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# Integrated Approach to Control of Fruit Drop and Improvement of Yield in Kinnow (*Citrus nobilis* X *Citrus deliciosa*)

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**Abstract**

Fruit drop is a major problem with Kinnow mandarin in all fruit growing regions of the world. Kinnow growers suffer a greater economic loss when natural fruit drop (98.0 to 99.5 %) is accelerated by pathogenic infection, insect-pest infestation, and physiological or hormonal imbalance due to poor orchard management. The application of fungicides to minimize pathogenic attack; 2,4-D (2,4-Dichlorophenoxyacetic acid) to maintain hormonal balance; and $KNO_3$ (Potassium nitrate) to maintain electrolytic balance and efficient utilization of nutrients for developing resistance against insect infestation has greater potential to reduce fruit drop in Kinnow. The fungicides, namely; Zeneb 75WP (0.25 %), Carzim-50 (0.1 %), Curzate M8 (0.25 %), COPRUS 50WP (0.3 %), and Cyproconazole 25EC (0.1 %), in combination with 2,4-D @ 20 ppm and $KNO_3$ @ 1 %, were applied twice, in September and October, and the number of fruits fallen on the ground were counted to determine fruit drop. It was observed that application of $T_3$ [Curzate M8 (0.25 %) + 2,4-D (20 ppm) + $KNO_3$ (1 %)] was an excellent treatment for the integrated management of fruit drop in Kinnow as it had ensured the lowest (1.90-entomological, 3.53-pathological, and 4.75-physiological) fruit drop percentage with the highest fruit yield (432 fruits per plant).

**Keywords:** Curzate M8, entomological, fruit drop, Kinnow, pathological, Zeneb

## Introduction

Kinnow (*Citrus nobilis* × *Citrus deliciosa* L.) is a hybrid variety of the mandarin group of citrus fruits. It has become exceedingly popular among growers of North India due to its high consumer appeal, good tree vigor, high cropping potential, wider adaptability, more economic return, and better performance than other citrus fruits. Kinnow is commercially grown for worldwide export in the Freozpur, Faridkot, Muktsar, Bathinda, Mansa, Hoshiarpur, Ropar, and Gurdaspur regions of Punjab. The eco-physiological conditions of these regions are highly suited for Kinnow cultivation. Kinnow is a heavy bearer, and bears over 300 fruits at the age of 3 or 4 years, which may increase to 600 fruits per tree from the sixth year onwards. The magnitude of flowering and fruiting largely depends on cultivar, the age of the tree, and environmental factors [1]. Those fruit trees which have a very high floral load, have set large numbers of fruits, and show natural fruit drop to maintain favorable source-sink relationships for proper development and maturity of fruits [2]. In citrus, only 0.5 to 2 % of flowers undergo development to maturity while remaining in a natural drop down state [3]. However, growers suffer a greater economic loss when this natural fruit drop of Kinnow is accelerated by pathogenic infection, insect-pest infestation, and physiological or hormonal imbalance due to poor orchard management. These fruit drops occur at various stages and are categorized as pathological fruit drops, entomological fruit drops, and physiological fruit drops [4].

The fruits may be infected in orchards right from the setting to harvesting stage, leading to premature fruit dropping. Entomological fruit drop is mainly due to citrus bud mite and orange bug which cause heavy drop of flowers and fruits in the early phase, and fruit fly in the later phase [5]. Citrus mealybug causes infestation on most of the part of plants; a sooty mold develops which reduces photosynthetic activities and attracts pathogens to induce fruit drops [6,7]. These insects are actively transported, through crawling between trees, or passively transported, through wind and machineries [8]. Premature fruit drop is a disease of economic importance which occurs throughout India and other citrus growing countries [9]. Species of fungi causing premature fruit drop are *Alternaria, Colletotrichum*, *Botrytis*, and several stem end rotting fungi. This disease is characterized by limited lesions on the stem, leaf, or fruit, often accompanied by withered tips or dieback of twigs or fruit stems and the abnormal persistence of buttons (floral discs along with pedicils) after the fruitlets have dropped in the months of July and August [10-12]. The disease symptoms develop rapidly under humid and warm conditions and ultimately infect the fruit, leading to fruit drop. Beside biotic factors, abiotic factors such as high temperature, water deficits, and wind velocity in the area also contribute to excessive premature fruit drop [13-15]. Premature fruit drop of Kinnow caused by *Colletotrichum gloeosporioide* is one of the major causes of the decline in quality and total fruit production and, thus, is of great concern for the citrus growers in Punjab and other citrus growing states of India [16,17].

