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Effect of Plant Growth Regulators for Improvement of the Quality and Shelf Life of Kinnow (*Citrus nobilis* x *Citrus deliciosa*): A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Plant growth regulator's plays a very important role in Kinnow production. There are different type of PGR's that includes GA_3, NAA, CPPU and Ethyl which when applied on kinnow performs well and give good results such as high quality, yield and long shelf life of the fruit. Plant growth regulators (PGRs) are well known for having a significant impact on fruit retention. Plant growth regulators are hormones that are involved in physiological functions, developmental aspect and have an impact on cell development and growth. They are cellular communication tools known as chemical

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messengers Also known by the name "plant hormones". Plant growth regulators enhance fruit set, minimize fruit drop, and correct a variety of physiological functions to improve quality and productivity by improving the physiology of fruits. Gibberellins and auxin are frequently used to reduce fruit drop and enhance fruit quality. The primary role of plant growth regulators in the creation of Kinnow mandarins is the main subject of this review.

Keywords: Kinnow mandarin; foliar applications; GA_3; NAA; CPPU; salicylic acid; brassinosteroids; 2, 4-D; shelflife.

1. INTRODUCTION

In the plant kingdom, Citrus is a very important genus that belongs to the family Rutaceae which originated in south-east Asia. The total area under citrus fruits in India was 1003'000 Ha and total production was 12546'000 MT[1]. After Mexico in India, the Citrus fruit crop ranks 6th in production and occupies 3rd position after Banana and Mango. Citrus fruits are a vital source of ascorbic acid and have high nutritional value. The north-western region of India is are major Kinnow growing areas among them Punjab occupies more area. The most common citrus cultivars that are grown are Kinnow, sweet oranges, Lime and Lemon, etc. and these are major fruit crops of Punjab. The total area under Citrus varieties is presence grown in Punjab over 52,836 ha, with a once-a-year production of 1,049,977 tons[2]. Kinnow is cultivated extensively throughout North India and Pakistan. The whole area in which kinnow fruit is grown in Punjab is 51,000, with an average yield of about 11,000 MT in 2016–2017[3]. It alone rules about 61.9% of the total.

A significant Rutaceae genus is a citrus family in plant kingdom that is native to Southeast Asia. The production of citrus all over the world is about 124 million tons. The total production area of citrus in India is 1003'000 ha and the total production of citrus is about12546'000 MT [1]. In India, citrus ranks 6th in production and occupies 3rd position after Banana and Mango in case of the region. Fruits are a vital source of ascorbic acid and have high nutritional value. The north-western region of India is a major Kinnow growing area. Punjab is the major citrus-producing state in North India. Kinnow, Sweet orange, Lime and Lemons are the major varieties that are grown in Punjab. The total area under Citrus crop in Punjab is over 52,836 ha, with an annual production of 1,049,977 tons [2]. The most widespread cultivation of kinnow is in Pakistan and North India. Punjab has 51,000 acres dedicated to kinnow production, with an average output of 11,000 MT in 2016–2017 [3]. It alone makes up around 61.9% of Punjab's entire fruit acreage, and it is India's top fruit producer [4]. The need for the production of kinnow has been increasing in Punjab proper to the best suitable climatic condition for growing. Kinnow cultivation has become a benefit for the farmers which sustains their income and livelihood compared to other fruit crops. In kinnow the trait of transmitted. abiotic stress tolerance gained from its mother parent King mandarin which makes this tropical fruit appropriate for the sub-tropical region to grow. A prime example of how Punjab's citrus sector has been strengthened is the introduction of Kinnow. After several decades of evaluation, it was approved as a novel citrus for commercial production in 1935. Its traits are intermediate between mandarin and sweet orange, with neither loose nor tight skin.

2. FRUIT DROP

Fruit drop is a significant issue and a barrier to boosting fruit yield in citrus plantations. Citrus trees go through a lot of blooming, and even if there is an initially strong fruit set, chronic fruit loss at different phases of fruit development significantly lowers the overall output. It is well known that plant growth regulators (PGRs) significantly affect both fruit retention and fruit loss in fruit. They are essential for keeping fruit from rotting and degrading for several days. The capacity of fruits to improve significantly after harvest is boosted by post-harvest treatments [5]. Fruits' taste and flavour are negatively impacted by water vapour loss during harvest because it causes skin to shrink, turgidity to decline, and resistance to gas diffusion to go down [6]. Under several conditions pertaining to their effect on the caliber and lifespan of kinnow, they were closely examined throughout these procedures.

