break stage	Mean (Treatments)
Control	22.06^{a}	18.00^{bc}	20.03^{a}	2.69^{d}	2.88^{cd}	2.78^{c}
AVG150 mg L^{-1}	17.063^{c}	22.13^{a}	19.59^{a}	5.19^{ab}	2.56^{d}	3.88^{b}
AVG 300 mg L^{-1}	21.00^{ab}	20.94^{ab}	20.97^{a}	2.94^{cd}	5.06^{ab}	4.00^{b}
AVG 600 mg L^{-1}	17.81^{bc}	19.31^{abc}	18.56^{a}	5.75^{a}	4.00^{bc}	4.88^{a}
Means (Stage)	19.48^{a}	20.09^{a}		4.14^{a}	3.63^{a}	
LSD ($p \leq 0.05$)						
Treatments	NS			0.00		
Stage	NS			NS		
Treatments*stage	0.01			0.00		

n = 4 replications (10 fruits per replications) any two means in column or a row followed by different letters are significantly different; NS = Not significant; T = Treatment

Conclusion

Evaluations for the pre-harvest spray of AVG in decreasing fruit drop and improving fruit quality in kinnow were examined. Various levels of AVG (150, 300 and 600 mg L^{-1}) were sprayed at mature and color break stage of fruit to explore its influence on fruit drop and quality at harvest. AVG (300 and 600 mg L^{-1}) at pre-harvest spray at both mature and color break stage showed significant reduction of fruit drop in kinnow. AVG treatment with 600 mg L^{-1} sprayed at color break stage in kinnow was the most effective in reducing fruit drop. AVG with 150 and 300 mg L^{-1} sprayed at both mature fruit and color break stage in kinnow had positive effects on fruit weight. Out of these two sprays, application of 300 mg L^{-1} was most effective at color break stage. Applications of ethylene biosynthesis inhibitors gave positive influence at both mature and color break stage regarding fruit diameter but at color break stage AVG at 300 and 600 mg L^{-1}, it enhanced fruit diameter. Foliar application of AVG had insignificant effects on rind thickness. In the case of juice % age foliar application of AVG 300 mg L^{-1} had the most profound effect on kinnow fruit. It was proved that foliar application of AVG 600 mg L^{-1} is most effective in minimizing preharvest fruit drop and improving commercial quality of kinnow.

Authors Contribution: A.I. conducted current research work under the supervision of Z.H. F.K. helped in laying out research work. G.S. helped to arrange the data for state. M.N.K. helped in collection of references. M.R.S. contributed in description and arrangement of the manuscript. I.A. contributed in editing the manuscript. All the authors agreed for the publication of current research work in Journal of Pure and applied Agriculture.

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