Original Research Article

Effect of Foliar Application of Plant Growth Regulators and Nutrients on Quality of Kinnow Mandarin

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ABSTRACT

The present study was undertaken to observe the response of Kinnow Mandarin to different forms of growth regulators and nutrients. The result of investigation indicates that fruit length and diameter were found maximum with the foliar application of K$_2$SO$_4$ 2%, shape index and ascorbic acid were found maximum with the foliar application of 2, 4-D 20 ppm, peel thickness, acidity, peel content were recorded minimum and juice content and TSS were recorded maximum with the foliar application 2, 4-D 10 ppm, while rag content was found maximum with the application of GA$_3$ 20 ppm. The total sugar was found maximum in fruits treated with treatment K$_2$SO$_4$ 2% while reducing sugar was found maximum under the treatment K$_2$SO$_4$ 1.5%.

Keywords
Kinnow, nutrients, 2,4-D, GA$_3$

Introduction

In India, citrus fruits rank third in production after banana and mango. Among citrus crops, mandarin (Kinnow mandarin, Nagpur, Khasi and Darjiling) covers largest area followed by sweet orange (Musambi, Pineapple, Blood Red and Jaffa) and Acid lime. Among these, Kinnow mandarin bears highest place in production, productivity, juice content and fruit quality. Foliar application of Zn and K improved N, P, K and Zn level in Washington Navel leaves (Hafez and El-Metwally, 2007) and effectively controlled fruit drop, increased yield, juice volume, total soluble solids and vitamin C in Kinnow mandarin (Ashraf et al., 2012). Foliar application of different levels of GA$_3$ (5, 50,100 and 500 mg L$^{-1}$) to young fruitlets just after fruit set has been reported to increase fruit weight and to reduce peel thickness and better recovery percentage with improved taste of grapefruit (Berhow, 2000).

As compared to other macronutrients, citrus fruit tree takes up higher amount of potassium (Alva & Tucker, 1999; Ashraf et al., 2010; 2012).
It has a key role in many physiological processes like water relations, opening and closing of stomata, cell division, formation of sugars and starch, neutralization of organic acids, synthesis of proteins, and activation of enzymes (Liu et al., 2000; Srivastava & Singh, 2006).

By enhancing fruit size, juice contents, color, size and juice flavor potassium improves the fruit quality (Tiwari, 2005; Ashraf et al., 2010).

Materials and Methods

The present study was carried out at Chaudhary Farm House, Village Malapur, Hisar. Thirty-nine trees of uniform size and plant vigour with spacing 6 X 6 m were selected. All the thirteen treatments were replicated three times taking one plant as a single unit. The treatments comprising of 2,4-D ppm, GA3, K2SO4 and ZnSO4 along with control were laid out in randomized block design.

| Sr. no. | Treatments | Concentration of plant growth regulators and nutrients for foliar application |
|---------|------------|--------------------------------------------------------------------------------|
| 1       | T1         | 2,4-D 10 ppm                                                                    |
| 2       | T2         | 2,4-D 15 ppm                                                                    |
| 3       | T3         | 2,4-D 20 ppm                                                                    |
| 4       | T4         | GA3 10 ppm                                                                      |
| 5       | T5         | GA3 15 ppm                                                                      |
| 6       | T6         | GA3 20 ppm                                                                      |
| 7       | T7         | K2SO4 1.0%                                                                       |
| 8       | T8         | K2SO4 1.5%                                                                       |
| 9       | T9         | K2SO4 2.0%                                                                       |
| 10      | T10        | ZnSO4 0.25%                                                                     |
| 11      | T11        | ZnSO4 0.50%                                                                     |
| 12      | T12        | ZnSO4 0.75%                                                                     |
| 13      | T13        | Control                                                                          |

Fruit length (mm), fruit diameter (mm) and peel thickness (mm) of four randomly selected fruits were measured with the help of digital Vernier Calipers.

Fruit shape index

Fruit shape index can be calculated by dividing fruit diameter with fruit height.

Peel content (%)

For peel content four randomly selected fruits were peeled manually. The percent peel content was calculated by using the formula:

\[
\text{Peel content (%) = } \frac{\text{Peel weight}}{\text{Fruit weight}} \times 100
\]
Rag content (%)  
\[
\text{Rag content (\%) = \frac{[\text{Fruit weight} - (\text{Peel weight} + \text{Juice weight})]}{\text{Fruit weight}}} \times 100
\]

Juice content (%)  
The percent juice content was calculated by using the formula:
\[
\text{Juice content (\%) = \frac{\text{Total juice weight}}{\text{Total weight of fruits}}} \times 100
\]

TSS (\(^0\) brix)  
The TSS of the representative fruit juice was determined with the help of digital hand refractometer.