The physiological fruit drop is associated with hormonal imbalance and poor nutritional management. 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" [18]. A tree drops its fruit when the concentration of auxins decreases and the concentration of abscisic acid (ABA) increases [19]. The exogenous application of plant growth regulator (PGR) has been reported to improve fruit set, increase fruit size, delay fruit maturity, and reduce fruit drop and, thus, significantly improves economic yield for growers when applied in the correct dose [20-22]. The balance of endogenous hormones is essential for establishing a balanced relation between the source and sink for the mobilization of nutrients to the developing organs. Exogenous application of plant growth regulators can effectively balance the endogenous hormonal level when applied at the appropriate time and in the proper dose, thereby reducing or retarding early fruit fall and harvest losses [23]. The application of 2, 4-D and $GA_3$ in desirable concentration inhibits abscission, softening of rind, and chlorophyll degradation to reduce preharvest fruit drop [24]. Auxins prevent synthesis of hydrolytic enzymes, like cellulose, to prevent fruit drop [1].

Potassium (K) is a regulator of a number of physiological activities in plants, such as; plant-water relation; stomatal movement; synthesis of sugar, starch, protein; cell division; enzymatic activation; and absorption and translocation of micronutrients [25,26]. Furthermore, the requirement of K for citrus is higher than that of other macronutrients [9,27]. Thus, limited availability of K may accelerate physiological fruit drops and affect the yield and quality of Kinnow fruits. Fruit drop is genetically, physiologically, and environmentally regulated. However, a number of factors stimulate this phenomenon, including; i) plant stress and premature ethylene production [28-33]; ii) stress factors like heat, drought, nutrient imbalance, or deficiency and heavy crop load [28,34]; iii) reduced photosynthates [35]; iv) nature of environmental factors [36]; v) if the orchard established on alluvial soils [37], and vi) water logging [38].

Thus, the present research paper puts emphasis on the integrated use of plant growth regulator (2,4-D), different fungicides, and $KNO_3$ for the effective management of fruit drop in Kinnow, and is based on the investigatory work carried out in the Kinnow orchard of a progressive farmer in the Hoshiarpur district during the cropping year 2014 - 2015.

## Materials and methods

### Experimental site

The experimental site is located at an elevation of 296 meters above mean sea level, at 31° 32' North latitude and 75° 57' East longitude, representing the piedmont and alluvial plain agro-eco-subregion of Punjab. The sub-region is characterized by a hot, dry sub-humid to semi-arid transition, with dry summers and cool winters, with mean annual air temperature range from 24 to 26 °C, and mean annual rainfall ranging between 700 - 1000 mm [39]. The monsoon ranges set in the last week of June and the end of the month of September cover 75 - 80 per cent of total annual rainfall [39].

**Experimental Plan**

The investigation was carried out on 5 treatments, along with one absolute control, each having 4 replications. Five trees were selected randomly per replication, and data on fruit drop was recorded at weekly intervals, starting from the September until harvest (end January) season of 2014 - 2015. The fruits trees were sprayed with both growth regulators and fungicides as per treatments (**Table 1**).

