emergent
Life Sciences Research

Review Article

Micronutrients and plant growth regulators affecting the yield and quality of fruit crops: A review

Devi Darshan, Debashish Hota, Reema Devi, Jitendra Kumar Shukla

Received: 28 March 2022
Accepted: 08 September 2022
Online: 12 September 2022

Authors:
D. Darshan,
Department of Fruit Science, Punjab Agricultural University, Ludhiana, Punjab, India

D. Hota ✉
Deparment of Horticulture, Institute of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India

R. Devi
Department of Foods and Nutrition, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, India

J. K. Shukla
Department of Horticulture (Fruit Science), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Uttar Pradesh, India

✉ dhota3@gmail.com

Emer Life Sci Res (2022) 8(2): 92-103

E-ISSN: 2395-6658
P-ISSN: 2395-664X

DOI: https://doi.org/10.31783/elsr.2022.8292103

Abstract

The application of micronutrients and plant growth regulators has a greater impact on enhancing plant productive efficiency by altering various aspects of horticultural attributes like a biometric response, fruiting potential, and qualitative parameters. All metabolic and cellular processes of fruit crops are influenced by micronutrients. The role of boron and zinc are well-known for nitrogen metabolism, cell division, and hormonal regulation which ultimately end with proliferation in flowering and fruiting by increasing fruit set and reducing fruit drop. The role of plant growth regulators (PGR) in plants in changing or normalizing the physiological cycle to create better plant health is well known. Hence, the combination of both these growth-promoting substances (micronutrients and PGR) in an optimum amount can positively and significantly influence the physiological activities of the plant. However, the literature regarding the combined effect of micronutrients and PGR on fruit crops is very limited. So this review paper focuses on the combined effect of these plant bio-stimulants, showcasing their remarkable role in fruit production.

Keywords fruit quality, fruit yield, plant growth regulator, micronutrients

Introduction

Micronutrient insufficiency is a serious problem in soil and plants all over the world [1] although proper distinction of micronutrients is compulsory for better growth, and improved physical and qualitative aspects of fruit crops [2-5] whereas its deficiency leads to a reduction in the productivity [6]. Aside from the basic plant nutrients, there are eight important nutrients that plants require in extremely small amounts. Boron not straight forward connected to photosynthesis compound execution, yet it is connected to the plants' carbohydrate chemistry and reproductive system. A suitable level of micronutrients is required for better plant growth, which results in a larger yield because of improved growth, better flowering, and fruit set [2].

The catalytic effect of micronutrients, especially at greater concentrations, may be responsible for the improvement in fruit quality. Foliar treatments with micronutrients boosted macronutrient uptake in tissues and organs quickly, which in turn improved fruit crop quality [7]. At present, micronutrients are slowly but surely in advance impetus among the fruit growers for the reason of their valuable nutritional hold-up and at the same time make sure improved yield and profits. The increased demand for fruit will necessitate a full understanding of the link between micronutrients and crop growth. Foliar application of oligo-elements is one of the implements to sustain or augment the nutritional position of the fruit plants for the duration of the growing season. To increase the yield of high-quality fruits and vegetables, contemporary crop husbandry practices have included the use of plant growth regulators. Foliar use of plant growth regulators improves fruit crop output and quality because fruits are a high-value crop. It is possible to maintain a good fruit setting with the use of exogenous plant growth regulators Anti-fruit drops agents like auxin and gibberellins are commonly utilized. There are several ways in which plant growth regulator sprays can be used for fruit size improvement, including directly encouraging cell division, or indirectly by reducing fruit number via treatment with plant growth regulators to facilitate inhibiting flower and fruit abscission, thereby increasing the size of the fruit. Fruit set, fruit retention, and yield are examples of physical attributes, while total soluble solids is an example of chemical properties. It has been demonstrated that plant growth regulators including Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA_3), 6-Benzylaminopurine (BAP), 6-Benzyladenine (BA), and 2-chloro-4-pyridyl-N-phenylurea (CPN) increase total sugars, acidity, reducing sugar, etc (CPPU). It was found that the foliar application of GA_3 considerably improved the retention of mango fruits as well as other fruit species such as citrus, apples, guavas, and pomegranates [8].

Effect of various micronutrients and plant growth regulators on fruit set and fruit retention

Fruit set is the transformative phase when a bloom (ovary) changes into an adolescent stage (fruit) that will grow till development. The fruit set percentage is determined by the following formulas:

$$\text{Fruit set (\%)} = \frac{\text{Number of fruit set}}{\text{Total number of blossoma}} \text{ x } 100$$

Fruit retention refers to the number of fruits that remain on plants following the fruit set. Fruits that remain on the plants are tallied at regular intervals, and the proportion of fruits that remain on the plants is computed as follows:

$$\text{Fruit retention (\%)} = \frac{\text{No.of fruit reaches till maturity}}{\text{No. of fruit set}} \text{ x } 100$$

