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APPLICATION OF PLANT GROWTH REGULATOR AND POTASSIUM NITRATE TO IMPROVE THE QUALITY AND YIELD IN WASHINGTON NAVEL ORANGES (*Citrus sinensis*)

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ABSTRACT

Fruit yields of traditional navels like "Washington" are lower as compared to other sweet oranges due to low fruit set and quality problems like creasing. The effect of plant growth regulator and potassium (GA_3 and KNO_3) alone and in combination were tested in Sargodha Punjab, Pakistan conditions at full bloom stage of Washington navel oranges. The impact of these treatments was tested on fruit yield, quality and to reduce the physiological disorder; incidence of creasing. Fruit set and yields were increased over non-treated trees, while combined treatment of GA_3 (25%) and KNO_3 (2%) had best results in fruit yields and quality i.e. fruit weight, size, TSS, acidity and other qualitative characteristics of the fruit. Creasing was effectively minimized by spraying plants in combination of GA_3 and KNO_3, thus reducing the quantitative and qualitative post-harvest fruit losses.

Key word: Washington navel, GA_3, KNO_3, quality, creasing, yield.

INTRODUCTION

Citrus fruit has gained importance in Pakistan and around the world due to its distinct flavor and therapeutic value. It is an excellent source of vitamin C with vitamins A, B and minerals such as calcium, phosphorus and iron (Nawaz *et al.*, 2008). Citrus is grown on more than 170,000 ha of land in Pakistan approximate 30% of the area under all fruit orchards (Saleem *et al.*, 2005a; Ashraf *et al.*, 2010).

Navel orange is a popular variety among others because of its quality characters like free of seeds, big size, special flavor and aroma (El-Enien *et al.*, 1985). Hence, it is a source of income for citrus growers because of its early maturity, good yield among the other commercial varieties of the world. Basically a low yield of citrus is due to lack of functional pollen, absence of valuable ovules and weakly parthenocarpic (Krezdorn, 1965). In case of navel orange flower and fruit drop occurs in three phases resulting a total fruit set 9% (Villafane *et al.*, 1989). Plant growth hormones i.e., Gibberellic acid (GA_3) and potassium nitrate have a wide range of uses in citriculture.

There are other serious problems in Pakistani citrus orchards which are responsible for low yield and quality. Low fruit set and excessive fruit drop in oranges is common leading to losses for Pakistani citrus farmers. Low fruit set and reduced quality of the fruit is due to malnutrition, insect pest attack, water stress and most importantly, hormonal imbalance (Nawaz *et al.*, 2008).

Application of plant growth regulators is effective in reducing the unnecessary premature fruit drop (Lahey *et al.*, 2004; Saleem *et al.*, 2005; Chen *et al.*, 2006; Modise *et al.*, 2009). Application of Gibberellic acid (GA_3) at fruit development stage is initiated by hormones as mentioned in the report of Talon *et al.* (1990) that the endogenous gibberellin hormone in citrus ovaries is the limiting factor for the initiation of fruit development. However, the application of gibberellin acid (GA_3) increases fruit set (Albrigo and Galan-Sauco, 2004).

Gibberellins (GA_3) have been used in citrus production including bloom reduction, increased fruit setting, improvement of fruit quality and improved maturation control (Manuel and Vicente, 1992). It has been reported that the application of 10 and 15 ppm GA_3 after flowering results in delayed abscission and increased fruit set, primarily in Clementine tangerines (El-Otmani, 1992). The foliar application of different doses of GA_3 to young fruitlets after fruit set have been reported to apparently increase the thickness of peel, fruit weight and juice content with better flavor of grapefruit (Berhow, 2000).

OBJECTIVES

Therefore, the present experiments were conducted to bring improvement in Washington Navel orange fruit yield and quality by the application of Gibberellic acid (GA_3), KNO_3 and their combinations. The overall objective of the experiment was to improve the quality and yield of navel oranges.

