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# Performance of Stionic Combination on Vegetative Growth and Flowering of Exotic Mandarin Germplasm under Sub-Tropical Plains of Punjab

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## ABSTRACT

Different exotic mandarin cultivars imported from Israel and budded on various root stocks were evaluated from 2017 to 2019. Kinnow scion grafted over Rough Lemon plant reached its maximum height (3.50 m). Fairchild budded on Volkamer lemon (3.19 m) was found to be promising in terms of average plant spread. Fairchild and Michal budded over Volkamer Lemon and X 639 produced the largest plant volume (13.30 $m^3$). Similarly, Michal grafted on Volkamer lemon achieved the scion girth (26.8 m) and root stock girth (33.7 m). Pearl Tangelo grafted on Rough lemon produced earliest bloom initiation while there was a lot of heterogeneity among the best cultivar and root stock combinations. Daisy x Rough lemon combination proved to be the best in terms of earliest maturity with the shortest number of days from fruit set to maturity (222.3 d). Volkamer lemon and X-639 outperformed the other stionic combinations in most of the criteria, indicating that they have the potential to replace the current leader Rough lemon. Thus, it can be said that these combinations can best replace the existing Kinnow budded over Rough lemon monoculture with nearly identical features.

**Key Words:** Citrus, Flowering, Kinnow, Rotstock, Scion, Vegetative.

## INTRODUCTION

Rootstock and scion girth is considered very important to determine the degree compatibility of stionic relationship between stock and scion. Sometime rootstock shows incompatibility with scion leading to unbalancing in physiological functions, plant vigor, productivity as well as fruit quality. The information about the behaviour of a scion cultivar on a particular rootstock in terms of vigour and other characters cannot be extended to other cultivars as these rootstocks behave differently with different scions and with same scion under varying soil and climatic conditions. The majority of the harvest is made up of citrus fruits such mandarins, sweet oranges, lime, lemons, and grapefruits. Sweet oranges account for 61.18 percent of the crop, mandarins for 22.12 percent, lime and lemons for 11.4 percent, and grapefruit and other citrus fruits for the remaining 5.5 percent. With an annual citrus production of 146.8 Mmt, there are roughly 140 major citrus-producing nations worldwide. India, with a production of 13.20 Mmt ranks in third (Annonymous,2019) and provides 8.99 percent of the world's citrus production from 0.43 million ha of land with a yield of 12.31 MT per hectare. States like Punjab, Haryana, and Rajasthan have experienced substantial growth in the citrus sector. The overall area under fruit crops in Punjab is over 66.0 per cent, while citrus has 57288 ha, of which more than 92.59 percent is under Kinnow mandarin, a hybrid of C. Nobilis and C. deliciosa.

Due to the genetic pool being reduced due to this type's dominance in citrus, disease and pest outbreaks are a potential problem. Citrus fruit supply is short-lived due to the late maturing cultivar (Kinnow). Similar to how there is an oversupply on the market due to the monoculture

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of this particular citrus type. It has been demonstrated that root stocks have a significant impact on tree growth output and fruiting quality ( Hussain *et al,* 2013). Citrus cultivars imported from other countries may exhibit differences in vegetative and fruit characteristics due to differences in soil and climate. As a result, these experiments were conducted to assess the effects of exotic cultivars on several root stocks that could perform well in the Punjab subtropics.

## MATERIALS AND METHODS

### Location of experiment and plant material

The current research was conducted between 2017 and 2019 in the Centre of Excellence for Fruits (Citrus), hamlet Khanaura, District Hoshiarpur (Punjab), which is located at 31.4041550 (31024'15.0"N) and 75.83505650 (75050'06.2"E). Eight exotic cultivars (Daisy, Michal, Murcott, Fairchild, Fremont, Pearl Tangelo, W Murcott, and Kinnow) were budded on four different rootstocks (Volkamer Lemon, Rangpur Lime, X-639, and Rough Lemon) and compared to the local commercial variety Kinnow for vegetative growth, flowering, and fruiting behaviour.

