



A review on combined effect of foliar spray of mineral nutrients and plant bio-regulators on quantitative and qualitative traits of fruit crops

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Abstract

Because of intensive cultivation and high yielding varieties, as well as poor nutrient management, the soil fertility status has been disrupted, affecting the yield and quality of fruits. Plant metabolic activities necessitate the consumption of both micronutrients and macronutrients. Nutrients are now mainly applied in the form of foliar spray because plants absorb nutrients more easily than soil application and deficiencies can be corrected easily. Plant bio-regulators or phytohormones are naturally synthesized in the various plant parts in minute concentration. Several studies have been conducted in fruit crops with different growth regulators such as auxins like NAA, 2,4-D, IBA and gibberellins, ethrel, Salicylic acid, brassinosteroids, cycocel to see if they had an impact on flower and fruit drop, fruit set, fruit retention, fruit size, and other quality parameters. Combined effect of mineral nutrients and bio-regulators has been studied to improve fruit production and quality parameters such as TSS, acidity, vitamin C, reducing and non-reducing sugars, and so on.

Keywords: plant bio-regulators, mineral nutrients, fruit crops, NAA, GA3

Introduction

The evolution of farming communities marks the beginning of civilization. Agriculture has been practised for thousands of years, and practical considerations of agricultural production goes back to approximately two thousand years. Even yet, agriculture faces numerous challenges around the world. In many areas, production must be improved to meet rising population demands, while in others, current production levels must be maintained while maintaining the appropriate balance between intensive farming and environmental concerns. (Mir, 2010) ^[29]. Horticultural crops are comprised of fruits, vegetables, spices, ornamental, aromatic and medicinal plants. Horticulture plays a unique role in food and nutritional security, job creation, and poverty alleviation. India has a diverse climate with tropical, subtropical, temperate, and soil conditions that allow for the cultivation of all types of fruit crops. India is one of the largest producer of fruits and vegetables in the world, ranks second after China in terms of production. Over the decades, agricultural and horticultural crops relied on organic fertilisers and pesticides, which could not meet the population's demand. Later in the green revolution period, the use of inorganic nutrients was promoted to boost the crop productivity, meet rising population demand, and reduce starvation. From there, the use of inorganic fertilisers and chemicals to increase crop yield began. Fruit orchards are the economical horticultural crops, but they require careful planning and management to establish successful orchard. An innovative and plenty of research work has been done to maximise the production and quality of fruit crops through the development of high yielding varieties, nutrient management, exogenous application of phytohormones, crop regulation methods, deblossoming and fruit thinning strategies, drip irrigation, fertigation, mulching practises, training and pruning, pest and disease management, high density planting, canopy management, and so on. Tyagi *et al.*, (2017) ^[45] Fruits have a numerous health benefits, including protection against various diseases and disorders, as well as antioxidant, antimicrobial, anti-inflammatory, anti-diabetic, and anti-aging properties. This is attributed to their high sources of bioactive compounds e.g. vitamin C, vitamin E, phenolic acids, flavonoids, carotenoids and ellagitannins.

Mineral Nutrients

Several factors influence the growth, yield and quality of fruit crops, the most important of which is plant nutrition, that influences the growth and production of all crops. Nutrient management includes determining the nutritional requirements for maximum production of high-quality fruits. (Dar *et al.*, 2015) ^[11]. Nutrient management ultimate goal is to ensure that a crop receives an appropriate supply of essential nutrients throughout the growth season. Soils differ greatly in their ability supply adequate nutrients, which must be supplemented through soil and foliar application. Plants require 17 essential nutrients out of a total 92 natural elements in the plant system to sustain their normal growth, health, and the production of nutritious food and feed. Mineral fertilisers have resulted in a massive increase in crop production, both in terms of quantity and quality of food and fodder, since the 1850s. (Noreen *et al.*, 2018) ^[32]. It has been observed that essential and suitable nutrients contribute to crop quality by acting as raw materials for the production of various plant compounds which has nutritional value to the both humans and animals. Nitrogen and sulphur are essential

building blocks for protein synthesis. Others, such as Calcium, Phosphorous, Zinc, and iron are engaged in enzyme synthesis and activation or as electron carriers, whereas Magnesium and potassium are mostly involved in enzyme activation and transportation of materials like fructose and sucrose from points of synthesis to sites of loading and thus have a significant impact on the quality of fruits, root, and tuber crops. It has been witnessed that the synergistic and antagonistic relationships in different nutrient uptake and utilisation have a significant impact on crop quality (Njira and Nabwami, 2015) ^[31]. Several nutrients had an impact on growth, yield and quality parameters and this can be accomplished by soil or foliar application. Both macro nutrients and micronutrients can be applied through fertigation. However, foliar spray application has been identified as the most effective method for application of nutrients in fruit orchard. Foliar nutrition is the one of the key tool for maintaining or improving plant nutrition during the growing season. Often immediate results are observed and deficiencies of fruit crops could be rectified quickly than soil application.