MATERIALS AND METHODS

The research work was conducted at the fruit experimental orchard of the Citrus Research Institute (CRI), Sargodha, Pakistan. Twenty seven plants grafted onto 'Rough lemon' rootstock of uniform size and age (10 years) was selected for this study. Foliar application of GA_3 and KNO_3 were performed at different concentrations (T1: Control, T2: GA_3 at 20%, T3: GA_3 at 25%, T4: KNO_3 at 2%, T5: KNO_3 at 3%, T6: GA_3 at 20% + KNO_3 at 2%, T7: GA_3 20% + KNO_3 at 3%, T8: GA_3 at 25% + KNO_3 at2%, T9: GA_3 25% + KNO_3 at 3%) at full bloom stage, during the month of March (at fruit set stage) and in the month of May (approximate fruitlet diameter 15-20 mm) to check their effect on fruit set and physio-chemical properties of the fruit. T1 was the control, i.e. no treatment applied. The experiment consisted of 9 treatments (including the control) with three replications; a single tree was considered to be an experimental unit. The Fruit set percentage was recorded, samples drawn from each side of the tree in the 2nd week of April. The Fruit set percentage was determined by using the following formula (Moeen-Ud-Din, 2000)

$$\text{Fruit set \%age} = \frac{\text{Total number of fruitlets}}{\text{Total number of flowers}} \times 100$$

Fruit retention was determined by counting the number of fruits retained up to final harvest. Fruit yield was noted at the time of harvest on an individual tree basis and expressed as a total fruit number. Yield from an individual tree was recorded by weighing and counting the total number of fruits per tree at the time of harvest.

$$\text{Fruit retention (\%)} = \frac{\text{Total number of fruit retained}}{\text{Total number of fruitlets}} \times 100$$

Fruit size was measured by randomly measuring the diameter of 20 fruits per tree with the help of a digital caliper. Randomly 20 fruit were taken from all sides of each tree and average fruit weight (g) was recorded. Peel thickness for each fruit was measured in mm with a digital caliper for the selected fruits from each treatment and then average peel thickness was calculated. While peel was also weighed (g) separately and the quantity was expressed on the percentage basis. The juice of 20 harvested fruit was extracted with the help of manually operated juice squeezer and weighed; average juice weight was calculated and juice percentage was obtained as follows (Nawaz *et al.*, 2008).

$$\text{Juice \%age} = \frac{\text{Juice weight}}{\text{Average fruit weight}} \times 100$$

Total soluble solids (TSS) were measured by an automatic digital Refractometer (RX 5000, ATAGO, Tokyo, Japan) by placing 1-2 drops of juice on the prism of the Refractometer. The acidity of the juice was determined by diluted juice and 2-3 drops of phenolphthalein were added for assessing the end point. The samples were titrated against a 0.1N solution of NaOH (Hortwitz, 1960). The results were expressed as percent citric acid (Ahmed *et al.*, 2006)

$$\text{Acidity \%age} = \frac{\text{N/10 NaOH used} \times 0.0064}{\text{Weight of sample}} \times 100$$

The Plant growth regulator solutions for spraying were prepared by dissolving plant growth regulator (GA_3) in 5 mL of 70% ethanol and then the required solution was prepared by adding the distilled water with 0.1% Tween-20 as the surfactant (Athar and Ashraf, 2006).

Recommended doses of fertilizers like nitrogen (N), phosphorus (P) and potash (NPK) (1000, 500 and 500g, respectively) and 50kg of farm yard manure (FYM) per plant were applied to experimental plants (Malik and Bashir, 1994). Nitrogen was applied in two split doses; first in February in combination with P and K (500g each) while the second application was made in the last week of August (500 g N); and 50kg of FYM was applied to each plant in December.

The experiment was executed according to a randomized complete block design (RCBD) and the means of the data collected were separated by one-way analysis of variance (ANOVA). Significant differences between treatment means were compared with the least significant difference (LSD) test at P= 0.05 (Steel *et al.*, 1990).

RESULTS AND DISCUSSION

The data depicted that maximum fruit set percentage (84.57%) was got from treatment T2 (GA_3 at 20%). Treatment T5 (KNO_3 at 3%) and T9 (GA_3 at 25% + KNO_3 at 3%) occupied the second position (82.87%). Poor fruit set percentage was observed in the control treatment (63.49%). The maximum fruit retained percentage was observed after 60 and 90 days in treatment T9 (GA_3 at 25% + KNO_3 at 3%) and after 120, 150, and 180 days was observed in T8 (GA3 at 25% + KNO_3 at 2%) (Fig. 1).