### Layout of experiment

The experiment was set up in a randomised block design (RBD), with four plants chosen for each treatment and planted in September/October 2014 on raised beds with a height of 1.5 feet and a width of 6 feet, with a gap between row and plant of 6 and 3 metre, respectively, and drip irrigation. There were 32 stionic combinations in total, with three replications each including four plants. A total of 384 plants were tested during the study.

### Observations recorded

Plant height (measured with a measuring pole from the ground up to the highest point of growth) and plant spread N-S and E-W were measured with a measuring tape and stated in metre. Using the following formula, the average plant sprea

d was obtained by combining both:

$$\text{Average plant spread} = \frac{\text{Plant spread in N-S} + \text{Plant spread in E-W}}{2}$$

To record plant volume, the plant was considered to be one half of a prolate spheroid, and the volume was computed using the formula:

$$\text{Plant volume} = \frac{0.524 \times \text{height} \times \text{spread}}{2}$$

Scion girth was measured 20 cm above the grafting union using Mitutoyo Inc.'s Digital Vernier Caliper. The same tool was used to measure rootstock girth 20 cm below the grafting union. Bloom initiation (the moment when roughly 5-10 percent of the flower opened) and the date was recorded during the flowering stage. When more than 80-90 percent of the flowers had opened and 75-80 percent anthesis had occurred, observatioin was recorded. In turn, a period of full bloom was seen when more than 75% of the flowers had anthesis. Only 5% of buds were left to open at the end of the flowering cycle and 95% of flowers were shed. Fruit set (when 95 % flowers shed and turned into berries) and days to maturity (when 80-95 percent of fruits have reached the right size and appealing colour) were both recorded.

## RESULTS AND DISCUSSION

### Plant height (m)

Among various scion cultivars the maximum height (3.13 m) was observed in Kinnow which was at par with Michal followed by Pearl Tangelo (2.60 m) and Fairchild (2.50 m). However, the minimum plant height (2.10 m) was recorded in cultivar Fremont. For all these cultivars Volkamer lemon was used as rootstock (Table 1). Kinnow budded on Rangpur lime (rootstock) attained a height of only 3.00m and was found at par with Fremont and Fairchild followed by Daisy (2.45 m), Michal (2.35 m), and Pearl Tangelo (2.30 m). On the contrary, when different exotic citrus cultivars were budded on X-639 (rootstock), maximum plant height was noted in Michal (2.73 m) and found at par with Fairchild, and Kinnow, significantly followed by Pearl Tangelo (2.76 m). In case of Rough lemon

(rootstock), maximum plant height was recorded in Kinnow tree (3.50 m) followed by Daisy (2.60 m), Michal, and Freemont. The increase in plant height may be due to better compatibility between scion and rootstock (Singh *et al*, 2019). Present findings were corroborated with the results of (Ahmed *et al,* 2006) who claimed better plant height in case Kinnow mandarin budded on Rough lemon rootstock followed by Volkamer lemon as compared to other rootstocks like Citrumelo 4475 and Brazilian sour orange. Maximum plant height in Kinnow plants grafted on Rough lemon followed by Kinnow stock was also reported (Nasir *et al,* 2011).

**Average plant spread (m)**

The data about plant spread disclosed that maximum spread was recorded in cv. Fairchild budded on Volkamer lemon (3.19 m) which was at par Pearl Tangelo followed by Michal (2.92 m), Kinnow (2.91 m) along with Murcott (2.86 m). On the other hand, when Rangpur lime was used as rootstock, the maximum spread was noted in Kinnow (2.78 m) and was at par with Pearl Tangelo (2.62 m) along with Fairchild (2.52 m) followed by Daisy and W Murcott (2.44 m and 2.41 m, respectively). The least plant spread was documented in Murcott (1.64 m). Use of X-639 as rootstock revealed that spread was the highest in the case of Michal cultivar (2.95 m) and was at par with Fairchild and Pearl Tangelo (2.77 m) followed by Daisy and Fremont cultivars. The lowest values were observed in W Murcott cv. where it was only 2.17 m. In the case of Rough lemon (rootstock) highest values were obtained in the case Fairchid (2.77 m), at par with Daisy and Murcott, followed by W Murcott (2.40 m), at par with other citrus cultivars *viz*., Pearl Tangelo (2.39 m) and W. Murcott (2.40 m). The cultivars like Kinnow, Fairchild, and Fremont also gained promising plant spread in the N-S direction (Josan and Kaur, 2006). Better plant spread in Rangpur lime and Volkamer lemon rootstocks resulted when budded over with Oneco mandarin (Gonzatto *et al,* 2011)