Acidity (%)  
The acidity was estimated by titrating the juice with 0.1 N NaOH using phenolphthalein as an indicator.

Ascorbic acid (mg/100 ml of juice)  
Ascorbic acid was estimated as per the method given by AOAC (1990). Two ml of fruit juice was mixed with 2 ml of 3% metaphosphoric acid as buffer and titrated with 2,6-dichlorophenol indophenol dye until the light pink colour appeared. The results were expressed as mg of ascorbic acid per 100 g of juice.

Results and Discussion  
Physical parameters  
The data recorded in Table 1 indicate that the application of different concentrations of 2,4-D, GA₃, K₂SO₄ and ZnSO₄ influenced the fruit length, fruit diameter and shape index significantly. The maximum fruit length was found in treatment T₉- K₂SO₄ 2% (62.85 mm) and minimum fruit length was found in control (54.92 mm). The fruit diameter was observed maximum in treatment T₉- K₂SO₄ 2% (71.81 mm) while it was observed minimum in control (63.37 mm). Malik et al., (2000), Ashraf et al., (2012) and Razzaq et al., (2013) observed maximum fruit size in Kinnow mandarin with foliar application of SA + Zn + K.

The shape index was found maximum under the treatment T₃- 2, 4-D 20 ppm (0.87). The shape index was found minimum under control (0.81).

The data in Table 2 shows the significant influence of different concentrations of 2, 4-D, GA₃, K₂SO₄ and ZnSO₄ on juice content, rag content and peel content in Kinnow mandarin fruit. The juice content was observed maximum in treatment T₁- 2, 4-D 10 ppm (49.75%) and minimum juice content was observed in treatment T₉- K₂SO₄ 2% (45.65%).

The rag content was obtained minimum in treatment T₁₂- ZnSO₄ 0.5% (24.77%) and maximum in treatment T₆- GA₃ 20 ppm (27.30%). Sangwan et al., (2008) observed that rag content was found non-significant but it increased with all the potassium treatments.

The treatment T₁- 2, 4-D 10 ppm (25.33%) showed the minimum peel content while the treatment T₉- K₂SO₄ 2% (27.93 %) showed the maximum peel content. Kaur et al., (2000) investigated the effect of GA₃ 15 and 20 ppm, 2,4-D 20 ppm, NAA 20 ppm and urea 1% on peel content of Kinnow mandarin fruit and found the minimum peel content in fruits under the treatment 2, 4-D 20 ppm (26.3%) and maximum in fruits of control treatment (30.3%). The treatment T₁- 2,4-D 10 ppm
(3.46 mm) showed the minimum peel thickness in Kinnow mandarin while the treatment T_{13}- Control (4.13 mm) showed the maximum peel thickness. The results of present study are in conformity with Sharma et al., (2013) who observed the minimum peel thickness (3.41 mm) in fruits taken from the plants sprayed with 2, 4-D 30 ppm and maximum (5.33 mm) in control fruits.

**Chemical parameters**

The data in Table 3 shows the significant influence of different concentrations of 2, 4-D, GA\textsubscript{3}, K\textsubscript{2}SO\textsubscript{4} and ZnSO\textsubscript{4} on TSS, acidity and ascorbic acid. The TSS was reported maximum in treatment T\textsubscript{9} - K\textsubscript{2}SO\textsubscript{4} 2\%(11.4 \text{ brix}) and minimum in treatment T\textsubscript{1} - 2, 4-D 10 ppm (9.8 \text{ brix}). The results of present study are in conformity with the findings of Ashraf et al., (2011) who found an increase in TSS in citrus juice with foliar application of Zn + K. The increase in TSS content with foliar application of K was related with the role of potassium in translocation of sugars from leaves to fruits (Havlin et al., 2007).

The acidity was found minimum in treatment T\textsubscript{1} - 2, 4-D 10 ppm (0.75\%), whereas maximum acidity was found in treatment T\textsubscript{9} - K\textsubscript{2}SO\textsubscript{4} 2\% (0.93\%). Saleem et al., (2008) found that the acidity in juice of Blood Red oranges increased significantly with the increase in 2, 4-D concentration.

