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Full Length Article

Plant Growth Regulators Application Time Influences Fruit Quality and Storage Potential of Young 'Kinnow' Mandarin Trees

Samina Khalid[1*], Aman Ullah Malik[2], Ahmad Sattar Khan[2], Kashif Razzaq[3] and Mudassar Naseer[4]
[1]*Department of Environmental Sciences, COMSATS Institute of Information Technology, Vehari, Pakistan*
[2]*Postharvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (38040), Pakistan*
[3]*Muhammad Nawaz Shareef University of Agriculture, Multan 60000, Pakistan*
[4]*Horticulture Research Station, Sahiwal, Pakistan*
[*]For correspondence: samina846@hotmail.com

Abstract

Poor fruit quality of young 'Kinnow' mandarin orchards limits its export potential and hence causes significant economic loss to the growers. Plant growth regulators (PGRs) are widely applied in mature citrus trees to improve fruit quality. However, their application in young orchards is scarce. The current study was designed to evaluate the influence of before and after color break (CB) applications of gibberellic acid (GA_3) 10 mg L^{-1}, 2, 4 dichlorophenoxy acetic acid (2, 4-D) 10 mg L^{-1}, putrescine (Put) 0.1 mg L^{-1} and spermine (Spm) 0.1 mg L^{-1}, on fruit quality of young 'Kinnow' orchards, at harvest, after seven days at ambient conditions (20±2°C and 60–65% relative humidity) and after 45 days at cold storage (4±1°C and 75–80% relative humidity). Application of 2, 4-D significantly reduced titratable acidity (TA) and improved TSS:TA ratio. The GA_3 reduced fruit colour development and enhanced mass loss (%); Spm reduced juice mass (%) and increased rind mass (%). The GA_3 application before CB significantly decreased reducing sugars (%) whereas, after CB application significantly increased rind mass (%) total soluble solids (TSS), total and non reducing sugars (%) in comparison with control. Polyamines (PAs) application after CB significantly reduced juice mass (%) and increased rind mass (%), TSS, total and non-reducing sugars (%). The 2, 4-D application after CB significantly decreased juice mass (%) and increased TSS, total and non reducing sugars (%) in comparison with control. After 45 days of cold storage 2, 4-D application significantly improved reducing sugars while, Put enhanced mass loss (%). In conclusion, 2, 4-D may be applied in young 'Kinnow' mandarin orchards after CB; however, PAs applications may be restricted due to their undesirable effect on fruit quality.

Keywords: Colour break; Fruit quality; Gibberellic acid; 'Kinnow' mandarin; Polyamines; 2, 4 dichlorophenoxy acetic acid

Introduction

'Kinnow' (*Citrus nobilis* Lour × *Citrus deliciosa* Tenora) mandarin is the most prominent *Citrus* cultivar of Pakistan. Its area and production has been increasing overtime, however, its life span is decreasing due to many biotic and abiotic factors (Ahmad *et al*., 2006) and its average life seldom exceeds 25 years (Ibrahim, 2004). In some countries the productive life of citrus tree is 50 years and in some cases it lives 100 years or more depending upon good management practices (Chaudhary *et al*., 2004). In Pakistan citrus tree takes 8–9 years to bear fruit commercially, whereas in Australia it takes only 6 years (Johnson, 2006). Exporters are reluctant to take fruit from young (less than eight years old) 'Kinnow' orchards due to quality concerns in terms of low juice and high rind and rag contents (Khalid *et al*., 2012b). Moreover, fruit from young trees also contains less TSS contents (Khalid *et al*., 2012a), hence rejected by the processers. Due to these reasons fruit from young trees are often sold in local market at very low price.

Growers of 'Kinnow' mandarin in this respect are highly disadvantaged because exporters are reluctant to buy fruit from young orchards and after 15–20 years their orchard starts declining and need replantation. So there is a need to increase the productive window of 'Kinnow' mandarin trees and it can be increased by improving quality of young orchards or extending life span of old orchards. A lot of research work has been done in extending life span of old orchards (Chung and Brlansky, 2005; Batool *et al*., 2007), but little information is available about the improvement of fruit quality of young orchards.

