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Effect of 2, 4-D with combination of fungicides to reduce the pre-harvest fruit drop and quality Improvements in Mandarins *cv.* Kinnow (*Citrus nobilis* x *Citrus deliciosa* L.)

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Abstract
Kinnow is considered as an important citrus fruit crop. Kinnow is the prime fruit of Punjab. Most of the growers like this fruit to frown in their orchards due to its high consumer demand, wider adaptability and good economics return, but fruit drop become a major disease of Kinnow. It causes excessive loss to its yield and economy of Kinnow growers. Fruit drop may be occurring naturally, but sometimes its due to various infections like pathological, Entomological and physiological infection. These infections cause low fruit retention and reduction in fruit quality and yield of Kinnow. Preharvest fruit drop mainly occur during July and continue till harvest (Dec-Jan.). At this stage fruit drawn the nourishment from the tree and reach at maturity and the most detrimental fruit drop occur in September and October. The main attributes which cause preharvest fruit drop are *Colletotrichum gloeosporioides*. The fungi built up on twigs and fruit stalk and cause die back and heavy fruit drops in Kinnow. So, in this case some application of fungicides minimizes the pathogenic infection, hormonal balance and efficient utilization of nutrients. Fungicide like curzate shows excellent result to control fruit drop. likewise, 2,4-D reduce the pathogenic attack, increase fruit retention and also improve fruit size, fruit weight, TSS, Juice percentage, Acidity and Vitamin C. Therefore, the main objective of this review is effects of different fungicides with the combination of 2,4-D on preharvest fruit drop and quality improvement in Kinnow.

Keywords: Fruit drop, Kinnow, Growth- regulators, fungicides, 2,4-D

Introduction
Citrus belongs to the Rutaceae family and subfamily Aurantoideae, with chromosome number 2n=18. The majority of citrus fruit cultivars are native to Southeast Asia's tropical and subtropical climates (Bhatt *et al.*, 2017) [1]. 'Kinnow' is the first hybrid between *Citrus nobilis* Lour and *Citrus deliciosa* Tenora, with the King (female) and Willow leaf (male) as parents. H.B. Frost invented it in 1925 at the University of California (Rajput and Haribabu, 1985) [2]. Kinnow (*Citrus nobilis Citrus deliciosa* L.) is a popular citrus fruit that is prized not only because of its attractive appearance and flavor, but also for its high nutritional content, high yield, fresh consumption, excellent processing quality, and superior agro-environmental adaption (Ahmed *et al.*, 2006) [3]. 'Navel' and 'Valencia' oranges, 'Page' and 'Kinnow' mandarin, and 'Orlando' tangelo are the most common citrus cultivars grown in Iran. The 'Kinnow' mandarin is a mix of 'King' which has been widely disseminated in numerous nations. The fruits of the 'Kinnow' variety are medium in size, seedy, extremely juicy, flavorful, fragrant, and unique. This variety is likewise quite productive, with a strong proclivity for alternating blooming (Ahmadpoor *et al.*, 2022) [6]. Citrus is a prominent fruit in agricultural commodity, with widespread availability and acceptance that contributes to human nutrition (Liu *et al.*, 2012) [5].

Brazil is the world's leading producer of oranges, followed by China and the United States, while China is the world's leading producer of Mandarin fruit. With the highest production of limes and lemons, India is the world's third-largest citrus-producing country, followed by China and Brazil (Anonymous 2018a) [7]. After mango and banana, it is the third-largest crop in India in terms of both acreage and production. It is grown over a 1.34 million ha area, with total output and average productivity of 13.20 million metric tone's and 9.68 tons per hectare, respectively (Anonymous 2018b) [8]. Kinnow has the biggest farmland (57280 hectares) of any mandarin variety in Punjab, producing 1.28 MT per year (Anonymous 2020) [9]. Kinnow is widely grown in North India, and it is also the most popular fruit in Punjab.