The coordination of developmental processes depends on plant hormones. Environmental influences commonly have inductive effects that alter the hormone distribution and metabolism in plants. They also regulate the manner in which a

plant's intrinsic genetic potential is manifested. There is evidence that phytohormones can control both the transcriptional and translational aspects of gene expression. Hormone receptors and specialized binding proteins for certain hormones have all been found on the membrane surface. For most crops, but notably for fruit trees, the use of plant hormones has become a crucial aspect of agronomic strategy. Plant growth regulators can therefore be applied exogenic to fruit crops to reduce excessive fruit drop. To reduce fruit drop and enhance fruit quality in citrus, auxins, and gibberellins can be utilized [7]. Reduced fruit drop due to the foliar application of GA_3 may boost yield [8]. NAA (naphthalene acetic acid) applied topically to foliage may benefit a variety of species or cultivars by lowering crop load, preventing alternate bearing, and increasing fruit size and quality [9]. Applying nutrients and growth regulators is strongly suggested to stop fruits from ripening too early. Plant growth regulators are hormones that regulate many physiological functions and developmental aspects in a different place from where they are produced. These are the organic substances that could be found within the plant. These might improve fruit productivity and quality, extending the fruits' shelf life after harvest. PGRs have been used since even the smallest change could have a significant impact on the product's value. Plant growth regulators such as phytohormones, gibberellins, cytokinin, ethylene, and abscisic acid were among the first and most often utilized ones discovered. The critical role that auxins play in preserving human health has led to their recognition as a very essential PGR. It contains both synthetic and natural components, with the synthetic ones being NAA, IAA, and IBA and the natural ones being NAA, IAA, and IBA. Additional plant hormones include polyamines, 1-methylcyclogas, 2-hydroxybenzoic acid, and brassinosteroids. While some of them are produced in carefully monitored environments, some of them are manufactured under controlled conditions, while others are generated naturally.

3. FLOWERING STAGE

Every year after the juvenile stage, citrus fruits bloom. Numerous internal and external factors affect the annual blossoming of mature trees. Citrus and the bulk of tropical and subtropical plants may bloom in cold temperatures [10]. In Wenzhou Mikan, trees exposed to 15° C for more than 1.5 months exhibit floral induction. Unless they are exposed to temperatures below 25^{o} C, trees typically stay in the vegetative development phase [11]. when the induction of flowers develops in the fall, trees are exposed to low temperatures [12]. Plant growth regulators promote the release of floral organs, which drastically lowers the number of blooms.

They found that when GA_3 (20–50 mg/L) was sprayed as a foliar treatment to all citrus fruits, Organized flowering fell by 60%, and hemidine blooming by 25% 6 L each tree [13]. It has been shown that adding GA_3 to citrus bud growth limits flower creation, boosts the proportion of terminal flowers in leaf buds, and encourages fruit development [14]. Similar findings were obtained when citrus blossoms were stimulated by GA_3, although GA_3 had an inhibiting impact [15].

They are necessary to prevent fruit from wilting and rotting for several days. Fruits have a substantially greater ability to keep quality after harvest thanks to post-harvest treatments [5a]. After harvest, the skin of fruits guarantee, their turgidity deteriorates, and their resistance to gas diffusion weakens, all of which have an adverse impact on flavour and taste perception [6a]. They were closely monitored during these procedures in a number of ways that had to do with how they might affect the quality and shelf life of Kinnow. The potential to develop was higher in untreated (control) fruits than in fruits treated with various agents across all treatments, and TSS increased with longer storage durations. They found that after a week of heavy winds, non-sealed fruits suffered the most damage [16].

3.1 Factors Affecting Citrus Production and Quality

In subtropical areas, the average wintertime low temperature is below 70°F for a number of months. During this period of freezing weather, citrus trees cease growing and hibernate for around three months. The frigid temperatures during this dormant season promote floral induction. High spring temperatures, among other factors, promote the return of vegetative growth, which induces buds to form and produces blooms. In tropical climates, there is no cold temperature phase that would produce dormancy. However, blooming and vegetative growth frequently follow times of insufficient soil moisture (drought stress).