Gibberellic acid at 35 ppm at full bloom increased fruit retention in Dashehari mangoes more than the control [9]. In comparison to other treatments than the control, Lal et al., [10] found that CCC @ 1000 ppm sprayed just before flowering produced the highest number of flowers per shoot (16), increased fruit set (93.13 percent), and the highest numeral of fruits per shoot at harvest (6.2), while GA3 @ 50 reduced fruit drop (38.8%). Chandra et al., [11] found that a foliar shower of $ZnSO_4$, $MgSO_4$, and $CuSO_4$ @ 0.5% applied in mid-June and after one month (fruit improvement stage) expanded fruit retention (24.35%) while diminishing fruit drop (70.11%) in Aonla cultivar NA-7. Pre-harvest sprays of plant growth regulators (GA_3 @ 50, 75, 100 ppm and NAA @ 10, 15, 20 ppm) and micronutrients calcium nitrate @ 1.0%, 1.5%, and 2.0% on kinnow fruit twice, on September 15th and November 15th, increased fruit retention compared to the control Deep et al., [12]. Saroj et al., [13] concluded that two foliar sprays of GA_3 @ 100 ppm and $CaCl_2$ @ 2% before flowering and after fruit set increased the fruit set (67.19%) and fruit retention (58.79%) in the guava cultivar Allahabad Safeda compared to other treatments than the control. Kaur [14] announced that borax @ 0.4% at new development flushes before the commencement of inflorescence recorded the maximum fruit set (78.15%) and fruit retention (60.17%) followed by GA_3 @ 50 ppm splashed after fruit setting in Dehradun cv. litchi. Narayanswamy et al., [15] found that foliar use of ethrel 250 ppm showered after full bloom created the greatest number of bisexual blossoms (25.22) with a base number of days taken for half (12.67 days), while NAA@ 40 ppm recorded the highest number of fruit per tree (62.44) in pomegranate cultivar Bhagwa. In guava, borax @ 0.4% and GA_3 @ ppm considerably raised fruit set (64.41%) and fruit retention (55.31%) [16]. Foliar feeding of dissimilar concentrations of $ZnSO_4$ (0.2%, 0.4%, and 0.6%) and NAA (20 ppm, 40 ppm, and 60 ppm) sprayed twice, i.e., the 1st week of March and the 2nd in the last week of March, improved fruit set and fruit retention in mulberry contrast with the control [17]. Dheware et al., [18] reported that foliar taking care of various micronutrients like $ZnSO_4$ 0.4%, $CuSO_4$ 0.2%, and borax 0.2% alongside the suggested portion of composts two times, i. e., first splash before blossoming and second at the marble phase of fruit development, expanded the quantity of fruit per tree (173.32) in the Alphonso cultivar of mango. Goyal et al., [19] reported that borax @ 0.4% and GA_3 @100 ppm at the time of the full bloom stage during the rainy season increased fruit set (83.5%) in Lalit cultivar guava. Singh et al., [20] investigated that pre-harvest spray of GA_3 @50 ppm sprayed at the pea stage improved the fruit set percentage (17.98%) and GA_3 @ 100 ppm at the stone formation stage increased the fruit retention (0.67%) in the Langra variety of mango as compared to the control. Suman et al., [21] recorded the highest fruit set (92.33%) and fruit retention (55.00%) in the guava cultivar Allahabad Safeda when splashed two times, i.e., the first shower should be done in the fourth week of July and the subsequent splash should be done after fruit set stage in the 1st week of September with the foliar treatment of GA_3 @ 60 ppm. 50 Kumar Suresh [22] recorded the maximum amount of fruits per tree (324.67) with the foliar feeding of NAA 100 ppm in the sweet orange cultivar Sathgudi compared to control other treatments. Several other effects of treatments of Phyto bio-stimulants on fruit sets and fruit retention in different fruit crops are given in Table 1.

Table 1. Impact of different phyto bio-stimulants on fruit set and fruit retention

SN.	Crop	Micronutrients and growth regulators	Quantity	Stage of treatments	Effect	References
1	Pomegranate cv. Ruby	NAA	25 ppm	The first spray should be applied when 50 percent of the fruit has been set, and the remaining two should be applied at 21-day intervals.	Fruit set and fruit retention are maximized	[23]
2	Bael cv. Pant Shivani	NAA	20 ppm	The first spray should be done 7th days after fruit initiation and 2nd spray should be done in the last week of June	Improved fruit set	[24]
3	Mango cv. Keitt	NAA + GA_3	25 ppm	When the flowers are in full bloom	Maximum fruit set, fruit retention, and maximum quantity of fruits per	[25]
4	Kinnow fruit	2,4-D+Zn+K	10 mg/l+ 0.25%+0.25%	At flowering, fruiting, and color initiation (Thrice)	Improved fruit retention, fruit set, and reduced fruit drop percentage	[26]
5	Litchi cv. Ambika Li tchi-1	Borax+GA_3	0.4%+10 ppm	Micronutrients at new growth flushes and PGRs after fruit set	Fruit set and fruit retention have both been improved.	[27]
6	Cape gooseberry cv. Aligarh	NAA	15 ppm	Immediately after fruit setting	The fruit set has been improved.	[28]
7	Aonla cv. NA-6	NAA + Thiourea	15 pm + 0.1%	15th May and 15th July (twice)	Increased fruit retention and reduced fruit drop	[29]

8	Custard apple cv. Sindhan	GA_3	50 ppm	During the peak flowering season, three times at a five-week interval	Reduced fruit drop per shoot, and improved fruit set and fruit retention	[30]
9	Mango var. Amrapali	NAA	50 ppm	Initial application at pea stage, followed by a second application after 21 days	Maximum fruit retention	[31]
10	Sweet orange cv. Washington Novel	GA_3 + NAA	20+25 ppm	One week after full bloom	The fruit drop % has been reduced, while fruit retention has been raised.	[32]
11	Ber cv. BAU Kul-1	2,4-D NAA	10 mg/l 20 mg/l	First, splash immediately after fruit set and second shower one month after the first splash (Twice)	Expanded fruit set and fruit retention	[33]
12	Guava cv. Lalit	Urea+ NAA	1% + 50 ppm	Twice (before blossoming and 2nd spray should be done after fruit setting) fruit	Maximum fruit set and fruit retention	[34]
13	Custard apple	GA_3	75 ppm	Two spray 1st at the time of blooming and 2nd at the time of fruit set	Fruit setting percentage was improved	[35]
14	Acid lime cv. Sai Sarbati	GA_3+ $ZnSO_4$ + $FeSO_4$	50 ppm + 1%+ 1%	1st at petal fall stage and 2nd 45 days after the first spray	Maximum fruit set	[36]
15	Litchi	Borax	0.4%	Before flowering, fruit set, and mature green stage (Thrice)	Increased fruit set	[37]