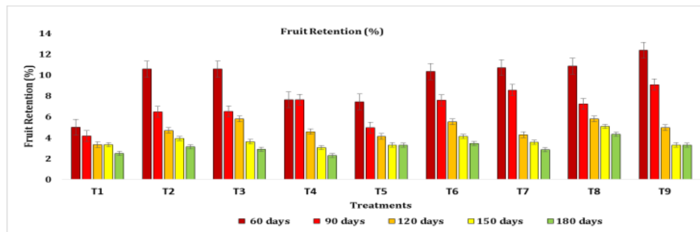

Figure 1: Fruit retention (%) after treatment of GA_3 and KNO_3.

The above results are well supported by some other reports published earlier (El-Saida, 2001; Saleem *et al.*, 2005) which clearly indicated that foliar-applied plant growth regulators or nutrients were effective in enhancing citrus fruit setting and retention. It is evident from various studies that citrus plants sprayed with GA_3 very less percentage of fruit drop ultimately increasing the fruit yield.

The foliar application of plant growth regulator and nutrient (GA_3+KNO_3) or their combinations significantly improved the fruit yield. The trees treated with GA_3 at 25% + KNO_3 at 3% (T9) revealed the highest yield 55.48 Kg/plant and minimum yield 41.31 Kg/plant were recorded in the control treatment. Huang and Huang (2005) reported that spraying GA_3 (50mg/L) on citrus achieved good results by protecting fruitlets and increasing yield in 'Nanfengmiju' mandarin. Similarly, Saleem *et al.* (2008) observed that application of 45 mg/LGA_3 to 15 years-old 'Blood Red' sweet orange plants at the full bloom stage increased yield (71 Kg/tree) more than the control (48 Kg/tree). These results are in agreement with the finding of Hafez and El-Metwally (2007), they found that the number of fruits/tree and yield were increased by foliar application of potassium. El-Saida (2001) and found that the increase in yield/tree could be rendered by spraying Washington navel orange trees with Zn + K. GA_3 application had pronounced effect to reduce the creasing incidence in various treatments as data depicted in the table 1. On an average basis creasing incidence 21%, was noted in the control treatment. Data depicts that creasing defect was

Table 1: Effect of GA_3 and KNO_3 on Morphological characters of Washington Navel.

Treatments	Fruit set %	Yield/plant/ Kg	Crease (%)
T1 (Control)	63.49h	41.31g	21.27h
T2 (GA_3 at 20%)	84.57a	42.00f	6.26e
T3 (GA_3 at 25%)	77.52d	45.45e	4.75d
T4 (KNO_3 at 2%)	70.81g	52.19c	12.25g
T5 (KNO_3 at 3 %)	82.87b	45.03e	11.55fg
T6 (GA_3 at 20% + KNO_3 at 2 %	77.12e	47.10d	2.23c
T7 (GA_3 at 20% + KNO_3 at 3%	82.35c	52.74c	1.87b
T8 (GA_3 at 25% + KNO_3 at 2 %	73.01f	53.68b	0.85a
T9 (GA_3 at 25% + KNO_3 at 3%)	82.87b	55.48a	0.93a

Means in a column followed by similar letters are not significantly different at P = 0.05 (LSD).

significantly controlled with the treatments having GA_3 spray, especially in T8 and T9 where GA_3 at 25% was sprayed in combination with KNO_3. Fruit size was also significantly affected by different treatments compared with control. Maximum fruit diameter (87.82 mm) was recorded from T8 which was followed by the T4 and T9 respectively. Whereas fruit of smallest size (78.08 mm) was attained in treatment T5 (KNO_3 at 3%) which did not significantly differ from T6 and T1 i.e. control treatment (Table 2).

Table 2: Effect of GA_3 and KNO_3 on physiochemical characters of Washington Navel.