Plant bio-regulators

Growth and development of fruit crops are influenced by both internal and external factors. The internal factors are genotype and endogenous hormonal balance whereas external factors are environmental conditions. There are other factors like planting density, fertilization and irrigation which may also effect the plant growth and development. Since their discovery, plant hormones are used to regulate plant growth and development in order to improve the quality and quantity of produce, allowing fruit producers to meet the rising demands for high quality food (Bons and Kaur, 2015) ^[8]. The plant growth and development are governed by two sets of internal factors, nutritional and hormonal. Nutritional factors are the raw materials necessary for growth. The utilisation of these nutrients for proper plant development is controlled by chemical messengers known as plant growth regulators, which influence the physiological processes in plants in minute amounts (Saho *et al.*, 2017). Plant growth regulators (PGRs) are produced naturally by higher plants (endogenously) or applied synthetically applied which effects the developmental or metabolic process of plants and they do not possess any nutritive value and usually are not phytotoxic (Rademacher, 2015) ^[37]. The five groups of growth regulators include auxins, gibberellins, cytokinin's, ethylene, abscisic acid (Suman *et al.*, 2017; Mishra *et al.*, 2019) ^[43, 30] and others like jasmonic acid, brassinosteroids, oligosaccharides, fusicocin are also found useful for growth and development of horticultural crops (Mishra *et al.*, 2019) ^[30]. When Plant bio-regulators are applied to the different parts of a plant, they are rapidly absorbed and have a specific mode of action (Kumari *et al.*, 2018) ^[25]. Plant growth regulators are used in production technology and quality improvement. In production technology, primarily used in nursery production, crop regulation (flower manipulation), fruit set, fruit growth and manipulation (delay or early harvest) of fruit harvest) while in quality improvement growth regulators have equal importance in internal fruit quality development, fruit storage (Bons and Kaur, 2015) ^[8] and also used in fruit drop control (Suman *et al.*, 2017) ^[43] deblossoming and fruit thinning and fruit ripening (Rademacher, 2015) ^[37]. However response of growth regulators varies from cultivar to cultivar, plant age, plant vigour, availability of nutrients, light, temperature and endogenous hormonal content (Singh *et al.*, 2022) ^[40].

The main objective of this paper to review the combined application of mineral nutrients and plant bio-regulators quantitative and qualitative traits of fruit crops.

Combined effect on the vegetative growth characteristics

Deshmukh *et al.*, (2016) ^[13] found that the plant height, plant spread, canopy volume of acid lime (hasth bahar) has been showed better performance by the spraying of 50 ppm GA3 (June) + cycocel 1000-2000 ppm, paclobutrazol 2.5-3.5 gms a.i./tree and 1000-2000 ppm in September+ KNO₃ 0.2% + Zn 0.34% + Boron 0.1% in October. Yadav *et al.*, (2017) ^[47] revealed that the plant height, plant canopy volume, chlorophyll leaf content was increased by spraying of GA3 20 ppm + ZnSO₄ 1% + FeSO₄ 1% + MnSO₄ 1% in the sweet orange cv. Mosambi at petal fall stage (2nd week of march) and second spray at 45 days after 45 days of first spray (last week of march). Gurung *et al.*, (2016) ^[17] reported that the foliar spraying of plant bio-regulators and micro nutrients in mandarin at pre monsoon and post monsoon in 2 split doses significantly improved the growth morphology in mandarin. The maximum tree height, trunk girth, canopy area, shoot length was recorded by the foliar spray of GA3 15 ppm + Zinc 0.5% + B 1%. Karole and Tiwari, (2016) ^[22] observed that the pre-harvest spray of NAA 60 ppm + GA3 30 ppm + urea 2% twice in October and September month influenced the leaf parameters like leaf length (1.70cm), leaf width (1.49 cm) and leaves per shoot (390.67) in Ber cv. Gola. Jawad *et al.*, (2016) reported that the foliar application of zinc sulphate @ 0.40% and GA3 @ 90 ppm enhanced the tertiary shoot length, shoot diameter and number of leaves/shoot in guava sv. G-27. Digrase *et al.*, (2016) ^[15] reported that the combination of 75 ppm GA3 + 0.3% boron recorded the highest growth in pomegranate cv. Bhagwa. Bhat *et al.*, (2011) ^[5] revealed that the application of new generation PGR's like CPPU (2ppm) + Brassinosteroids (0.4 ppm) along with ga3 (25 ppm) twice at 7 days and 15 days after fruit set in grapes cv. Tas-A-Ganesh recorded the highest number of leaves whereas leaf area and dry matter content was recorded maximum under CPPU (3 ppm) + BR (0.4%) + GA3 (25 ppm).