In terms of horticultural crops, citrus fruits stand out because of their size, high seasonality, and short shelf life. Citrus fruits should therefore be

handled carefully both during and after harvest. As the product is transported from citrus farms to final consumers, it is estimated that post-harvest losses for citrus range from 25 to 35 percent. The growers disregard sorting, grading, standardizing, and packing, which reduces their profitability. The majority of traditional packaging was created using materials that were easily accessible. Furthermore, products of various ages, grades, and conditions are blended since manufacturers are unfamiliar with maturity indices. In terms of horticulture crops, citrus fruits stand out because of their size, extreme seasonality, and short shelf life.

It was shown that after Zn was administered to the leaves, the ascorbic acid concentration in the juice of numerous citrus varieties increased [17]. Ascorbic acid concentrations increased in response to applications of Zn alone, Zn+Mn, or Zn+B [18]. Zinc and gibberellic acid sprays were used to produce large amounts of ascorbic acid [19]. They found that the 2,4-D treatment boosted the vitamin C content of grapefruit from the Duncan cultivar [20]. In ripening apricot, peach, and papaya fruits, ascorbic acid levels increased; whereas, in ripening apples and mangoes, they declined [21]. Applying SA, Zn, and K singly and in combination helped the juice's TSS: Acid ratio. Abd-Allah, 2006 showed that the administration of K in conjunction with improved TSS: acid ratio due to micronutrients.

4. ROLE OF MICRONUTRIENTS IN DISEASE MANAGEMENT

Citrus fruits include the micronutrients essential for quality improvement as well as sickness prevention. The most extensively used product for avoiding diseases in citrus and many other crops, together with other horticultural measures, is the copper-based pesticide, one of the most popular micro-nutrient-based pesticides [22]. Citrus illnesses include Alternaria brown spot (Alternaria alternative (Fr.) Kiesler), citrus black spot (Xanthomonas axonopodispv. citri), scab disease, and citrus canker must be controlled with the application of these pesticides. once fruit has bloomed, to create a thin barrier against disease invasion, Cu-containing insecticides are sprayed on the tree canopy's leaf, woody components, flowers, and/or fruits. For the best citrus fruit yields, balanced plant nutritional management and appropriate phytosanitary management techniques based on cupric fungicide administration are necessary.

5. EFFECT OF PGR'S ON BIOCHEMICAL COMPOUNDS

The authority group's GA_3 had the highest total soluble solids (TSS^oBrix) level at 25 ppm. Although the fruit was still ripe, treatment with GA_3 at 65 ppm and 85 ppm did not produce satisfactory results. This is because GA_3 slows down fruit ripening when applied prior to the bloom collapsing. They claimed that a 10 ppm GA_3 spray applied in the fall prevents the formation of skin colour by lowering levels of ascorbic acid, sugar, and TSS [23]. In Washington, it has been demonstrated that spraying GA_3 on trees increases orange TSS. The effects of pre-harvest foliar spraying NAA, Ethrel, and GA_3 on fruit drop in Satluj purple plums were [24]. Ethrel and NAA were the two treatments that had the greatest impact on reducing pre-harvest fruit drop. In terms of fruit weight, TSS, and yield, the fruit that had been sprayed with ethrel performed significantly better. Higher levels of carbohydrates were discovered in the shoots and leaves of NAA-sprayed plants. In Nepal, tested the effects of 10, 20, and 30 ppm of gibberellic acid on Mandarin. The factors that were looked at included fruit weight (g), rind colour (1–5 index), decay loss (percent), PLW (Peel Puncture Resistance), TSS/acid ratio, juice recovery (percent), ascorbic acid (mg100ml), and fruit firmness [25].