The maximum ascorbic acid was observed in treatment T\textsubscript{3} - 2, 4-D 20 ppm (29.70 mg/100 ml) while minimum in treatment T\textsubscript{5} - GA\textsubscript{3} 15 ppm (26.8). The results of present study are in conformity with the findings of Maurya et al., (1973) who observed that with the application of 2, 4-D 20 ppm ascorbic acid content increased in Dusehri mango. The data in Table 4 shows the significant influence of different concentrations of 2, 4-D, GA\textsubscript{3}, K\textsubscript{2}SO\textsubscript{4} and ZnSO\textsubscript{4} on total and reducing sugar. The maximum total sugar was found in fruits treated with treatment T\textsubscript{9} - K\textsubscript{2}SO\textsubscript{4} 2\% (10.10\%), whereas minimum total sugar was found in fruits of control (8.78\%).

The increase in the content of total sugars in fruits might be due to degradation of polysaccharides into simple sugars by the enzymes, conversion of organic acids into sugars and loss of moisture from the fruits (Kumar et al., 2011). The results of the present study are in conformity with the findings of Khan et al., (2015) who found that the total sugars could be improved with exogenous application of nutrients (Zn and K) in Kinnow mandarin. The maximum total and reducing sugars increased with all the potassium treatments in Kinnow mandarin (Sangwan et al., 2008).

The reducing sugar was found maximum under the treatment T\textsubscript{8} - K\textsubscript{2}SO\textsubscript{4} 1.5\% (4.03\%). The reducing sugar was found minimum under T\textsubscript{10} - ZnSO\textsubscript{4} 0.25\% (3.31\%). However, Ram and Bose (2000) concluded that the foliar application of micronutrients (zinc, boron and Manganese) had no effect on reducing and non-reducing sugars in mandarin and sweet orange, respectively.

The effect of different concentrations of 2, 4-D, GA\textsubscript{3}, K\textsubscript{2}SO\textsubscript{4} and ZnSO\textsubscript{4} was found non-significant on non-reducing sugar. However, the maximum non-reducing sugar was found in treatment T\textsubscript{3} - 2, 4-D 20 ppm (5.23\%) and minimum non-reducing sugar was found in control (5.54\%). The results of the present study are in conformity with the findings of Jadhavar et al., (1991) who recorded a significant increase in non-reducing sugar content of Nagpur Santra fruits with 2, 4-D applied at 15 ppm. Wang et al., (2004) recorded that the sugar content could be increased with the application of 2, 4-D, GA\textsubscript{3} and some other growth regulators in fruits of various mandarin and sweet orange cultivars.
Table.1 Effect of different plant growth regulators and nutrients on length (mm), diameter (mm) and shape index in Kinnow mandarin fruit

| Treatments  | Fruit size (mm) |       |       |       |
|-------------|-----------------|-------|-------|-------|
|             | Fruit length (mm) | Fruit diameter (mm) | Shape index |
| T₁: 2,4-D 10 ppm | 55.12           | 64.34           | 0.84    |
| T₂: 2,4-D 15 ppm | 57.82           | 66.71           | 0.84    |
| T₃: 2,4-D 20 ppm | 56.23           | 65.63           | 0.87    |
| T₄: GA₃ 10 ppm   | 56.29           | 65.23           | 0.83    |
| T₅: GA₃ 15 ppm   | 59.22           | 68.83           | 0.82    |
| T₆: GA₃ 20 ppm   | 59.63           | 68.74           | 0.84    |
| T₇: K₂SO₄ 1.0%  | 60.04           | 69.23           | 0.82    |
| T₈: K₂SO₄ 1.5%  | 60.41           | 69.88           | 0.82    |
| T₉: K₂SO₄ 2.0%  | 62.85           | 71.81           | 0.82    |
| T₁₀: ZnSO₄ 0.25%| 55.93           | 64.78           | 0.82    |
| T₁₁: ZnSO₄ 0.50%| 58.43           | 67.89           | 0.84    |
| T₁₂: ZnSO₄ 0.75%| 58.29           | 67.45           | 0.84    |
| T₁₃: Control     | 54.92           | 63.37           | 0.81    |
| CD at 5% level of significance | 1.57           | 4.28           | 0.01    |