Combined effect on flowering and fruit set

Joshi *et al.*, (2016) found that the number of flowers/shoot and fruit set percentage was maximum over the control by combined application of KNO₃ 2% + GA3 50 ppm thrice in first week of July, August, September and also induced the early flowering in sapota cv. Kalipatti. Bhati *et al.*, (2016) stated that the spraying of growth

regulators like NAA, GA3 and Zinc influenced the reproductive parameters. Application of NAA @ 200 ppm + GA3 @ 100 ppm + Zinc @ 1% during flower initiation and fruits at peas stage minimized the number of days taken flower initiation to fruit set, number of days taken fruit set to maturity, fruit set percent in acid lime cv.Kagzi lime. All the three components used in combinations their synergistic effect improved the reproductive parameters. Ashraf *et al.*, (2013) ^[3] stated that the foliar spraying of PGR's and nutrients (2,4-D, Salicylic acid, Zn, K). or their combinations influenced the fruit setting in kinnow mandarin. Combination of 2,4-D (10 mg L⁻¹) + Zn (0.25%)+ K (0.25%) sprayed at flower initiation, fruit formation and colour initiation of fruits recorded the highest fruit setting followed by SA(10 mg L⁻¹) + Zn (0.25%) + K(0.25%). Saraswat *et al.*, (2006) ^[39] found that the combined spraying of NAA (20 ppm) and ZnSO₄ (0.6%) before flowering and at fruit set stage recorded the highest number of inflorescence/tree and fruit set/panicle in litchi cv.Calcuttia. Anusuya *et al.*, (2018) ^[2] observed that the hermaphrodite flowers/panicle, length of panicle and number of panicles/m² found maximum by application of PBZ 0.75 gms a.i./m² + KNO₃ 1% + NAA 20 ppm in mango cv.Banglora during the main season (applied PBZ on September and nutrients on 30th November, December and January) compared to the off-season. Rathod *et al.*, (2019) revealed that the spraying of Borax (0.5%) and NAA (20 ppm) on 15th May, June and July recorded the highest fruit set in aonla cv.Gujarat Aonla-1. Mandloi *et al.*, (2021) ^[27] noticed that the spraying of GA3(60 ppm) + Cycocel (2000 ppm) + Thio-urea (1%) minimized the days for flowering, improved the number of flowers/shoot and fruit setting in acid lime cv.Vikram.

Combined effect on the fruit drop and fruit retention

Final yield in the fruit orchards depend on flowering, fruit setting and fruit retention. It can be manipulated by application nutrients and plant growth regulators. In kinnow mandarin, application of ZnSO₄ (250 ppm) + NAA (50 ppm) on the pruned trees twice in November, the pre-harvest fruit drop was reduced (Kumar *et al.*, 2017). At the treatment of NAA(20 ppm), GA3 (40 ppm), ZnSO₄ (0.4%) and their combination applied at fruit setting stage, significantly reduced the fruit drop and maximised the fruit retention in Ber cv.Banarasi Karaka (Pandey *et al.*, 2012). Auxins are required in higher quantity, when fruits are in developing stage. If auxin level falls, fruit drop occurs. When mango tree was applied with combined dose of SA@ 100 ppm and urea @ 2% at before panicle initiation (1st week of December) and after fruit set(last week of March), number of fruit set/panicle was maximum along with fruit retention. Exogenous application of SA and urea controlled the auxin deficiency, as result fruit drop was reduced and increased the fruit retention in mango cv.Amrapali (Chourasia and Mandal, 2021) ^[9]. Application of 2,4-D(15 ppm) + Zinc (0.5%) + Boron (0.1%) twice at pre and post monsoon season lowered the fruit drop in Darjeeling mandarin (Gurung *et al.*, 2016) ^[17]. In plum cv.Kala Amritsari, combination of 10 ppm NAA + 0.5% ZnSO₄ + 2% Urea applied at 2 different times (mid-march and mid-April). As a result, fruit drop was minimized. Highest fruit drop percent was observed in April compared to May. No significant effect was found between treatments and time of application of treatment (Rajput *et al.*, 2017) ^[36]. Maximum fruit retention and minimum fruit drop was founded by Deshlehra *et al.*, (2019) ^[14] in acid lime Vikram by application pf GA3 (100 ppm) + KNO₃ (2%) + SA (200 ppm) + FeSO₄ (1%) + Boron (1%) 4 months before flowering. Application of 100 ppm GA3 + 20 ppm NAA in sweet cherry cv. Bing and Hardy giant during white bloom stage and after fruit setting minimized the fruit drop in both the cultivars (Askarieh *et al.*, 2021) ^[4].