Impact of different Phyto-bio stimulants on physical attributes of fruit crops

Ghosh [31] reported that foliar feeding of NAA @ 50 ppm for the duration of the pea stage at the 21st day period in the Amrapali variety of mango resulted in the maximum quantity of fruits (216.50) and fruit weight (224.58g). In the case of Cape gooseberry, GA_3 @ 10 ppm just after fruit setting produced a maximum yield (1.58 kg/plant) than the rest of the treatments as studied by Gurpinder et al., [28]. Kishor et al., [38] studied the effect of foliar treatments of 2.4-D @ 15 ppm (3 times at fortnight intervals) in the Bhagwa variety of pomegranate and recorded the maximum fruit weight (101.67 g), fruit volume (92.00), fruit length (6.00 cm), specific gravity (1.10), number of aril/fruit (363.33), and number of segment/fruit (5.00). Kulkarni et al., [39] concluded that the use of CPPU @ 20 ppm in mango variety 'Kesha' at the pea stage and marble stage brought about the greatest fruit length (10.56 cm), fruit diameter (6.43 cm), and fruit weight (328.73 g), while CPPU @ 10 ppm at pea stage delivered the most extreme fruit per tree (362.33) and yield of fruit (107 kg/tree and 10.7 t/ha). Majumdar et al., [33] investigated foliar feeding of GA_3 @ 20 mg/l in ber cv. shortly after the fruit set and again after 30 days. BAU Kul-1 generated the maximum fruit yield (30.67 kg/tree) and enhanced fruit weight (60.5 g), fruit length (5.8 cm), fruit breadth (5.1 cm), pulp-to-seed ratio (13.9), and specific gravity (1.104). Mishra et al., [40] found that applying micronutrients such as $CuSO_4$ @ 0.4 percent, $MgSO_4$ @ 0.5 percent, and $ZnSO_4$ @ 0.25 percent right after fruit set and again in July significantly boosted the fruit size, weight, and pulp stone ratio in aonla cv. NA-7 as compared to other treatments. According to Arunadevi et al., [41], soil application of Paclobutrazol @ 1.5 g a.i /m^2 and foliar application of NAA 200 ppm improved the largest number of fruits per tree (885) and fruit yield (52.05 kg) in acid lime. Lenka et al., [42] noticed that foliar feeding of Salicylic acid @ 100 ppm before flowering, 50% fruit set, and four weeks after fruit set recorded the maximum fruit length, fruit diameter, and fruit yield of guava during the winter and rainy season. Bharti et al., [43] discovered that exogenous application of 2.4 D @ 20 ppm between the 15th of October and the 15th of November resulted in the highest fruit weight (194.67gm), fruit length (74.35 mm), fruit breadth

(79.80mm), juice percent (51.52 percent), and fruit yield (69 fruits per plant) in kinnow mandarin when compared to other treatments. Vankar et al., [44] found that pre-bloom and post-fruit set foliar treatments with Brassinosteroid @ 15 mg/l improved the fresh weight (85.62g), juice % (57.80), and yield (17.44 t/ha^{-1}) of Phalsa. Some other effects of the application of various micronutrients and plant growth regulators on yield in different fruit crops are given in Table 2.

Table 2. Effect of various micronutrients and plant growth regulators on physical attributes of fruit crops

SN.	Crop	Micronutrients/ PGR	Quantity	Stage of treatments	Effect	References
1	Persimmon cv. Costata	GA_4	25 ppm	The first spray should be administered after the pea stage is achieved, followed by the marble stage.	Improved physical attributes such as fruit weight and fruit yield	[45]
2	Olive	GA_3 + $ZnSO_4$	30 ppm + 0.75%	At the time of the pit hardening stage	Increased the fruit weight	[46]
3	Aonla cv. Banarasi	Borax GA_3	0.4% 150 ppm	1st August	Increased fruit length, weight, diameter, and volume	[47]
4	Ber cv.Banarsi Karaka	NAA+GA_3 +$ZnSO_4$	20+ 40 ppm+ 0.4%	Fruit setting stage	Improved physical properties of fruit such as (fruit weight, width, length and yield)	[48]
5	Guava cv. Bhavnagar Red	Urea + Zinc sulphate	1.5% + 0.6%	Twice (once during flowering and once three weeks after the first spray) during the growing season	Increased fruit weight and fruits yield	[49]
6	Cape gooseberry	GA_3	250 ppm	Twice (before flowering and after 15th days)	Fruit size, fruit weight, and fruit yield have all increased.	[50]
7	Phalsa	GA_3	150 ppm	Twice (during the pre-flowering period and again during fruit setting)	Fruit production per plant and fruit yield per hectare increased	[51]
8	Jamun cv. Chintamani	$ZnSO_4$ + Boran	0.5%+ 0.2%	Thrice (at the time of emergence of new flush, flowering, and fruit set)	Increased fruit length and fruit weight	[52]
9	Strawberry cv. Winter Dawn	GA_3	100 ppm	Twice (30 and 60 days subsequent to transplanting)	Increased fruit weight and fruits yield	[53]
10	Guava cv. Lalit	Calcium chloride + borax	0.2% +0.1%	Twice (1st weeks of August and 2nd weeks of September	Increased fruit weight, width, length, volume, specific gravity, and fruits yield	[54]
11	Mango cv. Amrapalli	GA_3	50 ppm 75 ppm	At pea stage	Increased fruits yield Increased fruit weight , fruit volume, and specific gravity	[55]
12	Kinnow mandarin	GA_3	60 ppm	At the pre-harvest stage (December)	Increased peel color, fruit weight, and juice weight	[56]
13	Guava cv. Sardar	Zinc sulphate + boron + copper sulphate + magnesium sulphate	1.0%	Twice (at marble stage and 15th days after the first spray)	Increased fruits yield	[57]

Effect of various micronutrients and plant growth regulators on the qualitative aspect of fruit crops