6. EFFECT OF PGR'S ON YIELD

Evidently, the administration of NAA enhanced the fruit's weight, which contributed to the increase in production per plant. In aonla, mango, guava, pomegranate, ber and sapota, these results are consistent with previous findings [26-33]. With varying concentrations, significant differences were seen for the yield and its constituents (average fruit weight and fruit number/tree). The yield may be explained by the two growth regulators' beneficial effects on the translocation and biosynthesis of carbohydrates, which were reflected in rising fruit numbers and average fruit weight. Results are consistent However, their findings demonstrated that the use of GA_3 and NAA increased yield/tree, fruit weight [34-38]. The higher fruit set from improved flowering and higher hermaphrodite flowers, as well as the altered source-sink relationship in the plant, which directly reallocates the carbohydrate reserves by suppressing the vegetative growth, were the causes of the yield increase in paclobutrazol-treated trees before the bud break, during vegetative growth, paclobutrazol

application will not only prevent the increased growth but also increase the yield. In lime and acid lime also discovered similar outcomes [39,40]. By encouraging greater fruit cell division, cytokinin enhances fruit size. Cytokinin is one of the main factors limiting fruit growth and final size and they are used to induce fruit set or parthenocarpic fruit development when applied exogenously [41]. Cell division during the early stages of fruit development may have a major influence on final fruit size. Using GA_3, 2, 4-D, and a combination at various bloom stages, a study on sweet orange (Blood Red) was successfully completed. The findings demonstrated that at a concentration of -120 mg L, both GA_3 and 2, 4-D greatly decreased flower and fruit drop and enhanced fruit set. As GA_3 and 2,4-D were combined, 2,4-D additionally dramatically decreased fruit drop when compared to control. Different concentrations of gibberellic acid, i.e., 10, 20, and 30 ppm, and were applied as a foliar application on three different cultivars of sweet orange at full bloom stage in Tarnab, Peshawar, Pakistan, to study the influence of gibberellic acid on fruit drop and fruit set in sweet orange [42]. Results revealed that applying 30 ppm of gibberellic acid to fruit set branch-1, pre-harvest fruit drop, and fruit weight significantly reduced percent fruit drop, percent June drop, and yield tree. Spraying GA_3 (50 mg/l) on citrus produced positive outcomes by safeguarding fruitlets and boosting output in "Nanfengmiju" mandarins [43]. Applying 45 mg. l^{-1} GA_3 at the full bloom stage to 15-year-old 'Blood Red' sweet orange trees enhanced yield (71 kg/tree) higher than the control (48 kg/$tree^{-1}$) [44].

7. EFFECT OF PGR'S ON QUALITY

It is well established in the literature that PGRs can be used to enhance citrus fruit quality. In this study, GA_3, higher BA and kinetin concentrations, and a control group all significantly increased juice mass (%) and decreased rag mass (%) [45]. This might be a result of the application of these growth regulators, which have promoted vascularization in the pedicel. GA_3 has been shown to have simultaneous impacts on juice output in "Satsuma" mandarins, "Sunburst" mandarins, "Hamlin" oranges, and "Hamlin" oranges [30]. GA_3 decreased juice mass (%) while having little impact on juice content in "Clementine" mandarins. GA_3 and 2, 4-D as spring treatments at the full bloom stage in an experiment on blood red delicious oranges in Faisalabad, Pakistan [11]. The morphological and physiological characteristics of the fruit were examined. The findings demonstrated that, when compared to control, the plant growth regulators significantly decreased fruit weight, fruit diameter, peel thickness, and peel quantity. But compared to untreated fruits, gibberellic acid markedly improved all sugar levels, including reducing, non-reducing, and total sugars, pulp percentage, juice %, seed quality and quantity, and organoleptic qualities, including taste, peel colour, pulp colour, and appearance. Kinnow mandarin using various concentrations of GA_3, 2, 4-D, and NAA to prevent fruit drop and improve qualitative features of the kinnow mandarin fruit in Faisalabad, Pakistan [6]. The growth regulators were applied during the last week of November. The findings showed that all growth regulators improved the qualitative traits, caused little fruit loss, and increased the number of fruits generated per plant. Spraying Washington navel oranges with NAA at level GA_3 at 25 ppm at full bloom increased juice volume in comparison to the control. Increase in Mandarin juice% [16]. Nutrients and plant growth regulators (PGRs) are critical for the development of mature trees [29]. In addition to influencing rind and juice quality, fruit colour, size, and total soluble solids, the PGRs have been used to alter flowering, fruit set, and fruit drop in a number of citrus species found that adding GA_3 at 50 ppm boosted the juice volume of Valencia oranges [32]. Endogenous PGRs and nutrient concentrations in citrus plants change with vegetative and reproductive development, which affects fruit set and fruit quality. Previous research showed that compared to adult plants, Kalanchoe and Valencia orange juvenile plants have low levels of endogenous GA_3 and cytokinin, respectively. It has been established that plant growth regulators (PGR) and nutrients affect fruit rind thickness. Rough fruit exhibited higher levels of endogenous cytokinin and GA_3 than smooth fruit on mature Shamouti orange trees that were 18 years old. Auxins and gibberellins are widely used to improve fruit quality and decrease fruit drop. Some fruits are not able to attain full maturity because of a variety of causes, including fruit setting and ripening. PGRs were used to reduce the acidity of fruit, which is a desired trait for improved fruit quality. Because the juice of the "Kinnow" fruit has a high acidity level and a bitter taste, Pakistan's harvest is delayed. The preharvest stage of the harvest can be accelerated by at least 15 days by using 15 mg/l NAA [32]. It has been demonstrated that plant growth regulators (PGRs) work to increase fruit