Plant growth regulators (PGR) are being used in citrus orchards to manipulate vegetative and reproductive growth, to modify fruit set and fruit growth and to improve fruit quality (Saleem *et al*., 2008). As Fidelibus *et al*. (2002) reported that 45 g ha^{-1} a.i. GA_3 applied at color break to 'Valencia' orange trees can increase 2–10% juice yield

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compared to non-treated trees. In citrus 25 mg L^{-1} GA_3 application might reduce rind thickness (Pozo *et al.*, 2000) and fruit having thinner rind should yield more juice (Fidelibus *et al*., 2002). In 'Baldy' mandarin GA_3 application by mid-November affected fruit weight, diameter, volume, juice percentage, TSS, TA, TSS: TA ratio and ascorbic acid (El-Hammady *et al*., 2000). Preharvest GA_3 applications extended the storage life of citrus by delaying its maturation and senescence (El-Otmani and Coggins, 1991). In 'Navel' oranges 20 mg L^{-1} 2, 4-D application was found effective in improving fruit quality (Kassem *et al*., 2011). Likewise polyamines are also found to improve fruit quality in mango (Malik and Singh, 2006), litchi (Mitra and Sanyal, 1990) and sweet orange (Saleem *et al*., 2008). In lemon storage, polyamines significantly improved fruit firmness and reduced weight loss and chilling injury (Valero *et al*., 1998).

Several researchers reported that endogenous PGRs concentrations alter during fruit growth and development (Gambetta *et al.*, 2011; Nathan *et al.*, 1984), which result in maturation, ripening and senescence. Exogenous application of PGRs during fruit growth and development can affect its fruit quality. Khalid *et al.* (2012b) reported the influence of PGRs application at flowering and fruit setting in young 'Kinnow' mandarin trees. However, to the best of our knowledge, pre-harvest exogenous application of PGRs before and after CB in young orchards has not been investigated before. This study was, therefore, conducted to determine the effect of PGRs application before and after CB stage, on fruit quality of young 'Kinnow' orchards.

Materials and Methods

Plant Material

The experiment was performed on young (3–4 years old) 'Kinnow' mandarin trees budded on 'Rough' lemon (*Citrus jambhiri* Lush.) rootstock growing in a commercial orchard located in Silanwali area (latitude 31°49´ N; longitude 72°32´ E), of Sargodha District, Punjab, Pakistan. Thirty uniform and healthy trees (five treatments, two spray application times and three replications) were selected for evaluating the effect of application time of PGRs on 'Kinnow' mandarin fruit quality. Cultural practices in the experimental area were carried out according to the commercial recommendations.

Application of PGRs

Plant growth regulators like Put and Spm were purchased from Sigma Alderich chemical company while, GA_3 and 2, 4-D were procured from Applicam. The 2, 4-D, GA_3, Put and Spm were applied on 1st September i.e. before CB and 1st November after CB. The 2, 4-D and GA_3 10 mg L^{-1} were first dissolved in 1 N NaOH and ethanol respectively and made volume up to the mark with distilled water. Put and Spm 0.1 mg L^{-1} were simply dissolved in distilled water. Foliar application of PGR solution containing 0.1% Tween 20 as wetting agent was made to single tree as a treatment unit till point of runoff. Control trees received simple water spray containing same concentration of wetting agent.

At commercial harvest maturity (when rind color changes to 100% orange-yellow), 45 fruit per treatment per replication were harvested except in 1st Nov application, where only 30 fruit per treatment per replication were harvested due to less number of fruit per tree. Fruit were packed and brought to Postharvest Research and Training Centre (PRTC) Institute of Horticultural Sciences (IHS), University of Agriculture, Faisalabad where these were washed with tap water, dipped in fungicide (0.2% thiabendazole) for 1 min and air dried at room temperature (20±2°C). The study was further divided into following two experiments:

Experiment 1: Effect of Application Time of PGRs on Shelf-life of 'Kinnow' Mandarin

Two lots each of 450 fruit (5 treatments × 2 application time × 3 replications ×15 fruit) were used to determine the effect of application time of PGRs on shelf-life of 'Kinnow' mandarin. One lot was analyzed immediately after harvest and 2nd lot was kept at ambient conditions (20±2°C and 60–65% RH) and analyzed after seven days.