The majority of growers prefer to grow this fruit because of its high market demands, versatility, and financial impact. The states of Punjab, Rajasthan, Haryana, Himachal Pradesh, Jammu & Kashmir, and Uttar Pradesh are among the fastest-growing. India is among the biggest exporters of Kinnow mandarin (Chundawat *et al.*,1975) [30].

Fruit drop, nutritional deficits, and insect pests and diseases are among issues that are affecting Kinnow production. Fruit drop is one of these issues, and it has become a limiting factor in growing fruit production. Kinnow trees often produce a large number of flowers, however a significant percentage of blossoms and fruits drop off during the fruit growth and development phase (Bharti, 2017) [10]. *Colletotrichum gloeosporioides* is the most common pathogen responsible for fruit drop in Kinnow (Kumar and Garg, 2012) [11]. The initial fruit drop is caused by an abscission layer generated at the stem end due to differential concentrations of gibberellins, auxins, and cytokinins. The physiologic method of extracting plant organs from the total plant body is called abscission layer development (Balal *et al.*, 2011) [12]. Gardeners have no choice but to apply integrated nutrition management strategies, as well as the application of fruit setting plant growth regulators and fungicides, across 3 stages of fruit drop, to decrease fruit drop and promote fruit retention on trees (Singh *et al.*, 2017). As a result, effective administration of growth regulators at different vegetative phases, which can promote fruit set and reduce fruit drop, and further helps in enhancing fruit quality, is the crucial factor responsible for increasing Kinnow mandarin production. As a result, techniques have been applied on improving fruit set, quality, and growth of less seeded cultivars using a variety of traditional and non-traditional for a long time (Raza *et al.*, 2003) [13].

Effect on Physical Characteristic

Fruit Set

Fruit set is one of the most key moments in fruit crops since it impacts the amount of fruit produced and the total yield. Several other normal events, including as the formation of male and female parts, pollination, germination of pollen grains on stigmatic surfaces, pollen tube growth, and finally complete fertilization, all influence fruit set. Fruit set increased dramatically with the spraying of Growth regulators in Kinnow mandarin, according to the study (Nawaz *et al.*, 2011) [14]. Fruit set is a critical stage in the conversion of a flower into a fruit in order to get a high yield and maximize a grower's profits (Lovatt, 1999) [15]. The application of GA3 10 ppm resulted in the most initial fruit set, followed by NAA 10 ppm and 2, 4-D at 15 ppm, respectively. GA is the major factor in regulating fruit set regardless of Citrus species (Mesejo *et al.*, 2013) [16]. In Kinnow, the spray of 0.5 percent ZnSO4 +10 ppm 2,4-D resulted in the greatest number of fruits (Gurjar and Rana, 2014) [17]. GA3 applications had a major effect separately and in combination with 2, 4-Dichlorophenoxyacetic acid (2, 4-D), with optimum fruit set in 'Blood Red' sweet orange trees compared to the control (Saleem *et al.*, 2008) [18].

Fruit Retention

Fruit retention refers to the fruits who remain on the plant until harvesting, indicating the plant's production. Auxin and gibberellin are commonly utilized to improve fruit retention and quality by reacting in a timely order on fruit set (Suman *et al.*, 2017) [19]. In Kinnow mandarin, 2, 4-D 10 ppm and Aureofungin 50 ppm had the best fruit retention (Tiwana and Bajwa, 2007) [20]. In Kinnow mandarin, propiconazole 0.1 percent, Ziram 0.25 percent, and Carbendazim 0.1 percent in combined with 2, 4-D 10 ppm resulted in a better fruit retention (Thind and Kumar, 2008) [21]. Applying boric acid or 2, 4-D alone at the pea-stage of the Washington orange enhanced final fruit retention (El-Kobbia *et al.*, 2011) [22]. found that 2, 4-D can be a useful technique for controlling fruit loss and boosting the quality of Navel oranges in dry climates by increasing retention. The plant growth regulator 2, 4-D (20 mg/L) greatly reduced fruit loss by more than 50%, whereas greater concentrations of the plant growth regulator enhanced fruit drop. These results suggest that 2, 4-D could be a useful strategy for controlling fruit drop and increasing the quality of Navel oranges in dry climates by increasing retention (Modise *et al.*, 2009) [29].