Treatments	Fruit Size (mm)	Fruit Weight (g)	Juice (%)	Peel thickness (mm)	TSS (%)	Acidity
T1 (Control)	78.62e	297.5g	43.68c	5.13f	9.8d	0.34ab
T2 (GA_3 at 20%)	83.92d	302.0ef	44.80b	4.13a	9.8d	0.45e
T3 (GA_3 at 25%)	83.35d	303.4e	44.56b	5.46g	10.5c	0.36ab
T4 (KNO_3 at 2%)	86.87b	310.4bc	44.88b	6.31h	10.7c	0.38c
T5 (KNO_3 at 3 %)	78.08e	296.8g	43.70c	4.34d	10.4cd	0.33a
T6 (GA_3 at 20% + KNO_3 at 2 %	79.62e	301.3f	43.31cd	4.5e	11.0b	0.37b
T7 (GA_3 at 20% + KNO_3 at 3%	84.05c	307.6d	45.21ab	4.3c	9.9d	0.42d
T8 (GA_3 at 25% + KNO_3 at 2 %	87.82a	315.8a	45.34a	4.21b	10.8c	0.36b
T9 (GA_3 at 25% + KNO_3 at 3%)	86.15b	312.3b	44.52bc	4.23b	11.3a	0.31a

Means in a column followed by similar letters are not significantly different at P = 0.05 (LSD).

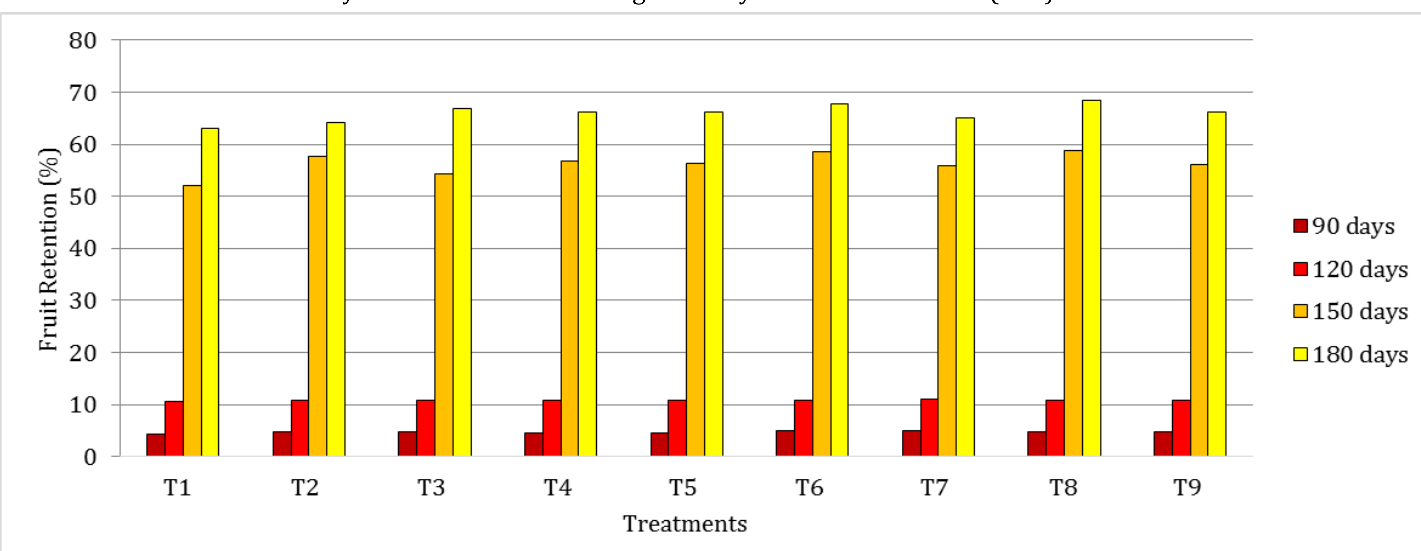

Figure 2: Fruit diameter (mm) after treatment of GA_3 on citrus crop.

Our results are contrary to (El-Rahman *et al.*, 2012) who reported that high concentration of potassium nitrate application increased the size of fruit which is might be owing to increasing of fruit peel thickness. The present results are in agreement with (kada *et al.*, 1994) on Satsuma mandarin describes that with the increase of K fertilization the fruit size increased, also (El-Rahman *et al.*, 2012) found that spray of 45 ppm promalin and 50 ppm GA_3 enhanced fruit size of navel orange fruits.

