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Effect of plant growth regulators in kinnow mandarin: A review

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Abstract
The plant hormones are extremely important agent in the integration of developmental activities. The use of growth regulators has become an important component of agro-technical procedures for most of the cultivated plants and especially for fruit plants. The production of poor quality fruits is a matter of common experience. So far in fruit crops, excessive fruit drop can be controlled by exogenous application of Plant growth regulators (2,4-D, GA3, NAA) decrease pre-harvest fruit drop percentage leading to increase in fruits size, number of fruits per plant, juice percentage, total soluble solids, acidity, vitamin-C. The auxin and gibberellins are widely used to control the fruit set to fruit ripening and final reach to customer, several agents are responsible for elimination of some fruits from fruit set to final maturity. In this review, we focus on the role of PGRs in Kinnow mandarin.

Keywords: plant growth regulators, kinnow, fruit drop, growth

Introduction

The use of growth regulators has become an important component of agro-technical procedures for most of the cultivated plants and especially for fruit plants. So far in fruit crops, excessive fruit drop can be controlled by the exogenous application of plant growth regulators. The auxin and gibberellins are widely used to control the fruit drop and to improve the quality of fruit. 1-naphthalene acetic acid (NAA) has been shown to greatly increase cellulose fiber formation in plants. In majority of fruit plants fruit drop is controlled by spraying of NAA in different fruit crops in different concentration. Gibberellins control fruit development in various ways and at different developmental stages. Ingle *et al*., (2001) [14] revealed that foliar application of GA3 @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control and similarly foliar application of 2, 4-D @ 10 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in Nagpur mandarin.

Citrus occupies a place of importance in the fruit wealth and economy of the country. Mandarin orange, a loose skinned orange (*Citrus reticulta*), is very common and widely grown citrus fruit across all region of the country. Kinnow is a hybrid of 'King' (*Citrus nobilis*) x 'Willow leaf' (*Citrus* x *deliciosa*). Kinnow is commercially cultivated for its high yield, high processing quality, fresh consumption, aromatic flavor and Citrus fruits are also very good source of vitamin-C with fair amount of A and B and mineral such as calcium, phosphorus and iron (Nawaz *et al.*, 2008) [19]. Fruits are medium sized with globose shape and golden yellow in colour. Peel is normally tight but it becomes loose if harvested up to February under North Indian condition. India is the third largest producer of Kinnow mandarin with 9,509.00 MT and it contain 12.08% share of total world production (FAO). In India, it is grown in parts of Punjab, Rajasthan, Himachal Pradesh, Haryana, Uttarakhand and Jammu & Kashmir. It contributes to nearly 31% of the citrus production in the country. The prevailing climatic condition during winter helps in enhancing sweetness index along with distinct taste. Along with their consumption as fresh fruit, a large number of products and by products are prepared and marketed with premium price (Niaz *et al.*, 2004) [20]. India earns good amount of foreign money exchange by exporting kinnow to other countries of the world like Iran, Singapore, Nepal, Srilanka, etc. In Punjab Kinnow occupies 90% of area out of 46290 ha with estimated production of 9.15 lac ton. The average yield of kinnow is 21 mt./ha. And have potential for double yield.

It has become popular among growers of North India due to its high consumer appeal, good tree vigour, high cropping potential, wider adaptability, more economic return, and better performance than other citrus fruits. Kinnow is a heavy bearer, and bears over 300 fruits at the age of 3 or 4 years. Magnitude of flowering and fruiting largely depends on cultivar, the age of the tree, and environmental factors (Monselise and Goren, 1978) [17]. In citrus, only 0.5 to 2 % of flowers undergo development to maturity while remaining in a natural drop down state (Erickson, 1986) [10]. In Kinnow, it is primarily associated with the first and second stage of fruit growth from June to July, with a peak in June in the so-called "June drop". A tree drops its fruit when the concentration of auxins decreases and the concentration of abscisic acid (ABA) increases. The use of growth regulators has become an important component of agro-technical procedures for most of the cultivated plants and especially for fruit plants. So far in fruit crops, excessive fruit drop can be controlled by the exogenous application of plant growth regulators. The auxin and gibberellins are widely used to control the fruit drop and to improve the quality of fruit. 1-naphthalene acetic acid (NAA) has been shown to greatly increase cellulose fiber formation in plants. In majority of fruit plants fruit drop is controlled by spraying of NAA in different fruit crops in different concentration. Gibberellins control fruit development in various ways and at different developmental stages. Ingle *et al*., (2001) [14] revealed that foliar application

of GA3 @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control and similarly foliar application of 2, 4-D @ 10 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in Nagpur mandarin. The foliar application of plant growth regulators has been reported to improve fruit set, increase fruit size, and reduce fruit drop and significantly improves economic yield for growers when applied in the correct dose (Jain *et al.,* 2009). The application of 2, 4-D and GA3 in desirable concentration inhibits abscission, softening of rind, and chlorophyll degradation to reduce pre-harvest fruit drop (Otmani, 1992) [9].