Fruit Size

Fruit size is not just a factor in productive production, but it also influences customer demand for fruit on the market (Guardiola and García-Luis 2000) [23]. In comparison to control, foliar treatment of all nutrients (N, P, K) and plant growth regulators (GA3, NAA, and 2,4-D) resulted in a considerable increase in fruit length and width (Kaur *et al.*, 2016). GA3 10 mg/L provided the fruit with the largest diameter. Treatments of 10 mg/L GA3 and 20 mg/L 2,4-D improved fruit size better in all three PGRs, and both treatments were determined to be the best in Kinnow mandarin (Nawaz *et al.*, 2008) [25]. Kinnow mandarin, the maximum fruit weight was recorded with foliar sprays of 2, 4-D 20 ppm and the lowest with Zineb 75 WP + 2, 4-D (Dhaliwal *et al.*, 2009) [26]. Kinnow mandarin, foliar applications of 2, 4-D 20 ppm gave in the maximum fruit weight (Rattanpal *et al.*, 2009) [26]. Looked at the impact of NAA, 2,4-D, and GA across three seasons and discovered that NAA 15 ppm would have been most efficient in boosting fruit size and shape, followed by 2,4-D at 10 ppm (Ghosh *et al.*, 2012) [28].

Fruit Drop

Fruit drop is a major issue in citrus orchards, and it can be caused by a variety of factors including changes in temperature, a lack of water during flowering or fruiting season, and nutrient deficiency. Each of these aspects cause plant hormonal disparities (Modise *et al.*, 2009) [29]. Spraying plant growth regulators was found to be effective in reducing premature fruit drop (Chen *et al.*, 2006). Applied during the first week of September, 10 ppm 2,4-D and 20 ppm aureofungin reduced physiological and pathological pre-harvest fruit drop in Kinnow (Chundawat *et al.*, 1975) [30]. At blooming, fruit development, and color progression stages of fruit, foliar sprays of 2,4-D (10 ppm), SA (10 ppm), K (0.25 percent), and Zn (0.25 percent) significantly enhanced the amount of fruit per plant and significantly reduced fruit drop in Kinnow mandarin (Ashraf *et al.*, 2013) [31]. Fruit drop was reduced in Khasi mandarins when urea @ 1% + 2,4-D @15 ppm was applied, and it resulted in the maximum number of fruits remaining on trees when comparing to the others treatments (Singh *et al.*, 2017). Along with spray of 2, 4-D (10 ppm) + Carbendazim (0.1 percent) in Nagpur Mandarin, the cheapest pre-harvest fruit drop, recorded significantly higher retention percentage, largest fruit yield, and weight of

fruits were discovered (Patil *et al.*, 2010) [34]. From September to December, researchers tried various amounts of 2,4-D and NAA alone or in mixture 4 times during one-month intervals and discovered that a mixture of 20 ppm+ 30 ppm NAA, 10 ppm 2,4-D + 15 ppm NAA, and 10 ppm 2,4-D, among some other treatments, had the best results in preventing fruit drop in Kinnow mandarin (Jahromi *et al.*, 2013) [35].

Fruit Yield

When 20 ppm 2,4-D was given during the first week of September, October, and November, the showed maximum output of Kinnow mandarin was seen, as comparing to a control from which no plant growth regulators were provided (Mir and Itoo, 2017) [33]. In Kinnow mandarin, a foliar application of 0.5 percent FeSO4, MnSO4, ZnSO4 + 1 percent urea increases fruit production (Vijaya *et al.*, 2017) [36]. With foliar applications of 20 ppm 2,4-D, the maximum production of Kinnow fruits was observed (Pooja *et al.*, 2019) [37]. The maximum production was achieved with foliar sprays of urea (1%) + ZnSO4 (0.4%) + 2, 4-D (20 ppm) in Kinnow mandarin, whereas the minimum production was recorded under the controlled conditions when no fungicide or plant growth regulator was sprayed (Prasad *et al.*, 2015) [38]. In Nagpur mandarin, the use of 0.1 percent carbendazim (fungicide) in combined application with 10 ppm 2, 4-D (plant growth regulator) resulted in the highest fruit yield when compared to other studies (Patil *et al.*, 2010) [34].

