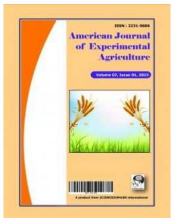

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Impact of Foliar Application of Growth Regulators and Micronutrients on the Performance of Darjeeling Mandarin

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Authors' contributions

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

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ABSTRACT

Investigation was carried out in the farmer's field of Kalimpong to evaluate the effect of foliar application of different level of GA_3 and micronutrients on Darjeeling mandarin. The experimental design was adopted randomized block design in which there was seven main plot treatments representing combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5% and Boron @ 0.1%). Foliar application of GA_3 at the rate of 15 ppm along with zinc (0.5%) and boron (0.1%) improved growth morphology, fruit yield attributes is also effective in enhancing the fruit yield with better fruit quality. Generally, it could be concluded that the treatment (T_3) seems to be the promising treatment for the hilly region of Darjeeling.

Keywords: Mandarin; growth regulator; micronutrient; morphology; quality.

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1. INTRODUCTION

Mandarin (*Citrus reticulate* Blanco.), the citrus species native to Darjeeling district is commonly known as Darjeeling orange and its nutrition management has become one of the most important factor for improving their plant growth and yield efficiency.

Foliar feeding has been used as a means of supplying supplemental doses of minor and major nutrients, plant hormones, stimulants and other beneficial substances. Therefore, judging which foliar materials to apply and at what plant stage to spray with soil applied organic and inorganic fertilizers are important principles to make best uses of this technique. The application of plant growth regulator (PGR) can provide significant economic advantages to citrus growers when used in appropriate situations as these have proven effective in stimulating a number of desired responses such as increase in fruit size and delay in fruit maturity [1]. Fruit development is thought to be triggered by hormones [2] that the endogenous gibberellins status of the developing citrus ovaries is the limiting factor for the initiation of fruit development. Foliar application of different levels of GA_3 (5, 50, 100 and 500 mg/l) to young fruit let's just after fruit set have been reported to clearly increase the fruit weight, peel thickness, juice content with improved taste of grapefruit [3]. Among the growth regulators, 2, 4-Dichloro phenoxy acietic acid (2, 4-D) is known to improve the fruit size, yield and fruit quality parameters in citrus [4].

Nutrient management is one of the most important factor in improving the plant growth and yield through increasing photosynthetic efficiency. Micronutrients deficiency in soil and plants is a worldwide nutritional problem and very severe in many countries [5]. In Darjeeling, the nutrient deficiencies particularly micronutrients are common due to climate and nature of soil. By choosing appropriate fertilizer rates, the grower can drive a crop toward earlier and heavier fruit setting [6]. Micronutrients like zinc and boron (B) are very important for optimal plant growth, physiological and biochemical pathways in citrus cultivation under agro-climatic conditions of Darjeeling. The application of zinc improves the citrus fruit yield and its juice quality [7]. Foliar or soil application of zinc increases the biosynthesis of chlorophyll and carotenoid synthesis that are important for proper performance of photosynthetic process. Foliar application of zinc had positive impact on fruit yield and quality of Kinnow mandarin, sweet orange and grapes [8]. Similarly, application of B with Zn enhanced the juice content [9]. Application of B increases fruit set and yields by its role in pollen tube germination and elongation [10] and increases growth and flowering in tomatoes [11]. The foliar application of Zn and B significantly enhanced fruit yield and juice content, total soluble solids, ascorbic acid and non reducing sugar [12].

Mandarin locally known as "*Suntala*" was once considered excellent in the world for its taste and flavor. In the present situation it cannot claim its superiority due to deterioration of fruit quality. Its acerage, production and fruit size have also been declined drastically mainly due to lack of proper orchard management especially nutrients management which leads to decline. In absence of data on the exact nutrient that is deficient a multi nutrient approach is followed to formulate the treatment. Therefore, an attempt is made to study the efficacy of growth regulators and micronutrients on the performance of this crop.