Effect of PGRs on fruit crops

Plant growth regulators or phytohormones are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amount. PGRs include auxin, gibberellins, cytokinins, ethylene, growth retardants and growth inhibitors. The use of plant growth regulators has assumed an integral part of modern crop husbandry for increasing production of quality fruits. Plant growth regulators are organic substances (other than nutrients), which in small amount promote, inhibit or otherwise modify any physiological process in plants. Thus the use of plant growth regulators has resulted in some outstanding achievements in several fruit crops with respect to growth, yield and quality. NAA is a synthetic plant hormone. The effect of NAA on plant growth depends on the time of application and concentration. Nawaz *et al.,* (2008) [19] studied the effect of foliar sprays of NAA @ 10, 15 and 20 ppm in Kinnow mandarin and maximum Vitamin C contents (45.30 mg/100g) was found in 15 ppm NAA and at 10 ppm NAA having 686.66 fruits per plant. Different developmental stages. Fruit development is a complex and tightly regulated process. Growing fruits are very active metabolically and act as strong sinks for nutrients with hormones possibly modulating the process (Brenner and Cheikh, 1995) [4]. Ingle *et al.,* (2001) [14] revealed that foliar application of GA3 @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in 'Nagpur' mandarin. Ashraf *et al.,* (2013) [2] conducted an experiment to see the influence of 2, 4-D in Kinnow and observed improved fruit weight, more number of fruits per plant, juice percentage, total soluble solids (TSS), ascorbic acid content, acidity, TSS/acid ratio, and reduced the fruit drop.

Effect of Auxin and Gibberellins on Kinnow mandarin

Physical characteristics

Pre-harvest fruit drop (%)

Pre-harvest drop of the fruit is of commercial loss to farmer as the drop occurs just before harvesting when fruit is physiologically mature. An imbalance of auxins, cytokinins and gibberellins may lead to the formation of abscission layer at the stem point and eventually fruit drop (Chen *et al.,* 2006). Nawaz *et al.,* (2008) [19] found that lowest fruit drop of 12.95% was observed in 20 ppm 2, 4 - D followed by 10 ppm 2, 4 - D with 15.02% whereas, maximum fruit drop (49.03%) was found in control. Study of Pooja *et al.,* (2019) shows that pre-harvest fruit drop (%) was found minimum in treatment 2, 4 - D 20 ppm (12.69%) and maximum in control. Devi *et al.,* (2015) [8] found that least fruit drop (16.21%) was recorded in 20 ppm 2, 4-D. While 2, 4 - D applied at lower concentration reduced the drop but at higher concentration it increased the fruit drop. Application of 2, 4 - D and GA_3 significantly reduced the pre-harvest fruit drop in citrus species (Davies and Zalman (2006) [4, 6], Nawaz *et al.,* (2008) [19]. Fruit diameter (mm)

Fruit diameter is of commercial importance for citrus fruit marketing and trade/buisness. Nawaz *et al.,* (2008) [19] found that maximum fruit size 71.20 mm was found in case of 10 ppm GA_3 and minimum fruit size of 66.52 mm was observed in case of 15 ppm NAA. Nawaz *et al.,* (2011) [18], studied that exogenous application of PGRs significantly increased the fruit size of treated plants compared to the control However, 2, 4-D and GA_3 increased fruit size more. The fruit with greatest diameter (73.63 mm) was found in 10mg/l GA_3 followed by 20 mg/l 2, 4-D; 72.57 mm.

Fruit weight (g)

Nawaz *et al.,* (2008) [19] found that highest fruit weight of 155.53g was found in 100 ppm GA3 and lowest fruit weight of 141.95g was observed in case of control treatment. Pooja *et al.,* (2019) studied foliar application of different concentrations of 2, 4-D, GA_3, K_2SO_4 and $ZnSO_4$ significantly influenced the fruit weight in Kinnow mandarin. The maximum fruit weight registered under the treatment K_2SO_4 2% (172.40 g). Devi *et al.,* (2015) [8] studied maximum fruit weight was registered in 75 ppm GA_3. It seems that the role of GA_3 was to multiply and to lengthen the meristem cells, which resulted in the increase of fruit weight.

Number of fruit per plant

In the study of Nawaz *et al.,* (2008) [19] maximum numbers of 708 fruits per plant were recorded in 20 ppm 2,4-D. Similarly, Pooja *et al.,* (2019) studied that treatment of 2, 4 - D at 20 ppm retained the highest (611.63) number of fruits per plant. Nawaz *et al.,* (2011) [19], found significant difference among various treatments. All PGR treatment increased the total number of fruits/plant. The highest number of fruits/plant (682.33) was observed in 5mg/l GA_3. All three PGRs (NAA, GA_3 and 2, 4-D) at lower concentrations, increased yield but at higher concentrations fewer fruits/plant were observed in most treatments. Since 2,4-D and NAA (auxin) have a dual function, i.e., when they are used at lower concentrations they act as growth promoters while at higher concentrations they act as growth inhibitors, they sometimes adversely affect the vegetative and reproductive behaviour of citrus (Saleem *et al.,* 2008) [22].