Experiment No. 2 Effect of Time of PGRs Application on Storage Life of 'Kinnow' Mandarin

In this experiment 225 fruit (5 treatments × 1 application time × 3 replications × 15 fruit) were stored (4±1°C; RH 75–80%) for a period of 45 days. After storage fruit were brought to ambient temperature and kept there for two days and then analyzed for various fruit quality variables.

Rind color scores were determined by the method described by Khalid *et al*. (2012a). Rind color was manually scored by using the following rating scale: 1 = 100% green, 2 = 75% green; 25% orange, 3 = 50% green; 50% orange, 4 = 25% green; 75% orange and 5 = 100% orange. Fruit mass loss was calculated by taking the difference between initial and final mass of fruit divided by their initial mass and then its percentage was calculated. Rind, rag and juice were weighed separately and their quantities were expressed in percentage. The TSS (Brix) of the juice were determined by using hand refractometer (Atago, ATC-1, Tokyo, Japan). Juice TA and sugars were determined by following the method of Hortwitz (1960). Juice samples were titrated against 0.1 N NaOH using two to three drops of phenolphthalein as an indicator, and the results were expressed in percentage. Reducing sugars were determined by titrating the juice against Fehling's A and B solutions using methylene blue as an indicator to brick-red end point. For the determination of total sugars juice samples were first acid hydrolyzed and then titrated by the method described for reducing sugars.

Statistical Analysis

First experiment was analyzed by three factor factorial and 2nd experiment was analyzed by two factor factorial randomized complete block design (RCBD). Data were analyzed by MSTAT-C software (Freed and Scott, 1986) and treatment means were compared by Duncan Multiple Range Test (DMRT).

Results

Experiment 1: Effect of Application Time of PGRs on Shelf-life of 'Kinnow' Mandarin

Physical fruit quality: Rind color development (4.99) was significantly reduced by GA_3 (10 mg L^{-1}) application in comparison to control (Table 1). More fruit mass loss (11.38%) during shelf-life was recorded with GA_3 (10 mg L^{-1}) as compared to control (4.83%) (Table 2). When PGRs were applied before CB no significant differences in mass loss (%) was observed whereas, after CB more mass loss (17.12%) was recorded with GA_3 (10 mg L^{-1}) application as compared with control (3.71%) (Table 2). Juice mass (41.16%) was significantly decreased whereas, rind mass (34.47%) was increased by Spm (0.1 mg L^{-1}) application in comparison with control (Table 3). The PGRs application before CB had no significant effect on rind mass (%), whereas after CB application of GA_3 (10 mg L^{-1}), Put (0.1 mg L^{-1}) and Spm (0.1 mg L^{-1}) statistically gave higher rind mass 31.82%, 33.46% and 32.45%, respectively when compared with control (28.11%) (Fig. 1a). Application of PGRs before CB gave statistically similar results for rag mass (%) while, after CB 2, 4-D (10 mg L^{-1}) significantly gave higher rag mass (31.37%) in comparison with control (22.17%) (Fig. 1b). Application of 2,4-D before CB gave higher juice mass (47.75%) although the results were statistically non significant with control, whereas after CB application of Put (0.1 mg L^{-1}), 2, 4-D (10 mg L^{-1}) and Spm (0.1 mg L^{-1}) had statistically lower juice mass 42.71%, 42.17% and 42.03%, respectively in comparison with control (50.18%) (Fig. 1c).

Biochemical fruit quality: Among PGRs Spm (0.1 mg L^{-1}) and 2, 4-D (10 mg L^{-1}) applications gave maximum TA (0.88%) and TSS:TA (14.91), respectively in comparison with control (Table 4). Application of PGRs before CB had statistically similar results for TSS whereas, after CB all PGRs applications had higher TSS contents in comparison with control (9.60 Brix) (Fig. 2a). Application of GA_3 (10 mg L^{-1}) before CB had statistically lower reducing sugars (1.23%) in comparison with control (1.44%), whereas after CB Spm (0.1 mg L^{-1}) application had higher reducing sugar (1.67%) (Fig. 2b). The PGRs application before CB had no significant effect on non reducing sugars (%),whereas after CB, Put (0. mg L^{-1}), GA_3 (10 mg L^{-1}), and 2, 4-D (10 mg L^{-1}) had statistically higher non reducing sugars 6.17%, 5.83%, and 5.80% respectively in comparison to control (5.23%) (Fig. 2c). Total sugars (%) were statistically non significant with PGRs application before CB, whereas after CB all PGRs had statistically higher total sugar (%) in comparison with control (6.91%) (Fig. 2d).