Dutta et al., [58] conducted that pre-harvest spray of gibberellic acid @ 100mg/l was sprayed four times between September and December (the season for flower bud differentiation) at monthly intervals significantly improved the total soluble solids (14.3%), sugar acid ratio (23.8%), ascorbic acid (32.25 mg/100g pulp), and reduced the acidity percentage (0.60%), whereas, NAA @ 50 mg/l improved the anthocyanin content (25.24 mg/100 g^{-1} peel) in litchi cultivar Bombai. Jain et al., [59] noticed that foliar feeding of ethrel @ 500 in guava cv. Sardar before flowering resulted in maximum total soluble solids (15.66%), reducing sugar (4.58%), non-reducing sugar (3.11%), total sugars (86%), and minimum acidity (0.39%), whereas Paclobutrazol @ 500 ppm recorded maximum ascorbic acid (210.82 mg/100g pulp) and pectin (0.78%). Khalil et al., [60] discovered that foliar feeding of GA_3 @ 30 ppm in olives between March and June resulted in the highest oil percentage (17.9%) and pulp weight (1.68g), while the lowest was observed in the control. Kumar et al., [61] studied that foliar spray of micronutrients such as boron, zinc, calcium, and potassium at the time of fruit set and two weeks after the fruit set significantly improved the qualitative properties (TSS, total sugars, reducing sugars, non-reducing sugars and ascorbic acid content) of the guava variety Pant Prabhat and the lowest levels were observed in control than in the other treatments. Singh et al., [61] found that foliar feeding of GA_3 @ 50 ppm and Thiourea @ 0.1% during mid-May and mid-July significantly increased the total soluble solids (12.40%), ascorbic acids (670 mg/100g pulp), reducing sugar (3.42%), non-reducing sugar (2.45%), and total sugar (5.87 %) with lowest acidity (1.75%) in aonla cultivar 'NA-6'. Sau et al., [62] investigated the effects foliar of treatments of combined micronutrients (H_3BO_3 @ 0.2% + $ZnSO_4$ @ 0.5) were applied twice (1st spray at some stage in flowering and 2nd spray following one month of 1st spray) in guava cultivar Allahabad Safeda resulted in maximum total soluble solids (11.07%), TSS: Acid ratio (26.79), ascorbic acid (120.67 mg/100g pulp), total sugar (9.32%), reducing sugar (4.03%), non-reducing sugar (5.29 %), and reduced acidity (0.42%) content. The maximum total soluble solids (14.900 Brix) and total sugars (12.92 percent) were achieved with the administration of GA_3 at 50 ppm in aonla variety NA-7 during the fruit development stage, while the titrable acidity (1.56%) and stone weight (1.45 g) was reduced by GA_3 at 100 ppm (18.44 percent). The highest ascorbic acid content (608 mg/100g pulp) in plants treated with $CaCl_2$ @1.5 percent in August was observed by Tripathi et al., [63]. Some other effects of the application of various micronutrients and plant growth regulators on the quality of different fruit crops are given in Table 3. The effect of new-generation plant growth regulators on fruit crops is present in Table 4.

Table 3. Effect of various micronutrients and plant growth regulators on qualitative of fruit crops

SN.	Crop	Phtytobio-stimulants	Quantity	Stage of treatments	Effect	References
1	Grewia subinequalis	GA_3	100 ppm	The first spray should be done before flowering and the second spray should be done after flowering	Maximum total soluble solids to acid ratio, pulp to stone ratio, reducing sugar and reduced acidity contents	[64]
2	Papaya var. Red Lady	Ethrel	400 ppm	Three sprays after thirty, forty-five, and sixty days after transplanting	Improvements in total sugar content, which includes both reducing and non-reducing sugar content, as well as the lowest titrable acidity, were observed.	[65]
3	Guava	GA_3	200 ppm	At the time of anthesis	Improved TSS contents	[66]

4	Lemon cv. Pant lemon-1	NAA	50 ppm	Full bloom stage during the spring season	Total soluble solids, Vitamin C, total sugars, and fruits with a longer shelf life have all increased, and the lowest acidity	[67]
5	Papaya cv. Red Lady	GA_3 Ethrel	Each @ 150 ppm	Three sprays (45,75, and 125 days after transplanting)	Improved qualitative characteristics	[68]
6	Kinnow mandarin	$ZnSO_4$	0.6%	During October	Improved TSS, ascorbic acid, total sugar, total antioxidant, and total phenolics	[69]
7	Strawberry	Boran and zinc	2 kg + 3 kg/ha^{-1}	Soil application before transplanting	Increased total soluble solids and vitamin C	[70]
8	Aonla cv. NA-10	Urea + Borax + Vermiwash + NAA	0.2% + 0.5% + 3ml/l + 20 ppm	25th May, 5th July, and 5th August (Thrice)	The highest amount of TSS, total sugars, and ascorbic acid	[77]
9	Pear cv. Le-Conte	Boran + GA_3	100 ppm + 60 ppm	At 50% fruit set	Highest TSS, ascorbic acid, phenols, flavonoids, antioxidants, and lowest acidity	[78]
10	Pomegranate cv. Bhagwa	CCC Uracil	1000 ppm 1500 ppm 25 ppm	During ambebahar (Jan-Feb) and mrigbahar (Sep.- Oct)	Maximum total soluble solids, anthocyanin, and reduce acidity contents	[79]

Table 4. Effect of new generation plant growth regulators on fruit crops

SN.	Crop	PGRs	Quantity	Stage of treatments	Effect	References
1	Strawberry cv. Tufts and Cruz	Jasmonic acid	0. 50 mM	At the time of flowering	Improved fruit weight and total yield per plant	[80]
2	Plum cv. Qingnai	Salicylic acid	1.5 mM	Post-harvest treatments	Reduced chilling injury, disease incidence, MDA content, respiration rate, ethylene rate, increased PPO, and POD activities	[81]
3	Pomegranate cv. MalasYazdi and MalasAshkezar	Jasmonic acid Salicylic cid	0. 4 mM 1 mM	Postharvest treatments	Reduced chilling injury Improved TSS, total phenolic compounds, and reduced acidity	[82]
4	Peach	Methyl jasmonates	50 µm	70 days after blooming	Increased anthocyanin accumulation, volatile compounds, chlorophyll degradation, and reduced ethylene content and total acidity	[83]
5	Plum cv. Satluj purple	Salicylic acid	0.15 mM	Twice (10 days after the pit hardening stage and 2nd 10 days after the first spray	Maximum ascorbic acid contents, reducing sugar, and total sugars Reduced cell wall degrading enzymes like cellulose, polygalacturonase, and glucanase	[84]
6	Cape Gooseberry	Brassinosteroids	16 ppm	At vegetative, flowering and fruiting stage	Improved physical properties and qualitative aspects of cape gooseberry	[85]
7	Peach cv.	Jasmonic acid	30 µmol L-1	Postharvest	Reduced chilling injury	[86]