**Table 1** Treatment chemical combinations.

| Notations | Treatments |
|---|---|
| $T_0$ | Water spray (Absolute control) |
| $T_1$ | Zeneb 75WP 0.25 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %) |
| $T_2$ | Carzim-50 (Carbendazim) 0.1 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %) |
| $T_3$ | Curzate M8 (Cymoxanil 8 % + Mancozeb 64 %) 0.25 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %) |
| $T_4$ | COPRUS (Copper oxychloride) 50WP 0.3 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %) |
| $T_5$ | Cyproconazole 25EC 0.1 % +2, 4-D (20 ppm) + $KNO_3$ (1 %) |

**Spraying schedule**

Two sprays of all fungicides, namely; Zeneb 75WP (0.25 %), Carzim-50 (0.1 %), Curzate M8 (0.25 %), COPRUS 50WP (0.3 %), and Cyproconazole 25EC (0.1 %), in combination with 2,4-Dichlorophenoxyacetic Acid (2,4-D @ 20 ppm) as growth regulator, and potassium nitrate ($KNO_3$ @ 1 %), were given in September and October. In each treatment, 3 replications were taken, and 5 trees per unit replication were sprayed.

**Observations recorded**

The physical parameters recorded were fruit weight, fruit size, and fruit drop, while the chemical parameter was TSS (Total Soluble Solids). The data on the fruit drop (physiological, pathological, and entomological) were recorded starting from September 2014 to January 2015. The number of fruits per plant at spray time and the number after spray were counted on the tagged tree. Fruit drop was calculated by counting the fruits again in December, and percentage of fruit drop was calculated as given below [40];

$$Fruit\ Drop\ (\%) = \frac{Number\ of\ fruitlets\ at\ the\ time\ fruitset - Number\ of\ fruits\ retained\ at\ harvesting}{Number\ of\ fruitlets\ at\ the\ time\ fruitset} \times 100$$

Fruit yield was determined by the numbers of fruits per tree. The average fruit weight of 10 randomly selected fruits in each replication was determined by weighing the fruits on pan balance, and the average fruit weight was calculated. The fruit size was measured with the help of vernier calliper on randomly selected fruits per replication per treatment. Total soluble solids (TSS) of fruit juice was determined at ambient temperature with the help of a hand refractometer, and was expressed in °Brix [41].

**Statistical analysis**

The data recorded for all parameters were analyzed according to the method of Randomized Block Design (RBD), as advocated by Duncan's Multiple Range Tests, to compare significant differences among treatments at $p \leq 0.05$ [42].

## Results and discussion

### Fruit drop percent

The data presented in **Figure 1** indicates that all the combinations of growth regulator and fungicide helped in reducing the entomological, pathological, and physiological fruit drop significantly, as compared to water spray ($T_0$). The minimum (1.90 %) entomological fruit drop was obtained with application of $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)] which was on par with $T_1$ [Zeneb 75WP (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], having 2.17 % fruit drop; $T_5$ [Cyproconazole 25EC (0.1 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)] and $T_2$ [Carzim-50 (0.1 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], with 2.40 % fruit drop; and $T_4$ [COPRUS 50WP (0.3 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], with 2.76 % fruit drop, while the maximum fruit drop (4.2 %) was obtained in water spray.

The maximum pathological fruit drop (7.8 %) was observed in $T_0$ [water spray], and is presented in **Figure 1**, followed by 5.14 % in $T_4$ [COPRUS 50WP (0.3 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], and significantly the lowest (3.53 %) fruit drop was observed in $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)]. The treatments $T_1$, $T_2$, $T_3$, and $T_5$ were statistically on par in controlling fruit drop. The maximum fruit retention was observed in treatment $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %), as compared to other treatments.

The fruit drop calculated in the month of June-July was primarily physiological fruit drop [18], which was reported to be the least (4.75 %) in $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], followed by 5.75 % in $T_1$ [Zeneb 75WP (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)]; 7.12 % in $T_5$ [Cyproconazole 25EC (0.1 %) +2, 4-D (20 ppm) + $KNO_3$ (1 %)]; 7.18 % in $T_2$ [Carzim-50 0.1 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], and 8.16 % in $T_4$ [COPRUS 50WP (0.3 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)]. All the 5 treatments were statistically on par in controlling physiological fruit drop in comparison to $T_0$ [water spray], which showed maximum physiological drop (14 %) (**Figure 1**). The effect of spray time on interaction results were reported to be non-significant.