2. MATERIALS AND METHODS

The present study was carried out in the farmer's field of Kalimpong sub division of Darjeeling hill, West Bengal during the year 2010 to 2012. The climatic condition of this area is characterized by high rainfall varies from 2100 to 3000 mm, of which 80% is received during June to October. Minimum and maximum temperature of the area varies from 2-4℃ and 26-30℃ respectively. The relative humidity of the area varies from 65% to 98%. The topography is mainly hilly terrain and is characterized by anticline and syncline with undeveloped horizon of brown forest soil. The soil of the experimental field was low in pH (5.5), organic carbon (1.1%), available N (171.20 kg/ha), available P (37.14 kg/ha) and available K (367.81 kg/ha). The three growth regulators and micro nutrient were sprayed at pre and post monsoon as a two split doses. The experimental design adopted was randomised block design in which there was seven main plot treatments representing combinations of three growth regulators and two micro nutrients and replicated thrice. The growth regulators and micro nutrient were sprayed at pre and post monsoon as a two split doses taking seven different treatment combinations ie. T_1: Control, T_2: GA_3 7.5 ppm + zinc + boron (0.5% + 0.1%), T_3: GA_3 15 ppm + zinc + boron (0.5% + 0.1%), T_4: BA 200 ppm + zinc + boron (0.5% + 0.1%), T_5: BA 400 ppm + zinc + boron (0.5% + 0.1%), T_6: 2, 4-D 7.5 ppm +

zinc + boron (0.5% + 0.1%), T_7: 2,4-D 15 ppm + zinc + boron (0.5% + 0.1%). Observations on growth characters i.e. tree height, trunk girth, canopy area, shoot length and flowering intensity were recorded as when required whereas yield parameters *viz.* fruit set per cent, fruit drop per cent, fruit weight, segment number and juice content were recorded after harvesting of fruits. Physio-chemical parameters like total soluble solids (TSS) content of fruit in ^{0}Brix were determined by a method described by Mazumdar and Majumdar [13]. The total titrable acidity as mentioned by Ruck [14]. The total and reducing sugar content of fruits were determined by analyzing the fruits following methods of Lane and Eynon [15] and ascorbic acid was estimated by following the procedure of Rangana, [16]. Data collected from the field experiment were subjected to statistical analysis appropriate to the design RBD (Randomized Block Design) with 7 treatments and 3 replications (Gomez and Gomez) [17]. For the determination of least significance at 5% level of significance, the statistical table formulated by Fisher and Yates [18] was consulted.

3. RESULTS AND DISCUSSION

Growth morphology was significantly influenced by growth regulators and micronutrients which are illustrated in Table 1. Application of foliar spray of zinc, boron and growth regulators like GA_3, BA and 2,4-D were found effective. Highest tree height (3.82 m) was recorded in T_3 (GA_3 15 ppm + Zn + B) as compare to other treatments where as the highest trunk girth (33.95 cm) was observed in T_3 ($GA_3$15 ppm + Zn + B). This growth promotion may be due to action of gibberellins acid. This promotion of cell division is due to stimulation in G_1 phase to enter S phase as Gibberellins firstly stimulates the cell division in the shoot apex, especially in the more basal meristematic cell from which develop the files of cortex and pith cell [19]. Similar findings were also observed by Eliyeva [20] in apple and Balakrishna et al. [21] in pomegranate. Plant height and plant girth were increased due to the increased application of micro-nutrient including boron and zinc. Glozer and Grant [22] also reported the increased tree height and girth of plant in case of California lemon and sweet cherry, respectively on application of nutrients like zinc and boron. Canopy area (455.31 m^2) was highest in T_3 (GA_3 15 ppm + Zn + B) and this might be due to the application of zinc that enhances the photochemical reactions occurring in thylakoid membrane, electron transport through PSII and increases photosynthetic rate [23] and chlorophyll content [24] which may result increased canopy area. The lowest area of canopy (170.45 m^2) was recorded under treatment representing control plot. However, highest shoot length (5.94 cm) was observed in T_6 (2,4-D 7.5 ppm + Zn + B) and these findings can be supported by Pharis and Kua [25] who reported the growth of leaves and other plants parts in early stages under the influence of 2,4-D. Moreover, Zurflur and Guilfoyle [26] mentioned that 2, 4-D can increase the horizontal growth of tissue in leaves and other plants parts by inducing growth promotion by cell division. Maximum intensity of flowering (83.89) was in treatment supplied with GA_3 15 ppm along with zinc and boron. This might be due to the spraying of plant growth regulators and micronutrient that enhanced the auxin production, which in turn controlled abscission. This is in conformity with the findings of