Combined effect on physical fruit characteristics

Physical fruit parameters like fruit size, length, weight, volume, diameter and specific gravity. Fruit size and weight are the important parameters of fruits that determines the market value. Physical fruit characteristics are the result of plant vegetative activity. Various plant bio-regulators and mineral nutrients influenced the physical fruit traits. Effect of mineral nutrients and plant bio-regulators on physical fruit traits are presented below the table:

Table 1

PGR's/Nutrients used	Fruit crop	Time/stage of application	Fruiting attributes affected	Reference
Urea 1% + NAA 50 ppm	Guava	Before flowering (August) and after fruit set (September)	Fruit length, width, weight and volume	Shukla <i>et al.</i> , (2018)
NAA 25 ppm + GA3 30 ppm + Urea 2%	Ber	-	Fruit size	Katiyar <i>et al.</i> , (2010)
KNO ₃ 2% + GA3 100 ppm	Acid lime	Two sprays at monthly interval	Fruit weight and volume	Debaje <i>et al.</i> , (2011)
Boric acid + CaCl ₂ + NAA	Litchi	During anthesis(8 th and 10 th week)	Fruit length, breadth and fruit size	Anmol and Singh, (2018)
ZnSO ₄ 0.4% + NAA 15ppm	Strawberry	-	Fruit length, diameter, specific gravity	Yadav <i>et al.</i> , (2018)
GA3 50 ppm + CaNO ₃ 2% + Borax	Pomegranate	GA3, Ca and Borax at 45 & 90 days after fruit	Fruit length, diameter, fruit weight and aril	Beerappa <i>et al.</i> , (2019)

0.2% + SOP2 2%		set while SOP2 at fifteen days before harvest	weight	
SOP2% + Brassinosteroids 2 ppm	Banana	After complete inflorescence and 30 days after 1 st spray	Weight of hand and finger, finger length and girth	Damodhar <i>et al.</i> , (2019)
IBA 20 mg L ⁻¹ + GA3 10 mg L ⁻¹	Grapes	Full bloom stage	Enlarged thin bunches and berries, improved rachis & berry firmness	Guzmán <i>et al.</i> , (2021)

Combined effect on yield/Production of fruit crops

Bhati *et al.*, (2016) noticed that the foliar application of NAA (100ppm) + GA3 (100 ppm) + Zinc (1.0%) during flower initiation and pea stage in Acid lime cv. Kagzi lime, resulted in maximum number of fruits/plant(976.33) and higher fruit yield/plant (38.10 kg), while control found minimum number of fruits/plant (743.0) and 20.56 kg yield/plant. Karole and Tiwari, (2016) [22] studied that application of 60 ppm NAA + 30 ppm GA3 + 2% Urea in Ber cv. Gola, first spray in October and second at 30 days after first spray was found effective in increasing fruit yield/tree over the control. Rathod *et al.*, (2019) recorded the highest yield in aonla cv.Gujarath Aonla-1 with the combined application of 0.5% Boron and 20 ppm NAA. Masoud *et al.*,(2019) stated that the three times spraying of 50 ppm GA3 alone or combined with CaCl₂ @ 2% and ZnSO₄ @ 0.025% in the two seasons of pomegranate recorded the maximum yield (103.64 & 103.58 kg per tree). While minimum yield was noticed under control trees (84.07 kg/tree). Rajput *et al.*, 2017) [36] concluded that application of 10 ppm NAA + 0.5% ZnSO₄ + 2% Urea in mid-march and mid-April influenced the fruit yield (60.26 kg/tree) in plum cv.Kala Amritsari. But application of treatment during mid-April recorded highest yield 50.27 kg per tree than the application of treatment during mid-march 48.51 kg per tree. Anmol and Singh, (2018) noted that application of Boric acid 1% + CaCl₂ 2% + GA3 20 ppm and Boric acid 1% + CaCl₂ 3% + GA3 20 ppm twice at 8th and 10th week of anthesis in litchi cv. Culcuttia, both the treatment recorded highest fruit yield (1.31q and 1.1q). Chourasia and Mandal (2021) [9] studied that foliar spraying of SA (100 PPM) + Urea (2%) in mango cv. Amrapali before panicle initiation (December) and after fruit set (March) followed by SA (200 ppm) + Urea (2%) increased the fruit number per tree (194.4 & 177.0). A significant increase in number of fruits/tree (307.66) and yield/tree (63.38kg) was observed in sweet orange cv.Mosambi when 2,4-D 20 ppm + ZnSO₄ 1% + FeSO₄ 1% + MnSO₄ 1% was applied twice at petal fall stage (2nd week of March) and last week of April(45 days later first spray) (Yadav *et al.*, 2017) [47].