	Jinqiuhongmi'			treatments	because it slows down ethylene production and enhanced sugars metabolism	
8	Kiwi fruit cv. Hongyang	Brassinosteroid	1µm	Roots treatments	Promoted root elongation, lateral root, and root hair growth	[87]

Conclusion

Several chemical and hormone-based PGRs have been used in the field to improve horticultural crops productivity and stress tolerance. Although a vast list of plant growth regulators is used to increase plant growth, development, defense, and productivity, the molecular processes behind their effects remain unknown. Their commercialization is also dependent on several factors, including field stability, inertness, cost-effectiveness, ease of application, and adaptability to a variety of stresses. Given the constantly changing and unexpected climatic conditions, future research may focus on developing combined-based growth regulators technology that incorporates a mix of varied plant growth regulators that can better handle several stress settings and have a significant impact on growth and productivity. Another region that must be entirely researched is the financial possibility of commercializing plant growth regulators according to the point of view of both the agrochemical area and the end clients, smallholder farmers. Accordingly, the field of plant growth regulators-based research is as yet in its earliest stages and might be explored with a definitive objective of fostering an exceptionally flexible and effective innovation that can be straightforwardly conveyed on the farmer's field to guarantee long-term horticultural maintainability. The review confirms qualitative enhancement in fruit quality by the combined effect of micronutrients and PGRs.

References

[1] M. Imtiaz, A. Rashid, P. Khan, Memon, M. Y. and M. Aslam **(2010)**. The role of micronutrients in crop production and human health. Pak. J. Bot., **42:** 2565-2578.

[2] R. A. Ram and T. K. Bose **(2000)**. Effect of foliar application of magnesium and micro-nutrients on growth, yield and fruit quality of mandarin orange (*Citrus reticulata Blanco*). Indian J. Hort., **57:** 215-220.

[3] M. E. Raja **(2009)**. Importance of micronutrients in the changing horticultural scenario in India. Indian J Hort. **4:** 1-27.

[4] M. M. Sourour **(2000)**. Effect of foliar application of some micronutrient forms on growth, yield, fruit quality and leaf mineral composition of Valencia orange trees grown in North-Sinai. Alex. J. Agric. Res., **45:** 269-285.

[5] C. Shekhar, A. L. Yadav, H. K. Singh and M. K. Singh **(2010)**. Influence of micronutrients on plant growth, yield and quality of papaya fruit (*Carica papaya* L.) cv. Washington. Asian J. Hort., **5:** 326-329.

[6] P. M. Zagade, G. R. Munde and A. H. Shirsath **(2017)**. Effect of foliar application of micronutrients on yield and quality of Guava (*Psidium guajava* L.) Cv. Sardar. J. Pharm. Biol. Sci., **12:** 56- 58.

[7] M. Anees, F. M. Tahir, J. Shahzad and N. Mahmood **(2011)**. Effect of foliar application of micronutrients on the quality of mango (*Mangifera indica* L.) cv. Dusehri fruit. Mycopath, **9:** 25-28.

[8] M. Iqbal, M. Q. Khan, J.-ud-Din, K. Rehman and M. Munir **(2009)**. Effect of foliar application of NAA on fruit drop, yield and physico-chemical characteristics of guava (*Psidium guajava* L.) red flesh cultivar. J. Agric. Res., **47:** 259-269.

[9] W. Ahmed, F. M. Tahir, I. A. Rajwana, S. A. Raza and H. U. Asad **(2012)**. Comparative evaluation of plant growth regulators for preventing premature fruit drop and improving fruit quality parameters in 'Dusehri' mango. Int. J. Fruit Sci., **12:** 372-389.

[10] N. Lal, R. P. Das, and L. R. Verma **(2013)**. Effect of plant growth regulators on flowering and fruit growth of guava (*Psidium guajava* L.) cv. Allahabad safeda. Asian J. Hort., **8:** 54-56.

[11] R. Chandra and K. K. Singh **(2015)**. Foliar application of zinc sulphate, magnesium sulphate and copper sulphate on the yield and quality of aonla (*Emblica officinallis Gaerth* L.) cv. "NA-7" under Garhwal Himalaya. J. Med. Plants Stud., **3:** 42-45.

[12] D. Lal, V. K. Tripathi, M. A. Nayyer, S. Kumar, M. Ahmed and M. W. Siddiqui **(2016)**. Pre-Harvest Spray of Gibberellic Acid, NAA, and Calcium Nitrate on Fruit Retention, Yield and Quality of Kinnow Mandarin. Environ Ecol., **34:** 2288-2292.

[13] N. L. Saroj, R. S. Verma, S. Prakash, S. S. Verma and V. Kumar **(2018)**. Studies on the effect of foliar spray of micronutrient and plant growth regulators on physical parameter of guava (*Psidium guajava* L.) cv. Allahabad Safeda. J. Pharmacogn. Phytochem., **7:** 01-02.

[14] S. Kaur **(2017)**. Effect of micronutrients and plant growth regulators on fruit set, fruit retention, yield and quality attributes in litchi cultivar Dehradun. Chem. Sci. Rev. Lett., **6:** 982-986.

[15] P. Narayanswamy, V. V. Anawal and S. D. Ekabote **(2019)**. Effects of plant growth regulators on flowering, fruit set and yield of 'Bhagwa' of pomegranate (*Punica granatum* L.). Acta Hortic., **1254:** 129-134.

[16] V. Kumar, R. B. Ram, R. S. Verma A. Yadav and N. L. Saroj **(2019)**. Effect of foliar application of micronutrients and plant growth regulators on yield and physical characteristics of guava (*Psidium guajava* L.) cv. Allahabad Safeda. J. Pharmacogn. Phytochem., **8:** 2715-2716.