Table 1. Effect of micro-nutrient and growth regulators on growth morphology of Mandarin

Treatment	Tree height (m)	Trunk girth (cm)	Canopy area (m^2)	Shoot length (cm)	Flowering intensity
T_1	3.36	26.45	170.45	2.97	81.60
T_2	3.53	32.61	394.23	4.05	83.82
T_3	3.82	33.95	455.31	4.51	83.89
T_4	3.52	31.26	285.64	3.72	83.27
T_5	3.73	30.23	328.00	3.80	83.08
T_6	3.80	26.92	358.92	5.94	83.45
T_7	3.78	32.81	381.98	4.41	83.01
SE±	0.28	2.02	18.60	0.52	0.48
$P_{0.05}$	0.64	6.23	57.32	1.60	1.48

Note: T_1: Control; T_2: GA_3 7.5 ppm + zinc + boron (0.5% + 0.1%) (0.5% + 0.1%); T_3: GA_3 15 ppm + zinc + boron (0.5% + 0.1%); T_4: BA 200 ppm + zinc + boron (0.5% + 0.1%); T_5: BA 400 ppm + zinc + boron (0.5% + 0.1%); T_6: 2,4-D 7.5 ppm + zinc + boron (0.5% + 0.1%) and T_7: 2,4-D 15 ppm + zinc + boron (0.5% + 0.1%)

Saraswathi et al. [27] who reported the Gibberellins can reduce the senescence of leaves and fruits. Application of boron increases flower numbers and act its role in pollen tube germination and elongation [11].

Significant difference was observed among the different treatments with respect to different yield attributing characters as in Table 2. Highest fruit set (21.31%) was observed in T_3 (GA_3 15 ppm + Zn + B) and lowest was recorded from trees belonging to treatment representing control. Ashraf et al. [7] also indicated that application of zinc improves the citrus fruit yield and this might be due to involvement of zinc in photosynthesis, activation of enzyme systems, protein synthesis and carbohydrate translocation [28]. Abscission layer at the stem resulting in fruit drop is formed due to imbalance of auxins, cytokinins, and gibberellins [29]. The cause of drop may be related to competition among fruit lets for carbohydrates, water, and hormones [30]. Lowest fruit drop (19.38%) was observed in treatment supplied with 2-4-D, 15 ppm with Zn and B as compare to other treatments and this finding also supported by Negin et al. [31] which are corresponding with the effect of auxin application [32]. Plant growth regulator like 2,4-dichlorophenoxyacetic acid (2,4-D) have been reported to be effective in controlling fruit drop in citrus [33]. Application of 2, 4-D at flowering reduced transiently fruit let growth rate and delayed abscission [34]. Micro nutrient in other hand attributes to high translocation of foods to fruit bearing portion of plants promoted by micro nutrient described by Khorsandi [35] on pomegranate. Talaie and Taheri [36] showed that foliar sprays of B and Zn significantly decreased fruit drop and improved fruit quality in 'Zard' olives. Highest fruit weight (66.24 g) was in treatment that received GA_3 (15 ppm) along with Zn and B. the beneficial effect of zinc significantly increases the size of fruit in Mandarin and this finding the reports of Hang et al. [37]. The average number of segments (10.44) was recorded highest in T_3 applied with GA_3 15 ppm along with Zn (0.5%) and B (0.1%) as foliar spray. This might be due to the increase of fruit weight and size which ultimately enhanced the number of segments per fruit. Moreover, the positive effect of GA3 was observed in this study with respect to number of segments. Gibberellins are known for their ability to increase cell enlargement and enhancing fruit growth in certain species such as citrus [38]. Juice percentage (33.83%) was highest in T_3 (GA_3 15 ppm + Zn +B foliar spray. Moreover, application of Zn and B enhances the juice content [9]. The lowest juice content (25.12%) was recorded under control and this might be due to the small size of fruit, weight and number of segments per fruit.