Fruit weight per plant (kg)

In the study of Nawaz *et al.,* (2008) [19] results showed significant difference among the various treatments. Maximum fruit weight per plant 103.55 kg was found in 20 ppm 2, 4-D closely followed by 10 ppm NAA with fruit weight of 102.80kg per plant. Nawaz *et al.,* (2011) [19] found maximum fruit weight/plant (96.14 kg) was observed in 5 mg/l GA_3. Huang and Huang (2005) [13] reported that spraying GA_3 (50 mg/l) on citrus achieved good results by protecting fruitlets and increasing yield in 'Nanfengmiju' mandarin.

Similarly, Saleem *et al.,* (2008) [22] observed that application of 45 mg/l GA_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).

Juice percentage

Juice is important parameter for its industrial processing. Nawaz *et al.,* (2008) [19] found that highest juice percentage 52.16% was observed in 50 ppm GA_3. Devi *et al.,* (2015) [8] studied that maximum juice percentage of 53.80 % was recorded with the application of 75 ppm GA_3. Increased juice content with the application of GA3 in different citrus cultivars has also been reported (Fidelibus *et al.,* (2002); Saleem *et al.,* (2008) [22], Nawaz *et al.,* (2008) [19]. Nawaz *et al.,* (2011) [18] studied the application of PGRs significantly increased the juice percentage, maximum (53.29%) in 10 mg/l GA_3 followed by 20 mg/l GA_3 with 51.18%. The juice percentage could be increased by as much as 10% simply by the application of PGRs. An increase in juice percentage was observed following the application of PGRs, which affect many physiological and biochemical processes within plants. Davis *et al.,* (1997) [7] also concluded that the application of GA_3 (18 g a.i. (active ingredient)/acre) had the potential to improve processing juice extraction weight by 3.2 to 9.4% depending on the cultivar and harvesting time.

Chemical characteristics

Total soluble solids (TSS) (%)

TSS measurement is considered to be an important parameter of quality of citrus fruits. Nawaz *et al.,* (2008) [19] found that maximum TSS 12.03% was observed in case of 30 ppm 2, 4-D. Result in relation to TSS percentage were found to be in consonance with that of Atawia & El-Desouky (1997) and Huang and Huang (2005) [13] who reported that by application of PGRs like Auxin and Gibberellins we can significantly increase the total soluble contents of the fruit in citrus species. Devi *et al.,* (2015) observed (15 ppm NAA) exhibited highest total soluble solids 12.70 ^oB. By application of growth regulators like auxin and gibberellins, TSS content of citrus species can be significantly increased (Huang and Huang (2005) [13] and Nawaz *et al.,* (2008) [19].

Acidity percentage

In the study of Nawaz *et al.,* (2008) [19] maximum acidity 1.33% was found observed in case of 15 ppm NAA treatment and minimum acidity 1.04% was found in case of 10 ppm 2,4-D. They found that as the concentration of 2.4-D increases the acidity is also increasing and GA3 application also proved helpful to reduce acidity as compared to NAA. Nawaz *et al.,* (2011) [18], found Fruits sprayed with PGRs showed a significant decrease in acidity. Highest acidity (1.10%) was recorded for control followed by (10 mg/l 2, 4-D) i.e., 1.01% whereas, minimum acidity (0.78%) was recorded in (20 mg/l NAA).Vitamin-C (mg/100g) Vitamin-C is a powerful antioxidant and is an important part of human feed. It helps to save human from many serious diseases and scavenges the reactive oxygen species produced in the body. Nawaz *et al.,* (2008) [19] maximum vitamin-C contents 25.67 mg/100g were observed in case of 10 ppm NAA. Devi *et al.,* (2015) [8] observed maximum ascorbic acid was recorded in (15 ppm NAA) i.e. 25.90 mg/100 ml. Significant increase in fruit acidity and ascorbic acid, by pre-harvest application of auxins, has been observed earlier (Ratnababu *et al.,* (1984) [21] Xiao *et al.,* (2005) [24], Nawaz *et al.,* (2008) [19] and Ahmed *et al.,* (2012) [1]. Nawaz *et al.,* (2011) [18] found maximum 45.11 mg/100 ml in 10 mg/l NAA. The application of auxins (2, 4-D and NAA) was better than the use of GA_3 in improving the vitamin C content of 'Kinnow' mandarin.

Sugar content

Sugars are an important parameter of quality measurement in citrus fruits as they are main and ready source of energy when used by human. Nawaz *et al.,* (2008) [19]studied maximum total sugars (8.86) were found in 30 ppm 2, 4-D. Devi *et al.,* (2015) [8] observed highest sugar content was recorded in T9 (15 ppm NAA) i.e. 8.65 %.Application of 2, 4-D, GA_3 and some other growth regulators increased the sugar contents in various mandarin and sweet orange cultivars (Wang *et al.,* (2004) [23]; Nawaz *et al.,* (2008) [19] and Ahmed *et al.,* (2012) [1].

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