[17] A. Dhakad, S. Baloda, S. K. Sehrawat, J. R. Sharma, S. Sharma, J. Tokas and A. Kumar **(2020)**. Effect of NAA and zinc sulphate application on fruit drop, yield and quality attributes of mulberry (*Morus alba* L.). J. Pharmacogn. Phytochem., **9:** 1937-1943.

[18] R. M. Dheware, N. A. Nalage, B. N. Sawant, P. C. Haldavanekar, R. A. Raut, A.Y. Munj and S. N. Sawant **(2020)**. Response of micronutrient on the quality yield of mango cv. Alphonso under Konkan agro-climatic conditions. J. Pharmacogn. Phytochem., **9:** 2004-2006.

[19] S. Goyal, K. V. Singh, V. Mandloi and D. Vishvkarma **(2020)**. Effect of foliar application of boron and GA3 on morphological and quality parameters of guava (*Psidium guajava* L.) cv. Lalit. J. Pharmacog. Phytochem., **9:** 655-658.

[20] D. D. Singh, R. R. Singh and P. K. Roy **(2021)**. Study on physiological changes in mango cv. Langra under the influence of GA_3. J. Pharmacogn. Phytochem., **10:** 1501-1505.

[21] M. Suman and M. C. Jain **(2021)**. Interactive impacts of plant growth regulators and fertigation on quality of pomegranate (*Punica granatum* L.) in sub-humid agro ecological zone of Rajasthan. Bangladesh J. Bot., **50:** 623-631.

[22] T. S. Kumar **(2021)**. Role of plant growth regulators on vegetative growth, yield and quality of sweet orange (*Citrus sinensis* L.) cv. Sathgudi. J. Pharma Innov., **10:** 1007-1009.

[23] S. N. Ghosh, B. Bera, S. Roy and A. Kundu **(2009)**. Effect of plant growth regulators in yield and fruit quality in pomegranate cv. Ruby. J. Hortl. Sci., **4:** 158-160.

[24] S. Uniyal **(2011)**. Studies on the causes and control of fruit drop in bael (Aegle marmelos Correa) (Ph.D. Thesis). G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

[25] G. Q. Nkansah, J. Ofossu and A. Mawuli **(2012)**. Gibberellic acid and naphthalene acetic acid affect fruit retention, yield and quality of keitt mangoes in coastal savanna ecological zone of Ghana. Am. J. Plant Physiol., **7:** 243-251.

[26] M. Y. Ashraf, M. Ashraf, M. Akhtar, K. Mahmood and M. Saleem **(2013)**. Improvement in yield, quality and reduction in fruit drop in kinnow (*citrus reticulate blanco*) by exogenous application of plant growth regulators, potassium and zinc. Pak. J. Bot., **45:** 433-440.

[27] A. Dixit, S. S. Shaw and V. Pal **(2013)**. Effect of micronutrients and plant growth regulators on fruiting of Litchi. Hort Flora Res. Spectrum, **2:** 77-80.

[28] G. Kaur, and A. Kaur **(2016)**. Plant growth and fruit yield attributes of Cape gooseberry cv. Aligarh as affected by the use of different growth regulators. Agric. Sci. Digest., **36:** 138-141.

[29] A. Singh and H. K. Singh **(2015)**. Application of plant growth regulators to improve fruit yield and quality in Indian Gooseberry (*Emblica officinalis* Gaertn.). J. AgriSearch, **2:** 20-23.

[30] J. C. Chaudhari, K. D. Patel, L. Yadav, U. I. Patel and D. K. Varu **(2016)**. Effect of plant growth regulators on flowering, fruit Set and yield of Custard Apple (*Annona squamosal* L.) cv. Sindhan. Adv. Life Sci., **5:** 1202-1204.
[31] S. N. Ghosh **(2016)**. Effect of plant growth regulators on fruit retention and physico-chemical properties of mango cv. Amrapali gown in laterite soil at close spacing. J. Crop Weed, **12:** 83-85.
[32] H. A. Hifny, S. M. Khalifa, A. E. Hamdy and A. N. Abd El-Wahed **(2017)**. Effect of GA_3 and NAA on growth, yield and fruit quality of Washington navel orange. Egypt. J. Hortic., **44:** 33-43.
[33] I. Majumder, S. Sau, B. Ghosh, S. Kundu, D. Roy and S. Sarkar **(2017)**. Response of growth regulators and micronutrients on yield and physico-chemical quality of Ber (*Zizyphus mauritiana* Lamk) cv. BAU Kul-1. J. Appl. Nat. Sci., **9:** 2404-2409.
[34] A. Shukla, R. S. Verma, S. Prakash, S. S. Verma and D. Singh **(2017)**. Effect of foliar application of nutrients and plant growth regulators physical parameter of guava (*Psidium guajava* L.) fruit cv. Lalit. J. Pharmacogn. Phytochem., **7:** 2837-2838.
[35] K. D. Mahorkar, U. M. Naglot, R. I. Navsare and P. M. Chavhan **(2018)**. Effect of plant growth regulators on flowering, fruit set and yield of custard apple (*Annona squamosa* L.). Int. J. Chem. Stud., **6:** 2381-2384.
[36] S. S. Tagad, M. B. Patil, S. G. Patil and D. P. Deshpande **(2018)**. Effect of foliar application of plant growth regulators and micronutrients on growth and yield parameters of acid lime (*Citrus aurantifolia* L.) CV. Sai Sarbati. J. Pharmacogn. Phytochem., **7:** 741-744.
[37] O. Megu, B. N. Hazarika, L. Wangchu, P. Sarma, A. K. Singh, P. Debnath and T. Angami **(2021)**. Effect of plant growth regulators and micronutrients on vegetative growth, flowering and yield attributes of Litchi (*Litchi chinensis* Sonn.). Int. J. Plant Soil Sci. 33: 176-181.
[38] S. Kishor, S. Maji, M. L. Meena, H. Deepa, S. K. Dwivedi and S. Kumar (2017). Effect of plant bio-regulators and chemicals on fruit physico-chemical traits of pomegranate (*Punica granatum* L.) cv. Bhagwa. J. Pharmacogn. Phytochem., **6:** 1573-1575.
[39] S. S. Kulkarni, S. S. Patil and S. D. Magar **(2017)**. Effect of plant growth regulators on yield and quality of mango (*Mangifera indica* L.) cv. Kesha. J. Pharmacogn. Phytochem. **6:** 2309-2313.
[40] S. M. Mishra, D. Ram, A. Panedy, and A. K. Meena **(2017)**. Effect of foliar feeding of micro-nutrients on physico-chemical attributes of Aonla (*Emblica officinalis* Gaertn) cv. Na-7 under high density planting. Int. J. Curr. Microbiol. App. Sci., 6: doi: 10.20546/ijcmas.
[41] A. Arunadevi, R. K. C. Subesh, J. Rajangam and K. Venkatesan **(2019)**. Effect of plant growth regulators on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle.) var. PKM 1. J. Pharmacogn. Phytochem., **8:** 3438-3441.
[42] J. Lenka, G. C. Acharya, P. Sahu, D. K. Dash, D. Samant, C. M. Panda, K. N. Mishra and K. N. Panda **(2019)**. Effect of foliar nutrition of micronutrients and plant growth regulators on yield and quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda. Int. J. Chem. Stud., **7:** 1327-1333.
[43] A. Bharti, K. Karuna, H. Mir, Shashikala and S. Kumari **(2020)**. Studies on pre-harvest fruit drop and improvement in physical parameters of kinnow mandarin through exogenous application of plant growth regulators. Int. J. Chem. Stud., **8:** 1036-1040.
[44] S. Vankar, A. Kerketta and V. Bahadur **(2021)**. Effect of pruning and foliar application of brassinosteroid and salicylic acid on growth, yield and quality of phalsa (*Grewia subinaequalis* L.). Biol. Forum Int. J., **13:** 1-4.
[45] H. A. Kassem, A. M. El-Kobbia, H. A. Marzouk and M. M. El-Sebaiey **(2010)**. Effect of foliar sprays on fruit retention, quality and yield of costata persimmon trees. Emir. J. Food Agric., **22:** 259-274.
[46] S. Ramezani, A. Shekafandeh and M. R. Taslimpour **(2010)**. Effect of GA3 and zinc sulfate on fruit yield and oil percentage of Shengeh Olive Trees. Int. J. Fruit Sci., **10:** 228–234.
[47] H. S. Shukla, V. Kumar and V. K. Tripathi **(2011)**. Effect of gibberellic acid and boron on development and quality of aonla fruits 'Banarasi'. Acta Hortic., **890:** 375-380.
[48] G. Jat, and H. L. Kacha **(2014)**. Response of guava to foliar application of urea and zinc on fruit set, yield and quality. J. AgriSearch., **1:** 86-91.