size and some quality characteristics. PGRs might therefore be helpful for producers if applied appropriately and on time. PGRs enhance cherished fruit attributes including flavour and nutritional value while also having a good impact on fruit appearance [31]. The rind's colour is crucial in all citrus fruits, including Kinnow. Compounds called plant growth regulators are adaptable. The proportion of citrus mandarin fruit sets rose considerably when PGR (24 D, GA_3, NAA) was applied consistently, and the average fruit output per plant also increased. By using PGR at low concentrations of a certain compound, TSS, acidity, and fruit size were enhanced, and the improved fruit parameters were successfully lowered over high concentrations of a particular compound, GA_3, which is of special importance commercially in the horticulture industry. Particularly in Kinnow GA_3 application has demonstrated several advantageous characteristics in the case of Flowering, Fruit size, colour TSS, and general quality [22]. In mature trees of the "Satsuma" and "Sunbrust" mandarins, as well as the "Hamlin," "Valencia," and "Navel" oranges, the use of PGRs, mainly GA_3 and cytokinin for the advanceof high-quality fruit is well traditional [23]. Research on the effects of exogenous PGR treatment on the fruit quality of early citrus plants is special. Allowing a number of research, small plants have minor stages of endogenous GA_3 and cytokinin than grown plants. This verified the deviation in endogenous PGR stages among early and developed plants, which power be a likely reason for the subpar fruit quality in young orchards. The current study's objective is to ascertain if exogenous application of PGRs such as gibberellic acid (GA_3) and cytokinin like benzyl adenine (BA) and kinetin may improve the physicochemical quality traits of fruit from young 'Kinnow' mandarin trees. PGRs improve beloved fruit qualities including flavour and nutritional content while also improving fruit appearance [31]. The foliar spray of gibberellic acid can aid increase output by reducing the rate of fruit loss [7]. The size and quality of the fruits of different species and cultivated cultivars, as well as the biennial production and crop load, can all be improved by the foliar application of NAA (naphthalene acetate) [11]. In mature trees of grapefruit, 'Hamlin', 'Valencia', and 'Navel' oranges, as well as 'Satsuma' and 'Sunbrust' mandarins it is well known that PGRs work with GA_3 and cytokinins to produce superior fruit [29,30]. Rarely is research on the fruit quality of young citrus plants conducted using exogenous PGR submission. According to several research, immature plants have lower levels of endogenous GA_3 and cytokinin than adult plants. This revealed the difference in endogenous PGR levels between young and mature plants, which might be a factor in young orchards' low fruit quality. The goal of the current study is to determine if exogenous application of PGRs, such as gibberellic acid (GA_3) and cytokinin [benzyl adenine (BA) and kinetin], may enhance the physicochemical quality attribute of fruit from immature "Kinnow" mandarin trees [23].

8. EFFECT OF PGR'S ON SHELFLIFE

They are necessary to prevent fruit from wilting and rotting for several days. Fruits have a greatly extensive ability to keep quality after harvest thanks to post-harvest treatments [4]. After harvest, the skin of fruits contracts, their turgidity deteriorates, and their fight against gas diffusion weakens, all of which have a cooperative impact on flavour and taste perception [5]. They were closely observed during these actions in a number of ways that had to do with how they might affect the quality and shelf life of kinnow. The measures to develop were higher in coarse (control) fruits than in fruits treated with countless agents across all treatments, and TSS increased with stretched packing durations.