The significant reduction in fruit drops by using 2,4-D in combination with each of the applied fungicide (treatments) might be due to the inhibition of fungal growth developed on sooty mold caused after infestation by citrus mealy bug. These fungicides might have reduced the incidence of fungal pathogen (*Collectotrichum gloeosorioides*), which causes stem-end rot, thereby minimizing the fruit drop in treated plants. The application of fungicides for the control of pathological fruit drop in Kinnow mandarin has also been confirmed by Thind *et al.* [43]. The potential of curzate M8 in controlling fruit drop in Nagpur mandarin by reducing the incidence of (*Collectotrichum gloeosorioides*) has also been reported by Ingle *et al.* [44]. The effectiveness of K as $KNO_3$ zinc from zineb for effective control of citrus fruit drop has also been proven by Asharaf *et al.* [9].

The presence of 2,4-D in small concentrations is responsible for maximum fruit retention in Kinnow by reducing the formation of the abscission layer, as reported by Rattanpal *et al.* [45] while the application of fungicide in combination with 2, 4-D has proven to be excellent for the control of fruit drop in Kinnow by Thind and Arora [46]. The significant influence of auxins in controlling preharvest fruit drop in citrus crop has also been proposed by Stover [47] and Anthony and Coggins [48]. The effectiveness of all treatments in reducing fruit drop may be due to the herbicidal nature of 2,4-D, as it also acts as an auxin transfer inhibitor [49]. The application of 2,4-D for controlling the physiological fruit drop in Kinnow mandarin has also been reported by Kaur *et al.* [50].