**Plant volume ($m^3$)**

A significant variation was revealed in plant volume (Table 1). Maximum plant volume (14.69 $m^3$) was recorded in Kinnow followed by cv. Michal (12.50 $m^3$), which was at par with cv. Fairchild and Murcott. Significant lowest plant volume was recorded in case of Freemont when budded on Volkamer lemon. However, Kinnow exhibited the highest values (12.6 $m^3$) when budded over Rangpur lime rootstock followed by Fairchild (9.0 $m^3$). When all these cultivars were budded over X-639 (rootstock), significant results were obtained. The highest values were recorded in the case of Michal (13.3 $m^3$) followed by Pearl Tangelo. While budding on Rough lemon, best results were observed in Kinnow to the tune of 11.7 $m^3$, followed by Fairchild and Daisy cultivars. The results of the present investigations were corroborated with the observations where it was found maximum canopy volume in Sour orange followed by Rough lemon and Volkamer lemon while reviewing Nova mandarin on eleven rootstocks in Cyprus (Georgiou, 2010). A better canopy volume in Oneco mandarin budded on Caipira orange followed by Swingle citrumelo, Troyer citrange, Volkamer lemon, and Rangpur lime whereas, minimum in Flying Dragon trifoliate orange rootstock (Josan and Kaur, 2006; Gonzatto *et al,* 2011).

**Scion girth (cm)**

The data (Table 2) significantly divulged the differences in scion girth of budded cultivars over rootstocks. When Michal was budded over Volkamer lemon rootstock, the scion girth had exhibited the highest value of 26.8 cm followed by W Murcott (24.3 cm). It was interesting to note that Kinnow had a scion girth of 20.9 cm. But when Rangpur lime was used as rootstock maximum girth was noted in the case of the Kinnow cultivar to the tune of 21.0 cm. This value was at par with Michal, Freemont, and Fairchild (19.6, 19.5, and 19.0, respectively). While in another experiment, Pearl Tangelo (19.9) showed the highest values for the same when budded on X-639 followed by W Murcott but Kinnow displayed less value (18.9 cm) for the same. Rough lemon proved to be the best rootstock for Michal (22.5 cm) while at par with Murcott, trailed by Pearl Tangelo with 19.3 cm. In

a related study , Rough lemon and Vlokamer lemon had the greatest increases in scion girth (Ahmed *et al,* 2006). Additionally, Olinda Valencia budded at its highest scion girth on Benton rootstock, while Hamlin budded at its lowest scion girth on Benton rootstock research (Chahal and Gill, 2015)). Similarly, it has been reported that several rootstocks had displayed varied growth response on the diverse scion kinds, which may have occurred due to the rootstocks' innate genetic potential (Singh *et al,* 2018)).