Experiment 2: Effect of Application Time of PGRs on Storage Life of 'Kinnow' Mandarin

Physical fruit quality: Analysis of fruit after 45 days of cold storage, revealed that physical fruit quality variables like rind color (score), rind mass (%), rag mass (%) and juice mass (%) were non significantly affected by PGRs application (data not given). Fruit mass loss (22.98%) was higher in Put (0.1 mg L^{-1}) treated fruit, whereas minimum fruit mass loss (15.85%) was observed with control (Table 5).

Biochemical fruit quality: Biochemical fruit quality parameters like TSS, TA (%) and TSS:TA were found to be non significant due to PGRs application and their interaction with storage duration (data not given). Only reducing sugars (%) were significantly increased by 2, 4-D (10 mg L^{-1}) application (Table 6). On day-1, all PGRs had statistically similar reducing sugars (%) in comparison to control. Reducing sugars (%) increased during cold storage and maximum reducing sugars (2.11%) was observed with 2, 4-D (10 mg L^{-1}) in comparison with control (1.53%) (Table 6).

Discussion

The PGRs has been widely used in mature citrus plants to improve fruit yield and quality (Fidelibus *et al*., 2002; Saleem *et al*., 2008) and to increase on tree storage by delaying rind color development. In this study, GA_3 when applied to young 'Kinnow' mandarin plants before and after CB significantly reduced rind color development. In autumn when temperature decrease, the chlorophylls present in the rind are degraded and previously masked carotenes are freshly synthesized (Sinclair, 1984) and hence color development occur. The GA_3 is well recognized for its delayed transformation of chloroplast to chromoplast and hence reduced color development in citrus fruit (Goldschmidt, 1988).

GA_3 and Put treated fruit had increased mass loss after seven days shelf-life and 45 days cold storage, respectively. This might be due to more moisture loss from the fruit surfaces. Citrus fruit are covered by epicutical wax, which reduces moisture loss from the fruit (Albrigo, 1986). The GA_3 delayed the wax accumulation in 'Washington' navel orange (El-Otmani and Coggins, 1985), which caused more moisture and mass loss from the fruit. Similarly, Baez-Sanudo *et al*. (1993) also reported that GA_3 treated 'Clementine' mandarin had more mass loss due to less deposition of waxes on fruit surfaces. More fruit mass loss (%) in Put treated fruit during cold storage might be due to accumulation of more PAs in addition to applied Put under low temperature stress (Nair and Singh, 2004).

Table 1: Influence of concentrations and time of application of PGRs on rind color (scores) of 'Kinnow' mandarin fruit during 7 days shelf-life

PGRs	Before CB		After CB		Mean
	Day-1	Day-7	Day-1	Day-7	PGRs
Control	5.00	5.00	5.00	5.00	5.00A
GA_3 (10 mg L^{-1})	4.99	4.99	4.99	5.00	4.99B
Put (0.1 mg L^{-1})	5.00	5.00	5.00	5.00	5.00A
Spm (0.1 mg L^{-1})	5.00	5.00	5.00	5.00	5.00A
2,4-D (10 mg L^{-1})	5.00	5.00	5.00	5.00	5.00A
LSD ($P \leq 0.05$)					
PGRs			= 0.008		
PGR × application time × shelf duration			= NS		

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, GA_3= Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid, CB = Color break

Table 2: Effect of concentration and time of applications of PGRs on fruit mass loss (%) of 'Kinnow' mandarin fruit during seven days shelf-life studies

PGRs	Before CB	After CB	Mean PGRs
Control	5.94cd	3.71d	4.83D
GA_3 (10 mg L^{-1})	5.65cd	17.12a	11.38A
Put (0.1 mg L^{-1})	5.30d	8.98bc	7.14BC
Spm (0.1 mg L^{-1})	6.35cd	4.55d	5.45CD
2,4-D (10 mg L^{-1})	6.14cd	10.31b	8.23B
LSD ($P \leq 0.05$)			
PGRs		= 2.170	
PGR × application time × shelf duration		= 3.069	

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D =2 4 dichlorophenoxy acetic acid, CB = Color break