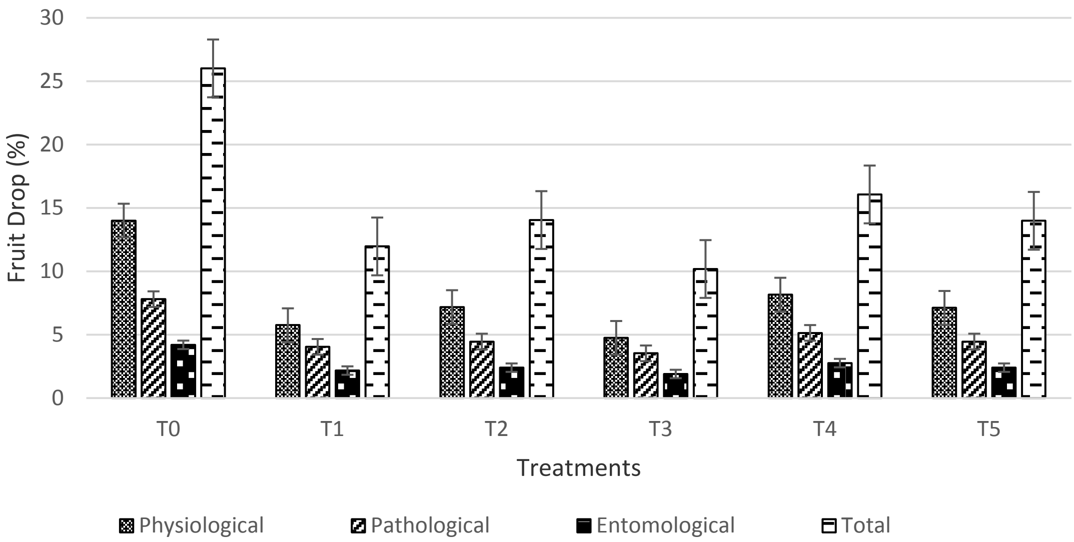


**Figure 1** Effect of various chemical combinations on Kinnow fruit drops (%).

All fungicides in combination with 2,4-D helped in reducing the fruit drop significantly (40 - 60 % reduction), as compared to water spray (26 % fruit drop). The lowest total fruit drop was reported in $T_3$ (10.18 %), followed by $T_1$ (11.96 %), while $T_5$ and $T_2$ were reported with nearly 14 % fruit drop throughout the season. The highest fruit drop (40) was recorded in September, followed by October, and the minimum in January (**Figure 2**). The maximum fruit drop was found in $T_0$ (water spray) in the month of September, while Curzate M8 in a combination of 20 ppm of 2,4-D and 1 % $KNO_3$ significantly minimized fruit drop. All treatment combinations were effective in controlling fruit drop. The high intensity of fruit drop in the month of September and October may be due to the severity of pathological fruit drop near maturity, which was associated with the occurrence of *C. gloeosporioides* [43]. The effectiveness of 2,4-D in reducing preharvest fruit drop in the months of September and October have been reported by Davies and Zalman [51] in *Citrus* spp. when applied in 20 ppm concentrations.

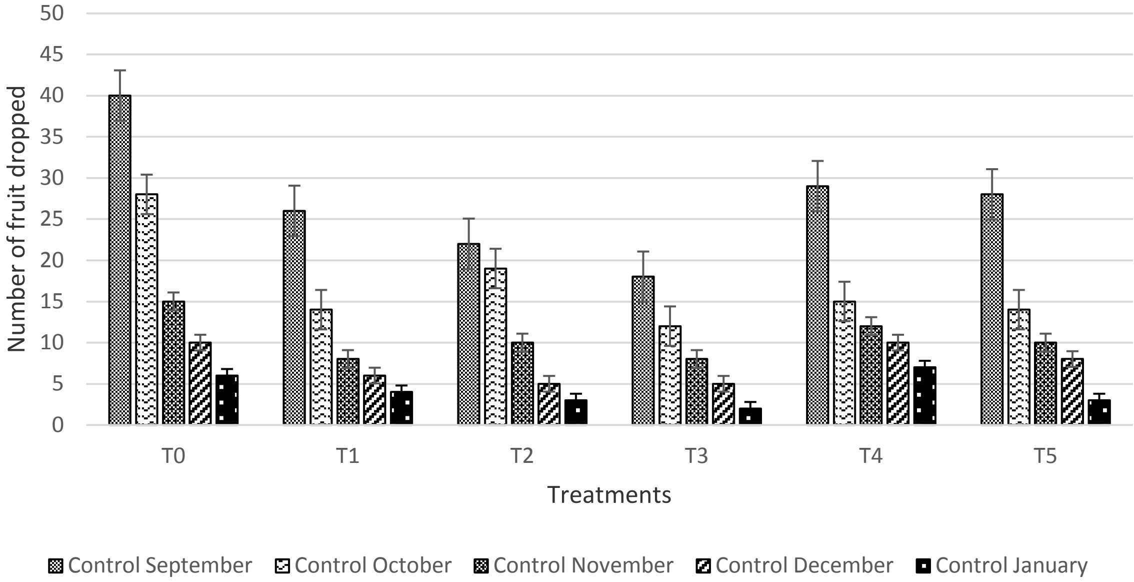


**Figure 2** Fruit drop in Kinnow by month under different treatments.

**Yield and quality parameters**

***Average fruit weight***

The data presented in **Figure 3** confirms maximum fruit weight (149.85 g) due to the application of $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)]; followed by 143.6 g with $T_1$ [Zeneb 75WP (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], and 142.25 g $T_5$ [Cyproconazole 25EC (0.1 %) +2, 4-D (20 ppm) + $KNO_3$ (1 %)]. The lowest fruit weight (127.21 g) was obtained in $T_4$ [(COPRUS 50WP 0.3 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %)] which was closer to 128.38 g in $T_0$ [water spray]. The results obtained in this experiment are in conformity with the reports of Singh and Randhawa [52]. However, the lower average weight in $T_4$ in comparison to $T_0$ cannot be confirmed through any finding.