Table.2 Effect of plant growth regulators and nutrients on juice, peel and rag content (%) in Kinnow mandarin fruit

| Treatments  | Content (%) |       |       |       |
|-------------|-------------|-------|-------|-------|
|             | Juice | Rag | Peel | Peel thickness (mm) |
| T₁: 2,4-D 10 ppm | 49.75   | 24.92 | 25.33 | 3.46 |
| T₂: 2,4-D 15 ppm | 48.52   | 26.05 | 25.43 | 3.58 |
| T₃: 2,4-D 20 ppm | 48.00   | 26.13 | 25.87 | 3.69 |
| T₄: GA₃ 10 ppm  | 47.83   | 26.07 | 26.10 | 3.74 |
| T₅: GA₃ 15 ppm  | 46.53   | 27.15 | 26.32 | 3.77 |
| T₆: GA₃ 20 ppm  | 45.90   | 27.30 | 26.80 | 3.85 |
| T₇: K₂SO₄ 1.0% | 47.80   | 24.92 | 27.28 | 3.98 |
| T₈: K₂SO₄ 1.5% | 47.23   | 24.89 | 27.88 | 4.00 |
| T₉: K₂SO₄ 2.0% | 45.65   | 26.42 | 27.93 | 4.04 |
| T₁₀: ZnSO₄ 0.25% | 49.33  | 25.19 | 25.48 | 3.53 |
| T₁₁: ZnSO₄ 0.50%| 48.15   | 25.27 | 26.58 | 3.63 |
| T₁₂: ZnSO₄ 0.75%| 47.80   | 24.77 | 27.43 | 3.82 |
| T₁₃: Control    | 48.56   | 25.86 | 25.58 | 4.13 |
| CD at 5% level of significance | 1.02  | 0.78  | 0.72  | 0.21 |
Table 3 Effect of plant growth regulators and nutrients on TSS (°brix), acidity (%) and ascorbic acid (mg/100 ml) in Kinnow mandarin fruit

| Treatments          | TSS (°brix) | Acidity (%) | Ascorbic acid (mg/100ml juice) |
|---------------------|-------------|-------------|---------------------------------|
| T1: 2,4-D 10 ppm    | 9.8         | 0.75        | 28.52                           |
| T2: 2,4-D 15 ppm    | 10.0        | 0.77        | 29.00                           |
| T3: 2,4-D 20 ppm    | 10.2        | 0.81        | 29.70                           |
| T4: GA3 10 ppm      | 10.2        | 0.83        | 27.52                           |
| T5: GA3 15 ppm      | 10.6        | 0.89        | 26.87                           |
| T6: GA3 20 ppm      | 11.0        | 0.92        | 28.36                           |
| T7: K2SO4 1.0%      | 10.8        | 0.90        | 27.00                           |
| T8: K2SO4 1.5%      | 11.0        | 0.91        | 27.41                           |
| T9: K2SO4 2.0%      | 11.4        | 0.93        | 28.00                           |
| T10: ZnSO4 0.25%    | 9.8         | 0.76        | 27.92                           |
| T11: ZnSO4 0.50%    | 10.0        | 0.79        | 28.72                           |
| T12: ZnSO4 0.75%    | 10.4        | 0.85        | 29.49                           |
| T13: Control        | 10.0        | 0.75        | 27.41                           |
| CD at 5% level of significance | 0.80 | 0.11 | 2.00 |

Table 4 Effect of plant growth regulators and nutrients on percent sugar in Kinnow mandarin fruit

| Treatments          | Sugars (%) | Reducing | Non-reducing | Total sugar |
|---------------------|------------|----------|--------------|-------------|
| T1: 2,4-D 10 ppm    | 3.63       | 5.17     | 8.80         |
| T2: 2,4-D 15 ppm    | 3.73       | 5.22     | 8.95         |
| T3: 2,4-D 20 ppm    | 3.87       | 5.23     | 9.10         |
| T4: GA3 10 ppm      | 3.60       | 5.58     | 9.18         |
| T5: GA3 15 ppm      | 3.32       | 6.45     | 9.77         |
| T6: GA3 20 ppm      | 3.86       | 5.84     | 9.70         |
| T7: K2SO4 1.0%      | 3.85       | 5.15     | 9.00         |
| T8: K2SO4 1.5%      | 4.03       | 5.90     | 9.93         |
| T9: K2SO4 2.0%      | 3.92       | 6.18     | 10.10        |
| T10: ZnSO4 0.25%    | 3.31       | 5.64     | 8.95         |
| T11: ZnSO4 0.50%    | 3.34       | 5.90     | 9.24         |
| T12: ZnSO4 0.75%    | 3.97       | 5.61     | 9.58         |
| T13: Control        | 3.36       | 5.44     | 8.78         |
| CD at 5% level of significance | 0.44 | N/S | 1.10 |
The present research findings indicate that foliar application of 2,4-D 10 and 20 ppm are effective in improving juice quality by increasing juice volume, Total soluble solids, acidity and ascorbic acid content. Sugar content can be increased with the foliar application of K₂SO₄.

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