Table 3: Effect of PGRs and shelf duration on juice mass and rind mass (%) of 'Kinnow' mandarin

PGRs	Before CB		After CB		Mean
	Day-1	Day-7	Day-1	Day-7	PGRs
		Juice mass (%)			
Control	51.09	37.58	50.83	48.60	47.03A
GA_3 (10 mg L^{-1})	47.79	40.24	52.82	43.17	46.01A
Put (0.1 mg L^{-1})	50.80	40.21	46.47	38.96	44.11AB
Spm (0.1 mg L^{-1})	43.09	37.48	44.44	39.62	41.16B
2,4-D (10 mg L^{-1})	51.60	44.55	45.51	38.83	45.12A
		Rind mass (%)			
Control	31.87	35.63	26.61	29.61	30.93B
GA_3 (10 mg L^{-1})	30.36	31.33	29.06	34.59	31.33B
Put (0.1 mg L^{-1})	34.57	32.85	30.50	36.42	33.59A
Spm (0.1 mg L^{-1})	36.86	36.11	31.32	33.59	34.47A
2,4-D (10 mg L^{-1})	33.90	31.28	23.80	29.12	29.53bB
LSD ($P \leq 0.05$)					
Juice mass (%)					
PGRs			= 3.04		
PGR × application time × shelf duration			= NS		
Rind mass (%)					
PGRs			= 2.18		
PGR × application time × shelf duration			= NS		

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid, CB = Color break

Table 4: Biochemical quality attributes of 'Kinnow' mandarin as influenced by PGRs and shelf duration

PGRs	Before CB		After CB		Mean
	Day-1	Day-7	Day-1	Day-7	PGRs
		TA (%)			
Control	0.87	0.69	0.82	0.69	0.77BC
GA_3 (10 mg L^{-1})	0.90	0.73	0.90	0.76	0.82AB
Put (0.1 mg L^{-1})	0.94	0.75	0.94	0.82	0.86A
Spm (0.1 mg L^{-1})	1.02	0.77	0.92	0.79	0.88A
2,4-D (10 mg L^{-1})	0.91	0.66	0.80	0.64	0.75C
		TSS:TA			
Control	12.48	16.29	11.97	13.67	13.60B
GA_3 (10 mg L^{-1})	11.54	15.50	11.95	13.81	13.20BC
Put (0.1 mg L^{-1})	10.86	15.00	12.18	12.79	12.71BC
Spm (0.1 mg L^{-1})	9.77	14.11	11.79	12.99	12.16C
2,4-D (10 mg L^{-1})	12.45	17.63	12.55	17.01	14.91A
LSD ($P \leq 0.05$)					
Titratable acidity (%)					
PGRs			= 0.0578		
Application time			= NS		
PGR × application time × shelf duration			= NS		
TSS:TA					
PGRs			= 1.059		
Application time			= NS		
PGR × application time × shelf duration			= NS		

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, CB = Color break, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid

Increased in PAs due to low temperature stress might have inhibited the ethylene production, as PAs and ethylene had the same precursor S-adenosyl methionine (SAM) (Kakkar and Rai, 1993). Ethylene increased surface wax (Ju and Bramlage, 2001) and also increased new wax formation in 'Fortune' mandarin (Sala, 2000). Reduction in ethylene synthesis might reduce the surface wax deposition and hence more mass loss (%) was observed from the fruit treated with Put.

Polyamines (Put and Spm) treated fruit had significantly higher TA (%) as compared with control. Since predominant acid in citrus fruit is citric acid. PAs may have increased the activity of phosphoenolpyruvate carboxylase (PEP carboxylase) enzyme (Mattoo *et al*., 2006), which may increase the formation of oxaloacetate and that later converted to citric acid (Buslig, 1970). Similarly, Mitra and Sanyal (1990) reported that Put application before anthesis to litchi fruit significantly increased TA (%). In 'Florida King' peach cultivar exogenous application Put significantly increased TA (%) in comparison with control (Ali *et al*., 2014). High TSS:TA with 2,4-D might be due to higher TSS (data not given) and lower TA of juice while, reverse results was seen by Spm and Put treatment (Table 4). Analogous results were also reported in litchi fruit by Put application (Mitra and Sanyal, 1990).