Effect of growth regulators and micronutrients on fruit quality was significantly influenced by different treatments as depict in Table 3. The maximum TSS (10.36 ^{0}Brix) was recorded in T_3 (GA_3 15 ppm + Zn +B). Takidze [39] also found that application of Zinc sulphate significantly increased T.S.S. content in the juice of sweet orange. Total sugar (10.15%) was recorded highest in T_3 (GA_3 15 ppm + Zn +B). Applying zinc to the trees might improved fruit quality by enhancing formation and translocation of

Table 2. Effect of micro-nutrient and growth regulators on yield attributes of Mandarin

Treatment	Fruit set (%)	Fruit drop (%)	Fruit weight (g)	Segment number	Juice content (%)
T_1	19.46	48.54	49.35	7.55	25.12
T_2	20.24	20.37	62.65	10.44	32.37
T_3	21.31	23.66	66.24	10.33	33.83
T_4	19.93	26.41	63.62	9.55	31.02
T_5	19.94	26.28	63.15	9.66	31.86
T_6	20.19	22.58	66.19	9.55	30.46
T_7	19.76	19.38	65.46	10.00	32.38
SE±	**0.49**	**1.13**	**0.92**	**0.17**	**0.29**
$P_{0.05}$	**1.49**	**3.50**	**2.84**	**0.51**	**0.83**

Note: T_1: Control; T_2: GA_3 7.5 ppm + zinc + boron (0.5% + 0.1%) (0.5% + 0.1%); T_3: GA_3 15 ppm + zinc + boron (0.5% + 0.1%); T_4: BA 200 ppm + zinc + boron (0.5% + 0.1%); T_5: BA 400 ppm + zinc + boron (0.5% + 0.1%); T_6: 2,4-D 7.5 ppm + zinc + boron (0.5% + 0.1%) and T_7: 2,4-D 15 ppm + zinc + boron (0.5% + 0.1%)

Table 3. Effect of micro-nutrient and growth regulators on fruit quality of Mandarin

Treatment	T.S.S (^{0}Brix)	Total sugar (%)	Reducing sugar (%)	Tritable acidity (%)	Ascorbic acid (mg/100 g)
T_1	9.50	9.51	3.83	0.70	25.36
T_2	10.07	10.09	4.01	0.69	29.57
T_3	10.36	10.15	4.11	0.66	29.94
T_4	9.77	9.86	3.86	0.67	29.13
T_5	10.14	9.98	3.89	0.65	29.44
T_6	9.80	10.00	3.92	0.68	28.15
T_7	10.08	10.04	3.96	0.69	28.76
SE±	**0.10**	**0.03**	**0.06**	**0.01**	**0.04**
$P_{0.05}$	**0.32**	**0.08**	**0.03**	**0.03**	**0.12**

Note: T_1: Control; T_2: GA_3 7.5 ppm + zinc + boron (0.5% + 0.1%) (0.5% + 0.1%); T_3: GA_3 15 ppm + zinc + boron (0.5% + 0.1%); T_4: BA 200 ppm + zinc + boron (0.5% + 0.1%); T_5: BA 400 ppm + zinc + boron (0.5% + 0.1%); T_6: 2,4-D 7.5 ppm + zinc + boron (0.5% + 0.1%) and T_7: 2,4-D 15 ppm + zinc + boron (0.5% + 0.1%)

carbohydrates and carbohydrate enzymes [40] which resulted the increased percentage of total sugar in Mandarin. The content of reducing sugar (4.11%) was also highest in treatment T_3 and in sweet orange [41,10] in Washington navel also found improved reducing sugar content on boron application. The maximum titrable acidity (0.703%) was recorded in control plot and this might be due to unavailability of micronutrients and growth regulators and zinc and boron deficient may leads to increase in acidity. The data presented, reveals that different combination of growth regulators along with zinc and boron significantly affects ascorbic acid content. Highest ascorbic acid (29.94 mg/100 g) was recorded in T_3 (GA_3 15 ppm + Zn +B). But Sindhu and Singhrot [42] reported minimum acidity in GA_3 (200 ppm) treated lemon fruits cv. Baramasi. No doubt, foliar application of Zn and B significantly influences the content of ascorbic acid [12].

4. CONCLUSION

Foliar application of GA_3 at the rate of 15 ppm along with zinc (0.5%) and boron (0.1%) improved growth morphology, fruit yield attributes and also effective in enhancing the fruit yield with better fruit quality. Generally, it could be concluded that the treatment GA3 15 ppm, zinc (0.5%) and boron (0.1%) (T_3) seems to be the promising treatment for the hilly region of Darjeeling.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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