[49] M. Suman, S. V. Dubalgunde, O. Poobalan and P. D. Sangma **(2016)**. Effect of foliar application of micronutrients on yield and economics of guava (*Psidium Guajava* L.) cv. L-49. Int. J. Agric. Environ. Biotechnol., **9:** 221-224.
[50] R. Kumar, S. P. Singh, A. Tiwari, S. Maji and V. L. Patidar **(2017)**. Effect of gibberellic acid (GA3) on fruit yield and quality of Cape gooseberry (*Physalis peruviana* L.). Int. J. Advanced Biol. Res., **7:** 724-727.
[51] B. Singh, A. L. Yadav and A. K. Meena **(2017)**. The Effect of foliar feeding of plant growth regulators on growth and fruiting behaviour of phalsa. Int. J. Agric. Innov. Res., **5:** 2319-1473.
[52] G. N. Hemavathi, S. V. Patil, G. S. K. Swamy, T. H. Shankrappa and K. Tulsiram **(2019)**. Effect of zinc and boron on physical parameters of fruit, seed and quality of Jamun (*Syzygium cumini* Skeels). Int. J. Chem. Stud., **7:** 2410-2413.
[53] K. D. Rathod, T. R. Ahlawat, S. Kumar, M. Sarkar and B. Chakraborty **(2020)**. Effect of plant growth regulators on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn under open field conditions of south Gujarat. Agric. Sci. Digest., **41:** 329-333.
[54] S. Poojan, D. Pandey, A. K. Trivedi, A. K. Pandey and M. Pandey **(2020)**. Efficacy of foliar application of nutrients on yield and quality of guava. J. Environ. Biol., **41:** 1061-1067.
[55] P. K. Maurya, V. K. Tripathi and S. Gupta **(2020)**. Effect of pre-harvest application of GA3, Naphthalene acetic acid and borax on fruit drop, yield and quality of Mango cv. Amrapali. J. Pharmacogn. Phytochem., **9:** 2123-2127.
[56] H. Talat, W. Shafqat, M. A. Qureshi, N. Sharif, M. K. Raza, S. Din and Sufian Ikram et al., **(2020)**. Effect of gibberellic acid on fruit quality of kinnow mandarin. J. Glob. Innov. Agric. Soc. Sci., **8:** 59-63.
[57] K. S. Giram, S. J. Shinde, S. B. Jaiswal and L. G. Pavankumar **(2021)**. Influence of foliar application of micronutrients on yield and chemical attributes of Mrig bahar guava (*Psidium guajava* L.) cv. Sardar. J. Pharm. Innov., **10:** 842-844.
[58] P. Dutta, K. Chakraborti, J. A. T. Silva, S. K. Roy and A. Samanta **(2011)**. Effect of plant growth regulators on fruit quality and leaf mineral composition of Litchi cv. Bombai grown in new alluvial zone of West Bengal. Fruit, Veg. Cereal Sci. Biotech. **5(SI-2):** 93-95.
[59] M. C. Jain and L. K. Dashora **(2011)**. Effect of plant growth regulators on physico-chemical characters and yield of guava cv. Sardar under high density planting system. Indian J Hortic., **68:** 259-261.
[60] F. Khalil, K. M. Qureshi, A. Khan, F. Hassan and N. Bibi **(2012)**. Effect of girdling and plant growth regulators on productivity in Olive (*Olea europaea*). Pak. J. Agric. Sci., **25:** 30-38.
[61] J. Kumar, R. Kumar, R. Rai and D. S. Mishra **(2015)**. Response of Pant Prabhat guava tress to foliar sprays of zinc, boran, calcium, and potassium at different plant growth stages. Bioscan, **10:** 495-498.
[62] S. Saul, S. Sarkar, B. Ghosh, K. Ray, P. Deb and D. Ghosh **(2018)**. Effect of foliar application of B, Zn and Cu on yield, quality and economics of rainy season guava cultivation. Curr. J. Appl. Tech., **28:** 1-10.
[63] V. K. Tripathi, S. S. Pandey, A. Kumar, V. Dubey and P. Tiwari **(2015)**. Influence of foliar application of gibberellic acid, calcium and boron on fruit drop, yield and quality attributes of aonla (*Emblica officinalis*) cv. NA 7. Indian J. Agric. Sci., **88:** 1784–1788.
[64] A. Debnath **(2010)**. Effect of growth regulators on flowering, fruit set, yield and quality in phalsa (*Grewia subinaequalis* DC) (Ph.D. Thesis). Andhra Pradesh Horticultural University, Hyderabad, Andhra Pradesh.
[65] T. K. Hazarika, B. D. Sangma, D. Mandal, B. P. Nautiyal and A. C. Shukla **(2015)**. Effect of plant growth regulators on growth, yield and quality of tissue cultured papaya (*Carica papaya*) cv. Red Lady. Indian J. Agric. Sci., **86:** 404–408.
[66] S. Mahmood, M. N. Hasan, S. Y. Ali, R. A. Ripa and M. G. Hossain **(2016)**. Effect of plant growth regulators on fruit-set and quality of guava. Turkish JAF Sci. Tech., **4:** 1088-1091.