Effect of application time of polyamines on fruit quality might be due to difference in their endogenous levels at the time of PAs applications, as Tassoni *et al.* (2004) reported a higher Put content in rind and rag of navel oranges during ripening. Endogenous GA_3 concentrations

Table 5: Influence of PGRs on mass loss (%) of 'Kinnow' mandarin during 45-days cold storage

PGRs	Fruit mass loss (%)
Control	15.85b
GA_3 (10 mg L^{-1})	18.83b
Put (0.1 mg L^{-1})	22.98a
Spm (0.1 mg L^{-1})	17.19b
2,4-D (10 mg L^{-1})	16.42b
LSD ($P \leq 0.05$) PGRs = 4.081	

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2, 4 dichlorophenoxy acetic acid

Table 6: Effect of PGRs on juice reducing sugars (%) of 'Kinnow' mandarin during storage

PGRs	Day-1	Day-45	Mean PGRs
Control	1.42def	1.53cde	1.48B
GA_3 (10 mg L^{-1})	1.20f	1.69bc	1.44B
Put (0.1 mg L^{-1})	1.38ef	1.67bcd	1.52B
Spm (0.1 mg L^{-1})	1.30ef	1.82b	1.56B
2,4-D (10 mg L^{-1})	1.36ef	2.11a	1.74A
LSD ($P \leq 0.05$)			
Reducing sugars (%)			
PGRs	= 0.175		
PGR × storage duration	= 0.247		

Means not sharing a common letter are significantly different ($P \leq 0.05$)
NS = Non significant, PGRs = Plant growth regulators, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid

started diminishing during colour break of citrus (Gambetta *et al*., 2011), this might be the reason of fruit quality differences in before CB and after CB application time.

Increase in reducing sugars (%) during cold storage in all treatments could be due to conversion of polysaccharides (starch or sucrose) into monosaccharides (glucose and fructose). Increment in reducing sugars was more in 2, 4-D treated fruits as compared to control. This might be due to auxin (2, 4-D) induced synthesis of invertase enzyme (Rao *et al*., 2015). Since auxin is known to regulate the gene expression for the synthesis of invertase enzyme (Wang and Ruan, 2013). Invertase enzyme is responsible for breakdown of sucrose into fructose and glucose (Tymowska-Lalanne and Kreis, 1998). Hence results in more reducing sugars (%).

In young 'Kinnow' mandarin trees 2, 4-D application improved fruit quality, as compared to polyamines. The possible reason for this might be the increment in vegetative growth of young citrus trees in response to polyamines applications. Fruit from young vigorously growing trees usually have thick rind, low TSS, TA, high TSS:TA ratio and delayed color development (Hearn, 1993). Young Navel trees with limited vegetative growth produce better quality fruit as compared to trees with more vegetative growth (Hearn, 1993). In young citrus trees 2, 4-D application causes leaf curling and growth retardation (Calavan *et al*., 1956). Reduction in vegetative growth diverts assimilates to reproductive growth (fruit) and hence improved fruit quality.