Table 1. Influence of plant growth regulators in different treatments in different crops

No	Name of crop	Treatment	Results	References
1	Kinnow Mandarin	GA_3 100ppm	The highest fruit weight production and fruit retention rate are obtained when the Ga_3 chemical is spared.	[34]
2	Apple Fruit	NAA(100PPM)	The impact of the growth regulator treatments on the apple's shelf life under 30 days of ambient storage was significant.	[35]

No	Name of crop	Treatment	Results	References
			7.53% was found to be the maximum physiological weight loss (CPLW). Growth regulators reduced the amount of malic acid relative to untreated fruits while increasing TSS, or total sugars, in the fruit.	
3	Lemon	NAA (50ppm)	To boost the production and quality in the future, citrus fabricators of Assam Lemon can be advised to apply RDF @ 100:100:100g NPK/plant/year together with 20 kg FYM and NAA @ 20 ppm + 2,4-D @ 20 ppm + 1% urea foliar spray twice (after fruit setting and fully grown stage).	[36]
4	Litchi Fruit	NAA at (20ppm)	Application of micronutrients and growth regulators to the leaves already harvested affects the appearances of litchi output. The findings suggest that plant growth regulators and micronutrients had a positive control on fruiting, flowering, fruit retention, and fruit crop.	[37]
5	Phalsa Fruit	GA_3@(150ppm)	GA_3 applied foliar at a concentration of 150 ppm increases fruit output and vegetative growth. Therefore, for increased output, GA_3 150 ppm can be advised for phalsa producers.	[38]
6	Acid Lime	CCC (200ppm)	The treatment combination of PP333 1.5g a. i/m2 + NAA 200ppm was found to have better growth, yield, and quality attributes in terms of tree spread, fruit set%, fruit retention%, number of fruits per tree, yield per tree, juice volume, acidity, and ascorbic acid.	[39]
7	Acid Lime	GA_3@(20ppm)	The treatments have included plant growth	[40]

No	Name of crop	Treatment	Results	References
			regulators are applied in addition to the calcium salts GA_3(20 ppm, 40 ppm, and 60 ppm), NAA(10 ppm, 15 ppm, and 20 ppm), Calcium Nitrate (0.5%, 1%, and 1.5%), and Calcium Chloride (1%, 1.5%, and 2%). All of the results were statistically significant, including the lowest mean Total Soluble Solids (6.82 brix), the highest mean Acidity (6.95%), the lowest rag percentage (45.46%), the highest TSS: acid ratio (0.98), the highest mean Decay Loss (10.48%), the highest ascorbic acid (30.49 mg/100g), and the highest percentage of fruit set (89.52 has been observed in the treatment [Calcium Nitrate 1.5%]). compared to control after harvest and throughout the first 15 days of storage.	
8	Litchi	GA_3(100 ppm)	In order to increase the quality and yield of the Culcuttia cultivar of litchi, the nutritional significance for quality and yield improvement study was conducted. While T4 (1% Boric Acid + 3% Calcium Chloride + 20ppm NAA) and (1% Boric Acid + 3% Calcium Chloride + 20ppm GA_3) were similarly significant for several features, (1% Boric Acid + 2% Calcium Chloride + 20ppm NAA) was determined to be the best treatment overall for all criteria.	[41]
9	Mango	2,4-d, (30PPM)	Auxin and gibberellins are frequently used to reduce fruit drop and enhance fruit quality. Several agents are in charge of removing some fruits from the ontogenic	[42]

No	Name of crop	Treatment	Results	References
			development from fruit set to fruit ripening and final reach to client. We concentrate on the key roles that plant growth regulators play in fruit production in this review.	
10	Pomegranate	GA_3, (75ppm)	The largest fruit diameter (8.57 cm), highest mean fruit volume (291.00 ml), most fruits per plant (99.9), average fruit weight (161.56 g), and fruit production per ha (16.25 Mt/ha) were all considerably increased by the preharvest application of boron at a concentration of 0.3%. GA_3 75 ppm+boron 0.3%, an interactive treatment combination, led to enhanced pomegranate fruit growth and yield.	[43]
11	Pomegranate	CCC (150 ppm)	The more efficient treatments for enhancing floral qualities, fruiting, yield, and quality were plant flowers fruit set.	[44]
12	Sapota	CCC (450 ppm)	The single most significant element affecting fruit yield is fruit retention. In coastal climates, sapota blooms virtually all year round. Fruit productivity and producers' profitability may suffer as a result of flowers and fruits dropping off at various phases of growth, from setting through maturity.	[45]
13	Sapota fruit	GA_3@(100mg\1)	Different chemicals (Calcium chloride at 2%, Calcium nitrate at 2%, Calcium sulfate at 2%, and Potassium chloride at 2%), as well as varying concentrations of plant growth regulators (GA_3 at 50 and 100 mg/l and NAA at 50 and 100 mg/l), are used in pre-harvest spraying treatments (Water spray and Absolute). The fruit	[46]