All the experimental treatments significantly differ in fruit weight compared with control except T5. Maximum fruit weight (351.8 g) was achieved from T8 followed by the T9 and T4 respectively. Minimum fruit weight was observed in treatment (T5; KNO3 at 3%) and control (Table 2). Total fruit weight difference of 19 g was observed among all trees treated by growth regulators, which might be due to increase in the total number of fruit (yield) per tree with application of PGR and KNO_3. Similarly, fruit weight is very important with respect to fruit quality as it adds towards fruit and juice yield. Fruit weight follows yield trends, i.e., generally larger fruits lower total number of fruits per plant and vice versa (Alva *et al.*, 2006). Aly *et al.* (2015) reported that application of potassium on Washington Navel Orange gave the best results as for average weight of fruit (270 g). Similarly, Zhang and Whiting (2011) noted that 200 mg/L GA_3 applied at 9 days interval after full bloom improved final fruit weight by 15%. Fruit from this treatment had fruit weight more than 9 g to the weight of untreated limbs.

Maximum fruit juice (45.34 %) was found in fruit harvested from T8; GA3 at25%, KNO_3 at 2% treated trees, statistically followed by T7; (45.21%). Minimum fruit juice (43.31%) was achieved from fruit harvested from trees treated with T6 and similarly through control treatment, which was statistically similar to T5; KNO_3 at 3% (43.70%). Davies *et al.* (1998) also concluded that the application of GA_3 (18 g) had the potential to improve processing juice extraction weight by 3.2 to 9.4% depending on the cultivar and harvesting time.

Application of plant growth regulator had a significant effect on fruit peel thickness as compared to control. The maximum peel thickness (6.31 mm) was observed with the application of (T4; KNO_3 at 2%), while minimum peel thickness (4.13 mm) was recorded in fruit treated with T2: GA_3 at 20%. Many of the treatments e.g., T8; GA_3 at 25% + KNO_3 at 2%(4.21 mm), T9; GA3 at 25% + KNO_3 at 3% (4.23 mm) and T7; GA_3 at 20% + KNO_3 at 3% (4.30 mm) significantly reduced thickness of peel compared with control. Ahmed *et al.* (2007) reported that pre harvest application of PGRs [2, 4-D (10, 20, 30 mg/L), GA_3 (10, 50,100 mg/L) and NAA (10, 15, 20 mg/L) at the pre harvest fruit drop stage had no significant effect on peel thickness in Kinnow mandarin. Similarly the results regarding fruit peel percentage displayed significant variances among the treatments as compared to control. Maximum peel percentage was recorded in fruit harvested from control and T4 treated trees. The minimum peel percentage was found in fruit treated with T2, T8 and T9 respectively.

Maximum TSS (11.3%) was recorded in T9; GA_3 at 25% + KNO_3 at 3% treatment, while minimum TSS (9.8%) was recorded in T2; GA_3 at 20%, which was statistically similar with control treatment. Berhow (2000) found that early foliar spray treatments of 100 mg/L GA_3 on grape fruit (*Citrus paradisi*) significantly lowered the concentration of the bitter *Flavonoid naringin* in grapefruit fruit tissues. Ashraf et al., (2010) reported that foliar supply of K enhanced the TSS of Kinnow juice. The present results are in a general harmony with Shaaban *et al.* (2006), who found that juice TSS content increased significantly with increasing applied potassium on Washington navel orange trees.

Fruits sprayed with GA_3 showed a significant decrease in acidity. The highest acidity (0.45%) was recorded for T2; GA_3 at 20% whereas, minimum acidity (0.31%) was found in T9; GA_3 at 25% + KNO_3 at 3%, statistically similar to T5; KNO_3 at 3% (0.33%). The application of PGRs reduced the acidity of fruit which is a desirable character for superior fruit quality (Nawaz *et al.*, 2008). Our results are in line with Aly *et al.* (2015) described that 2 and 3% K_2SO_4 treatments decreased fruit juice acidity compared with control treatment.

CONCLUSION

Generally it could be concluded that foliar application of GA_3 and KNO_3 enhanced the quality status of Washington navel fruit and corrected its physiological disorder; creasing thus minimizing the post-harvest fruit losses. Few added benefits were also noted like better on tree fruit storage, less pre-harvest fruit drop, better plant growth and better quality grade of fruit achieved. Therefore, combined spray of mentioned growth regulator is recommended in Washington navel oranges in Sargodha Punjab condition to achieve better yields and quality of fruit crop.

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