Effect on Chemical Characteristic

Juice Content (%)

Juice is a crucial characteristic in the processing industry. Cultural practices such as the use of PGRs have an impact on its content. Using PGRs, the amount of juice might be raised by as much as 10%. Due to the application of PGRs, which alter several physiological and biochemical processes within plants, an improvement in juice Content was found (Nawaz *et al.*, 2011) [14]. Fruits harvested from trees treated with Urea + ZnSO4 + 2,4-D treatment had the highest juice content (Prasad *et al.* 2013) [45]. In Darjeeling mandarin for said mountainous terrain of Darjeeling, the treatment that got GA3 15 ppm Plus zinc (0.5%) and boron (0.1%) foliar application had the maximum juice percentages (Gurung *et al.*, 2016) [47]. When used on citrus, the majority of cases show that 2, 4-D has a better impact on boosting juice quality (Greenberg *et al.*, 1995) [58]. found that when 100 ppm 2,4-D was sprayed, the highest juice per was measured (Jain *et al.*, 2016) [40] found that combining 2,4-D at 20 ppm with CuSO4 at 0.25 or 0.50% increased Kinnow mandarin juice cents (Singh and Mishra, 1986).

Total Soluble Solid

The impact of various dosages of GA3 and auxin (2,4-D, NAA) on a pre-harvest drop in citrus, yield, and fruit quality was investigated, and it was discovered that spraying 2,4-D 20 ppm considerably improved TSS in Kinnow mandarin (Nawaz *et al.*, 2008) [25]. The treatment of urea 1 percent + ZnSO4 0.4 percent + 2,4-D 20 ppm resulted in maximum TSS in Kinnow fruits (Ashraf *et al.*, 2013) [31]. The joined foliar application of 2,4-D (10ppm) + Propiconazole (1%) + Zinc sulphate (1%) showed maximum TSS level in Kinnow Mandarin (Singh *et al.*, 2019). In Kinnow mandarin, the optimum TSS was detected in fruits collected from trees sprayed with NAA 10 mg/L (Hussain *et al.*, 2011) [14]. While the highest TSS was reported in fruits harvested from trees treated with Urea + ZnSO4 + 2, 4-D (Prasad *et al.*, 2013) [45]. In the treatment of 15 ppm NAA application, a substantial increase in TSS levels was observed. In Kinnow mandarin, the maximum sugar level was recorded to be 15 ppm in NAA (Devi *et al.*, 2015) [46]. TSS was found to be considerably bigger in the pulp of fruits collected from trees doused with GA3 (20g/ml) in Kinnow mandarin (Kaur *et al.*, 2016). In the treatment of GA3 15 ppm + zinc (0.5%) + boron (0.1%) in Darjeeling mandarin, the greatest TSS was reported (Gurung *et al.*, 2016) [47].

Acidity

The use of PGRs reduced titrable acidity, which really is a desirable characteristic of high-quality fruits. discovered that foliar spraying of 2,4-D significantly enhanced the titratable acidity (Ashraf *et al.*, 2013) [31]. In Kinnow mandarin, the highest acidity was reported in fruits collected from plants treated with KNO3 2 percent + 2, 4-D 10 ppm (Gurjar and Rana 2014) [17]. The decrease in acidity with foliar applications of treatments was non-significant, although the juices of the fruits taken from trees given foliar sprays of KNO3 (2.5 percent) + 2, 4-D (20g/ml) had the lowest acidity (Kaur *et al.*, 2016). The treatment of 2,4-D (10ppm) + Propiconazole 1% + KNO3 1% resulted in the lowest acidity in Kinnow mandarin, which was comparable to the application of 2,4-D (10ppm) + Propiconazole 1% +ZnSO4 1%, and the maximum acidity was detected under control. The control treatment had increased fruit titratable acidity, which was statistically similar to the 2,4-D (1.07 percent) and ZnSO4 (1.06) treatments (Singh *et al.*, 2019).