***Fruit yield***

The maximum number of fruits (432) was observed in in $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], as given in **Figure 3**, followed by 426 fruits/plant in $T_1$ [Zeneb 75WP (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], and the minimum (350 fruits/plant) observed in $T_0$ [water spray]. The higher yield in the treatments containing fungicides and 2,4-D was due to reduced preharvest fruit drop, which is in conformity with of Gomez-Cadenas *et al.* [53] and Singh and Mann [54].

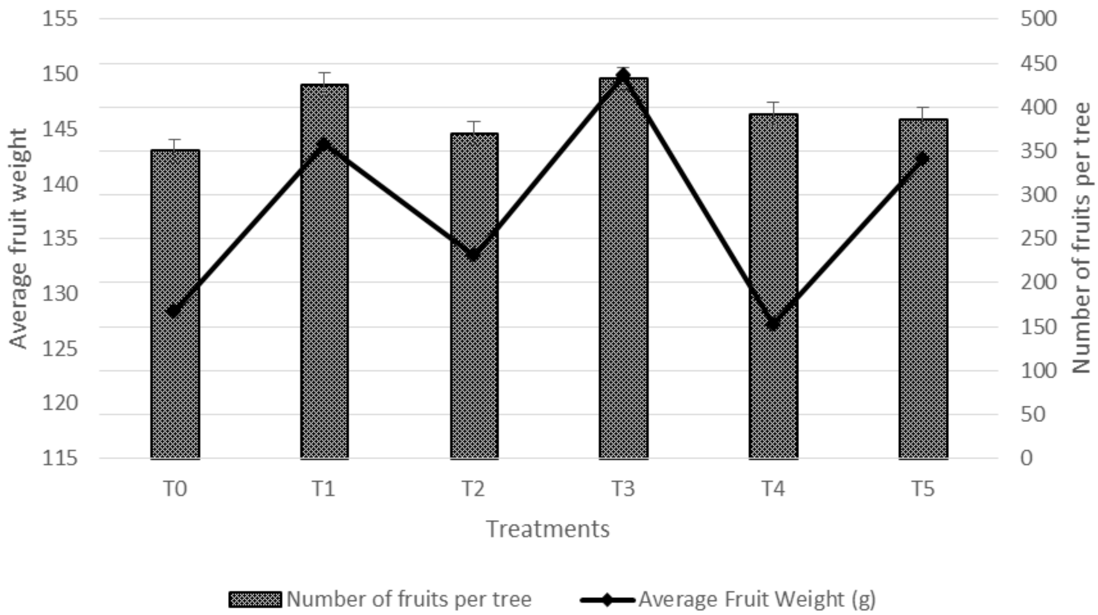


**Figure 3** Effect of various treatments on total fruit yield (number of fruits per tree) and average fruit weight (g).

***Average Fruit size (L×B)***

The data mentioned in **Figure 4** indicates that the highest average fruit size (53.5 cm) was achieved with $T_5$ [Cyproconazole 25EC 0.1 % +2, 4-D (20 ppm) + $KNO_3$ (1 %)], followed by 47.8 cm in $T_3$ [Curzate M8 0.25 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %)]. The minimum fruit size (38.67 cm) was obtained with untreated $T_4$ [(COPRUS 50WP 0.3 % + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], which was closer to 40.29 cm in $T_0$ [water spray] fruits. The results obtained in this experiment were in conformity with those reported by Randhawa and Sharma [55] and Pal *et al.* [56], who observed larger fruits in trees receiving 2,4-D (20 ppm) treatment. The effectiveness of plant growth regulator in increasing fruit size has also been reported by Nawaz *et al.* [57] in Kinnow mandarin. Although non-significant but smaller fruit size in $T_4$ in comparison to $T_0$ cannot be confirmed through any finding, this might be contributing factor towards the relatively lower average fruit weight in $T_4$ over $T_1$ (**Figure 3**).