No	Name of crop	Treatment	Results	References
			hardness, shelf life, and time it takes for the sapota fruits to ripen while in storage are also improved by these procedures.	
14	Acid lime	GA_3(30ppm)	The trees were sprayed with GA_3 mixed with NAA at a concentration of 20 ppm each to get the best results in terms of yield, and fruit physical and chemical attributes of Balady lime.	[47]
15	Kinnow	NAA (10ppm)	Exogenous treatment of growth regulators dramatically reduced preharvest fruit drop percentage, increasing total fruit production, fruit weight, juice percentage, total soluble solids, acidity, vitamin C, and reducing and non-reducing sugars% age while having no effect on fruit size. Gibberellins underperformed compared to auxin (2,4-D and NAA).	[6]
16	Acid lime	NAA (200ppm)	Excess return, yield, and quality parameters were observed in the treatment combination of PP333 1.5g a.i/m2 + NAA 200ppm, comprising tree spread, fruit set%, fruit retention%, fruit number per tree, yield per tree, juice quantity, acid, and ascorbic.	[48]
17	Sweet orange	NAA (20ppm)	The fruit production parameters, i.e., the fruit yield per plant and fruit yield per plant, were attained with NAA 20 ppm, whereas the other measures, such as fruit weight and fruit size, and height, were recorded with most foliar spray of GA_3 30 ppm.	[49]
18	Oranges	GA_3 and NAA 20+25	The effects of GA_3 and NAA gave one week after full bloom on Washington navel orange trees were	[50]

No	Name of crop	Treatment	Results	References
			studied. The results showed that spraying plants with GA_3 at 20 ppm with NAA at 25 ppm one week after fruit significantly boosted vegetative development metrics such as shoot length (cm), leaves per shoot at the three growth cycles, and leaf area compared to other treatments and the control (cm^2).	
19	Phalsa fruit	GA_3 (150ppm)	It is recommended for commercial vegetative multiplication till more research is done that 1000 ppm concentration of IBA with August planting time delivers the overall best performance under the mist situation to generate tallest plant of phalsa dwarf type in a short amount of time.	[38]
20	Acid lime	NAA (30ppm+ZnSO4 (0.5%))	Micronutrients and plant growth regulators have a significant role in the development and growth of acid lime. The study found that 2,4-D treatment decreased the number of seeds whereas NAA 30 ppm+Boric acid (0.2%) treatment enhanced yield, number of fruits per plant, weight, width, and volume of the fruits in comparison to controls.	[51]
21	Papaya fruit	NAA(100PPM)	The research showed that hand thinning significantly increased fruit set, fruit size, fruit weight, yield, physiological weight loss percentage, and firmness. In addition to considerably higher TSS and TSS/TA ratio, chemical thinning also resulted in slightly higher ascorbic acid	[52]

No	Name of crop	Treatment	Results	References
			concentration, reduced TA, and increased TSS. On the other side, chemical thinning shown an extreme thinning effect with the lowest yield and a higher abscission%. Defoliation treatments did not considerably improve output or quality.	
22	Acid Lime	GA_3(50 ppm) + ZnSO4 (1%) + FeSO4 (1%)	Due to the combined effects of GA_3, zinc, iron, and manganese in acid lime, the combined treatment (GA_3 + ZnSO4 + FeSO4 + MnSO4) recorded the maximum fruit weight. Sharma *et al.,* (2005) The treatment T11 achieved the highest fruit set (51.20%), highest yield (6.41 kg/tree), highest fruit number (148.00 fruit/tree), and lowest fruit drop (35.20%). The maximum number of fruits per tree was discovered in GA_3-treated acid lime trees, which greatly reduced fruit loss and improved fruit retention through foliar administration of the growth regulators GA_3 and NAA.	[53]
23	Acid Lime	GA_3(150ppm)	The growth characteristics of nursery seedlings were measured, including the percentage of germination, seedling height, number of leaves per plant, stem diameter, leaf area, chlorophyll index, taproot length, number of secondary roots per plant, girth of roots, root shoot ratio, root density, and final survival rate. Among these several treatments, GA_3 200 ppm was shown to be significantly	[54]