[67] B. B. Bhatt, K. K. Singh and S. S. Rawat **(2017)**. Influence of foliar application of bio-regulators and nutrients on the fruit quality of Lemon (*Citrus limon* Burma.) Cv. Pant Lemon-1. Int. J. Curr. Microbiol. App. Sci., **6:** 2451-2458.

[68] S. Dubey, G. D. Sahu, V. Kumar, R. R. Saxena and H. Hota **(2020)**. Effect of plant growth regulators on chemical quality of papaya (*Carica papaya*) cv. Red Lady. Int. J. Chem. Stud., **8:** 197-199.

[69] M. I. Liaquat, I. Ali, S. Ahmad, A. M. Malik, H. M. Q. Ashraf, N. Parveen and M. J. Tareene et al., **(2021)**. Efficiency of exogenous zinc sulfate application reduced fruit drop and improved antioxidant activity of 'Kinnow' mandarin fruit. Braz. J. Biol., **83:** 1-8. doi: 10.1590/1519-6984.244593.

[70] M. A. Quddusa, M. A. Siddikya, M. R. Alib, R. Ahmeda, K. K. Sarkera and M. S. Arfinc **(2022)**. Influence of boron and zinc on yield, nutrient uptake and quality of strawberry. J. Plant Nutr., **45:** 866-882.

[77] S. Dadheech, R. Khandelwal and R. Sharma **(2021)**. Effect of foliar spray of nutrients and plant growth regulators on yield, quality and physiochemical characteristics in Aonla cv.NA 10. J. Pharm. Innov., **10:** 44-47.

[78] S. A. Q. Gilani, A. Basit, M. Sajid, S. T. Shah, I. Ullah, H. I. Mohamed **(2021)**. Gibberellic acid and boron enhance antioxidant activity, phenolic content, and yield quality in *Pyrus Communis* L. Gesunde Pflanzen, **73:** 395-406.

[79] F. Hussain, B. N. S. Murthy, M. L. N. Reddy, J. Satisha, K. K. Upreti, R. H. Laxman and B. Srinivasulu **(2021)**. Induction of flowering and improvement of fruit yield and quality in pomegranate (*Punica granatum*) cv. Bhagwa by various plant growth regulators. Environ Conserv., **22:** 49-58.

[80] H. Yilmaz, K. Yildiz and F. Muradogi **(2003)**. Effect of jasmonic acid on yield and quality of two strawberry cultivars. J. Am. Pomol. Soc., **57:** 32-35.

[81] Z. Luo, C. Chen and J. Xie **(2011)**. Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai'plum fruit. Postharvest Biol. Technol. 62(2), 115-120.

[82] S. H. Mirdehghan and F. Ghotbi **(2014)**. Effects of salicylic acid, jasmonic acid, and calcium chloride on reducing chilling injury of pomegranate (*Punica granatum* L.) Fruit. J. Agr. Sci. Tech., **16:** 163-173.

[83] J. Wei, X. Wen and L. Tang **(2017)**. Effect of methyl jasmonic acid on peach fruit ripening progress. Sci. Hortic., **220:** 206–213.

[84] A. Kaur, N. Kaur, H. Singh, S. Murria and S. K. Jawanda **(2021)**. Efficacy of plant growth regulators and mineral nutrients on fruit drop and quality attributes of plum cv. Satluj purple. Plant Physiol. Rep., **26:** 541-547.

[85] A. Walling, V. Bahadur, V. M. Prasad, S. E. Topno and A. Paul **(2021)**. Effect of foliar application of brassinosteroids and salicylic acid on growth, flowering, yield and quality of Cape gooseberry (*Physalis peruviana*). J. Pharm. Innov., **10:** 2059-2064.

[86] Y. Zhao, C. Song, D. A. Brummell, S. Qi, Q. Lin, and Y. Duan **(2021)**. Jasmonic acid treatment alleviates chilling injury in peach fruit by promoting sugar and ethylene metabolism. Food Chem., **338:** 128005. doi: 10.1016/j.foodchem.2020.128005.

[87] Z. Wu, S. Gu, H. Gu, D. Cheng, L. Li, X. Guo and M. Wang **(2022)**. Physiological and transcriptomic analyses of brassinosteroid function in kiwifruit root. Environ. Exp. Bot., 194: doi: 10.1016/j.envexpbot.2021.104685.