***Total soluble solids***

The perusal of data in **Figure 3** indicates that all the growth regulators and fungicide treatments resulted in higher TSS than the water spray. The maximum total soluble solids (11.8 °Brix) were obtained with $T_3$ [Curzate M8 (0.25 %) + 2, 4-D (20 ppm) + $KNO_3$ (1 %)], which was comparatively higher than other treatments, while minimum total soluble solids (9.1 °Brix) was obtained with untreated fruits $T_0$ [water spray]. Similar results have been reported by Chundawat *et al.* [58] by using hormonal and fungicidal sprays in Kinnow mandarin. Saleem *et al.* [59] had also reported similar findings while studying the effectiveness of the exogenous application of growth regulators on the fruit drop and quality of Blood Red orange.

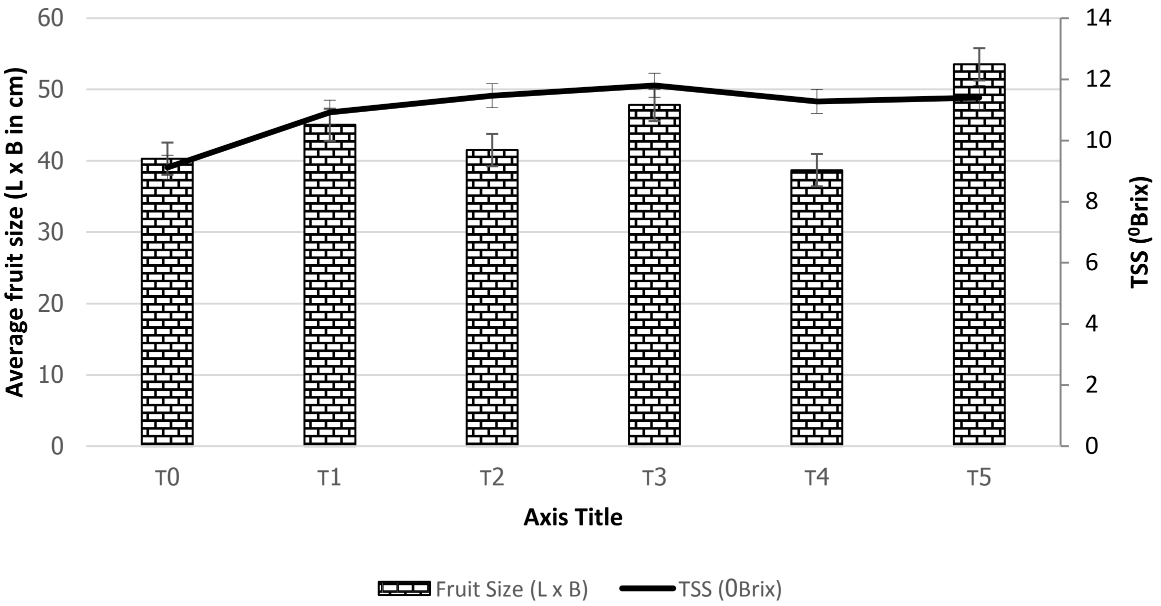


**Figure 4** Effect of various chemical combination on Fruit size and TSS content of Kinnow fruits.

## Conclusions

Curzate M8 0.25 %, in combination with 2,4-D (20 ppm) and $KNO_3$ (1 %), outcompeted all the other treatments, and provided maximum control of fruit drop, while the second-best treatment was Zineb 75WP 0.25 % in combination with 2,4-D (20 ppm) and $KNO_3$ (1 %). The findings support the positive influence of fungicides- Curzate M8 and Zineb 75WP in reducing pathological fruit drops in Kinnow by inhibiting fungal (*C. gloeosorioides*) growth. The application of potassium-containing salt ($KNO_3$) and lower concentrations (20 ppm) of 2,4-D minimized physiological fruit drops. Thus, a combination of fungicides (0.25 % of Zineb 75WP or Curzate M8), 2,4-D (20ppm), and $KNO_3$ (1 %) can be applied for the integrated management of fruit drop in Kinnow mandarin to obtain an economical yield.

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