No	Name of crop	Treatment	Results	References
			superior, and treatment (GA_3 200 ppm seed treatment) with high benefit-cost ratio also produced high net financial returns.	

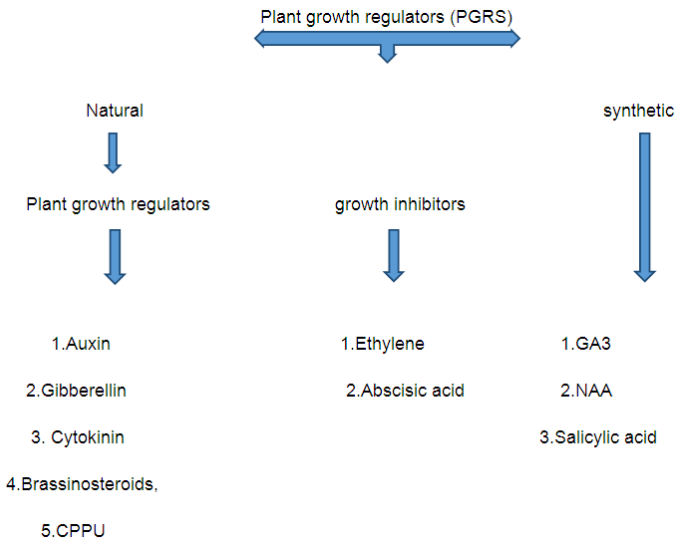

Fig. 1. Flowchart on the classification of plant growth regulators

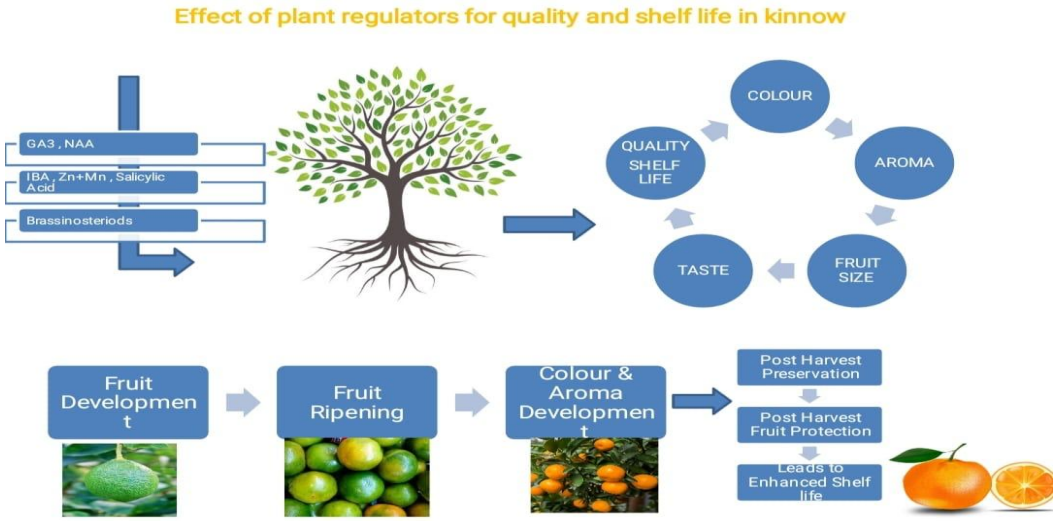

Fig. 2. Effect of plant regulators for quality and shelf life in Kinnow

9. CONCLUSION

The use of Chemicals formulations like NAA, Brassinosteroids, GA_3, and CCPU, improves the quality of growth resistance fruit size, color, acidic levels, and juice levels. They also help in the shelf life of plant fruits. Overall, hormones have proven their ability to maximize fruit retention and production per plant, in addition to fruit weight and other variables.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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