Combined effect on Bio-Chemical Parameters

Fruit bio-chemical parameters like Total soluble solids, acidity, TSS/Acid ratio, Ascorbic acid, total sugars. Reducing sugars and non-reducing sugars, pectin, juice content, phenols, anthocyanin content are measured in terms of quality parameters which are important for fruit processing and juice industries. The literature shows that these quality parameters can be influenced by combined application of mineral nutrients and growth regulators. Application of Urea 1% + K₂SO₄ 1% + Zinc 0.1% + NAA 50 ppm in guava cv.Sardar thrice, before flowering, at fruit setting and three weeks after fruit setting increased the Ascorbic acid (135.42 mg/100 gms) while minimum was recorded under control (Dutta and Banik 2005). In kinnow mandarin, when pruned trees (3rd week of January) are sprayed with Boron 250 ppm + GA3 50 ppm(twice in November) improved the TSS, Ascorbic acid, TSS Acid ratio and decreased the peel thickness and acid content of fruits (Kumar *et al.*, 2017) [24]. The highest TSS (8.33°B), ascorbic acid (32.0 mg), total sugars with lowest fruit acidity (6.42%) was recorded in acid lime cv.kagzi lime, when sprayed with NAA (200 ppm) + GA3 (100 ppm) + Zinc (1%) at flower initiation and again at pea stage (Bhati *et al.*, 2016). Application of GA3 (30 ppm) + KNO₃ (2%) in mango cv.Amrapali recorded the highest TSS, Ascorbic acid, total sugars, reducing sugars with minimum acidity of fruits followed by GA3 (20 ppm) + KNO₃ (2%) (Prauha and Pandey, 2019) and the highest phenolic content in mango was recorded by combined spraying of ethephon 200 ppm and urea 2% (Chourasia and Mandal, 2021) [9]. The application of GA3 75 ppm + ZnSO₄ 00.4% + Boric acid 0.4% recorded the highest TSS (13.71°B), ascorbic acid content (43.71 mg/100 gms), Sugars (7.11) with the lower total acidity in strawberry cv.Chandler (Bairwa *et al.*, 2020). In litchi cv Shahi, application of ZnSO₄ 1% + Boric acid 0.4% + SSR 20 ppm recorded the maximum TSS (21.1°B and 20.9°B)(Jana *et al.*, 2010). In pomegranate, when CaCl₂ 2% and ZnSO₄ 0.025% with GA3 50 ppm or NAA 25 ppm was applied thrice in 1st&2nd week of May and 2nd week of June improved the quality parameters like TSS, reducing sugars, vitamin C, anthocyanin content whereas acidity and tannin content was minimized by the same treatment compared to control (Masoud *et al.*, 2019). Pre-harvest application of NAA 25 ppm and GA3 30 ppm along with urea 2% in Ber cv Banarasi Karaka significantly increased the TSS 16°B and sugars 11.20% while minimum was noted under the control (TSS 13.8 B and sugars 8.52%)(Katiyar *et al.*, 2010).

Conclusion

Both the mineral nutrients and bio-regulators are commercially exploited in the fruit crops because of wide range of roles they play in increase of productivity per unit area. Their application in the fruit crops during different growth stages of fruit crops such as before and after flowering, fruit setting stage, fruit developmental stages is

currently in trend as is evident from the present literature. The application of various combinations of mineral nutrients and growth regulators at different growth stages of fruit crops showed the appropriate results in vegetative growth, flowering and fruit set, fruit retention, fruit drop, overall yield and various bio-chemicals parameters. But the suitable combination of mineral nutrients and bio-regulators at appropriate concentrations and time of application have need to be identified for effective results in fruit crops. One more thing need to be explored is the economic analysis of nutrients and plant growth regulators as most of the farmers are small and marginal land holders.

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