Ascorbic Acid

Ascorbic acid is a powerful antioxidant that is found in large amounts in human food. It protects humans against a variety of diseases by acting as a scrubber for damaging reactive oxygen species (ROS) created in the body, hence preventing oxidative stress (Rekha *et al.*, 2012) [48]. In Darjeeling mandarin, treatment with GA3 15 ppm + zinc (0.5%) + boron (0.1%) resulted in maximum ascorbic acid (Gurung *et al.*, 2016) [47]. The direct application of GA3 @ 20ppm + NAA @ 25ppm resulted in the maximum ascorbic acid content in Washington navel orange (Hifny *et al.*, 2017) [49]. Highest ascorbic acid concentration was found in fruits taken from plants treated with 20 ppm 2,4-D + 0.1 percent carbendazim + 0.5 percent micronutrients in Khasi mandarin (Babu *et al.*, 2002) [50]. In Nagpur mandarin, foliar applications of 2, 4-D 10 mg/L, NAA 30 mg/L, and GA3 25 mg/L improved ascorbic acid content considerably (Ingle *et al.*, 2001) [51]. Kinnow mandarin fruit treated with Zineb 75 WP 0.25 percent + 2, 4-D 10 ppm had the maximum levels of ascorbic acid (Dhaliwal *et al.*, 2009) [26].

Table 1: Show the Plant Growth Regulators and fungicide

Name of Fruit Crop	Plant Growth Regulators and fungicide	Outcomes	References
Mango	2,4-D (75 - 175 ml/L) Prochloraz (225- 900 ml/L	The incidence of stem end rot was reduced, and the quality of preserved fruits was enhanced.	(Kobiler *et al.*, 2001) [52].
Navel Oranges	2,4-D (20 mg/l)	Reduced the rate of fall fruit.	(Modise *et al.*, 2009) [29].
Citrus species	2,4-D (20ppm)	Pre harvest fruit drop reducing.	(Mollapur *et al.*, 2016) [56].
Sweet orange	2,4-D (15 mg/L) Mancozeb (1200 mg/L)	More number of fruits per plant.	(Antoniolli *et al.*, 2003) [55].
Valencia orange	2,4-D (20 ppm)	Increased fruit retention rate of fruit.	(Tamer *et al.*, 2012) [56].
Bael	2,4-D (20 ppm)	Maximum fruit retention.	(Shweta and Misra. 2015) [57].
Nova mandarin	2,4-D (40 ppm)	Enhance the fruit size, yield and fruit splitting.	(Greenberg *et al.*, 2006) [58].
Kinnow mandarin	2,4-D (20 ppm) KNO_3 5%	Maximum peel content in fruit after harvested.	(Rattanpal *et al.*, 2005) [59]
Kinnow mandarin	2,4-D (30 ppm)	Minimum number of seeds per fruit.	(Sharma *et al.*, 2013)
Kinnow mandarin	2,4-D (10 ppm) Propiconazole 1% $ZnSo_4$ 1%	Maximum fruit breadth.	(Singh *et al.*, 2019).
Apple	2,4-D (20 ppm)	Impact in anti-fruit drop before harvest.	(Zhao *et al.*, 2017) [61]
Thompson Naval orange	2,4-D (0.002%)	Enhance the length and width of fruit.	(Yaser *et al.*, 2016) [61]

Conclusion

Kinnow mandarin has become a major citrus cultivar and monopolized the citrus industry due to its high yield and good fruit quality. As a result, researchers tried to see how multiple doses of specific growth regulators and fungicides affected fruit drop in Kinnow mandarin. Foliar spray of plant growth regulators was discovered to be an effective method for boosting Kinnow mandarin fruit set and quality. Foliar sprays of 2, 4-D and fungicide resulted in maximum fruit set and fruit retention, respectively. Fruits of higher quality were discovered in terms of fruit size and biochemical characteristics.

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