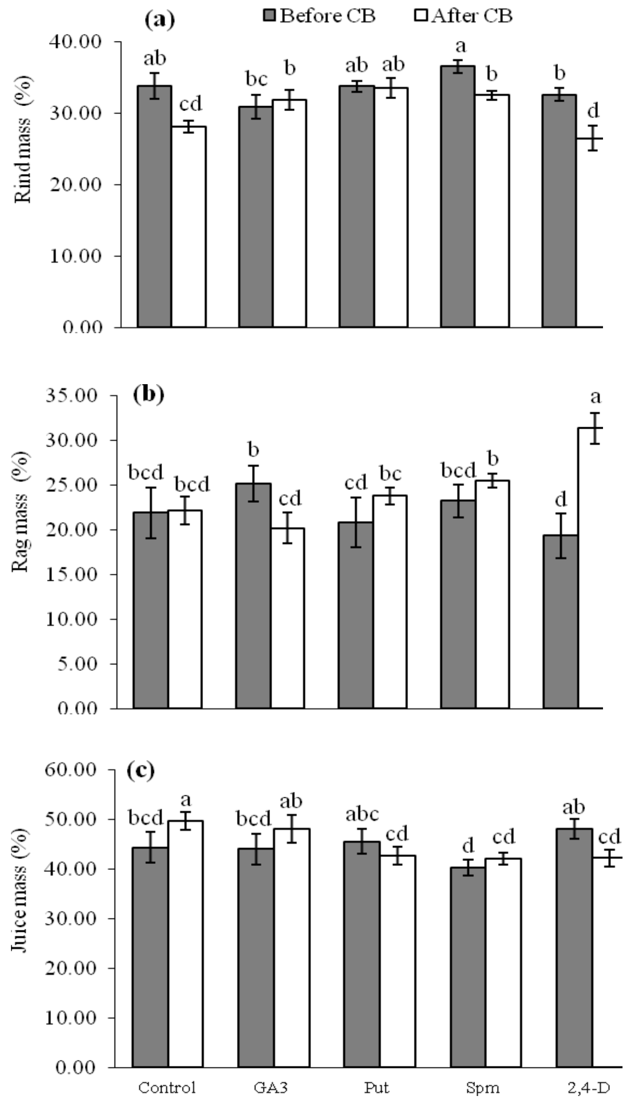

Fig. 1: Effect of concentration and time of PGRs application on rind mass (%) (a) rag mass (%) (b) and juice mass (%) (c) of 'Kinnow' mandarin. PGRs = Plant growth regulators, CB = Color break, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid

Conclusion

In conclusion 2, 4-D application after color break had positive effect on fruit quality of young 'Kinnow' mandarin trees and can be used as potential growth regulator while, PAs application must be restricted in young orchards due to their undesirable effect on fruit quality. It also suggests that while, GA_3 does not improve juice (%) but it delayed maturity and rind color development and can extend on tree storage.

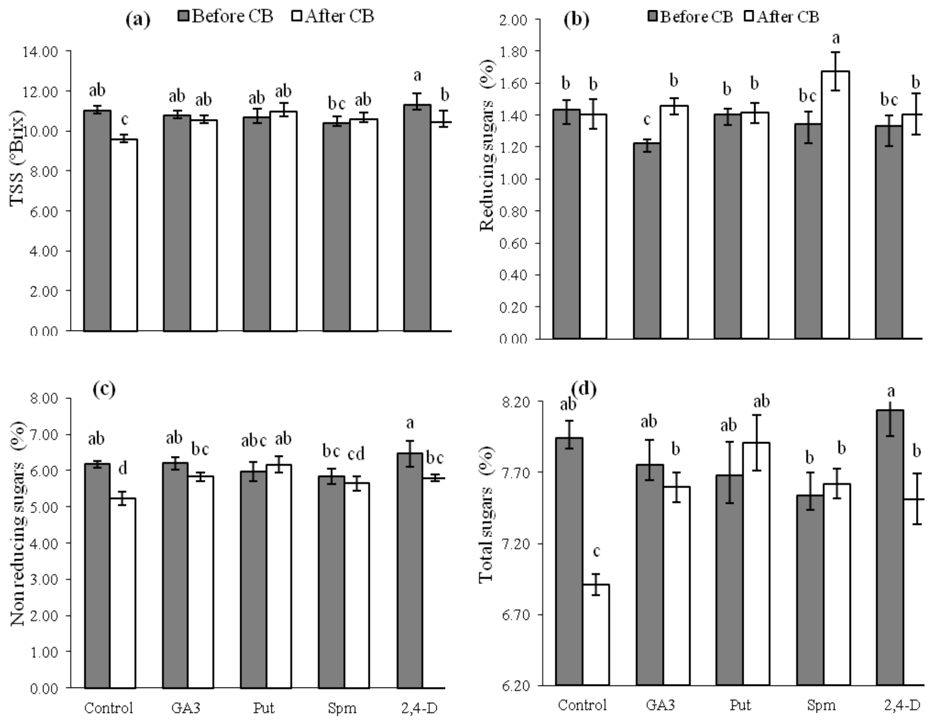

Fig. 2: Effect of concentration and time of PGRs application on TSS (Brix) (a), reducing sugars (%) (b), non-reducing sugars (%) (c) and total sugars (%) (d) of 'Kinnow' mandarin juice. PGRs = Plant growth regulators, CB = Color break, GA_3 = Gibberellic acid, Put = Putrescine, Spm = Spermine, 2, 4-D = 2 4 dichlorophenoxy acetic acid

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