**Rootstock girth (cm)**

Various mandarin cultivars did not significantly affect the rootstock circumference of the plant (Table 2). However, maximum rootstock girth was recorded in Michal (33.7) followed by W Murcott (31.9 cm) when budded over Volkamer lemon rootstock. The least girth was recorded in the case of Freemont to the tune of 27.2 cm. Similarly, rootstock girth was not affected significantly by any cultivar used in the study. But when Rangpur lime was used as rootstock, cv. Kinnow and Michal showed maximum value for stock girth (24.8) while Daisy was next to it (23.9 cm). Results were non-significant in the case of X-639 and Rough Lemon (both rootstocks) budded with different cultivars, during study. It was interesting to note that Kinnow exhibited improved performance regarding rootstock girth while using Rough lemon rootstock. In a similar experiment, maximum rootstock girth increment in Rough lemon followed by Volkamer lemon (Ahmed *et al,* 2006). The findings also demonstrated the variance in growth response of the rootstocks which might be due to the inherent genetic potential (Singh *et al,* 2018). They concluded that Rangpur lime trailed by rough lemon exhibited its dominance concerning spread tree volume of Sathgudi sweet orange upon other rootstocks, demonstrating their well-adapted nature to soil circumstances with good root system that might lead to higher buildup of nutrients. Similar in the case of sweet orange on various rootstocks (Yildiz *et al,* 2013; Ghosh *et al*, 2012).

**Flowering and Fruit setting parameters**

Several variations had been noted in different cultivars and rootstocks under investigation concerning flower initiation, flower duration, days required for fruit set, and maturity (February –March). Although the flowering was limited to these two months, variability has been seen concerning the time.

**Date of flower initiation**

The data concerning the date of flower initiation of different mandarin cultivars and rootstocks are presented in table3. The date of flower initiation varied between 4$^{th}$ February to 7$^{th}$ March among different cultivars of mandarin and different rootstocks used. The earliest flower commencement was seen in Pearl Tangelo (9$^{th}$ Feb) followed by Fremont (14$^{th}$Feb) when budded over Volkamer Lemon rootstock. In case of Pearl Tangelo budded over Rangpur lime (rootstock) flower initiation occurred by 5th Feb while in cultivar Kinnow, it was by 1$^{st}$ March. Similarly, Pearl Tangelo budded over rootstock X-639 showed flower initiation by 6$^{th}$ Feb while Kinnow showed late flowering initiation (2$^{nd}$Mar). Pearl Tangelo budded over Rangpur lime and had initiated flowering by 4$^{th}$ Feb. Kinnow mandarin budded on different rootstock did not show much variation in commencement of flowering (13). An early start of flowering on 11$^{th}$ March in Pink Pummelo and late on 17$^{th}$ March in NRCC Pummelo 4 (14). However, Kinnow had shown early flowering by 13$^{th}$ March in all eight rootstocks expect the latest by 14$^{th}$ March in NRCC-1 and NRCC-5 rootstocks. Rattanpal *et al* (2019) also reported variation in the initiation of flowering, where earliest flowering commenced on 15$^{th}$ February in Schaub and Chase whereas, late flower initiation was on 26$^{th}$ March in Florida both rough lemon strains.

**Flower duration**

The data regarding different flower-related activities revealed that Freemont exhibited a flowering duration of 34 d when budded over Volkamer lemon rootstock. This was significantly followed by Fairchild (33.0 d). The least days were taken by Daisy cultivar to the tune of 18 d. While in Kinnow cultivar this duration was recorded only 27 d. Similarly, in another experiment, Rangpur lime was used as rootstock, cultivar W Murcott showed the longest flower

**Table 1. Plant height, plant spread and plant volume of various scion cvs. of mandarin budded over different rootstocks.**

| Cultivar | Name of Root stock | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volkamer Lemon | | | Rangpur Lime | | | X-639 | | | Rough Lemon | | |
| | Plant Height | Plant Spread | Plant Volume | Plant Height | Plant Spread | Plant Volume | Plant Height | Plant Spread | Plant Volume | Plant Height | Plant Spread | Plant Volume |
| Daisy | 2.40 | 2.59 | 8.40$^{c}$ | 2.45$^{b}$ | 2.44 | 7.7$^{c}$ | 2.45$^{b}$ | 2.59 | 9.4$^{c}$ | 2.60$^{b}$ | 2.68 | 9.8$^{b}$ |
| Michal | 2.80$^{a}$ | 2.92 | 12.50$^{b}$ | 2.35$^{b}$ | 2.34 | 7.0$^{c}$ | 2.73$^{a}$ | 2.95 | 13.3$^{a}$ | 2.55$^{b}$ | 2.26 | 6.8$^{c}$ |
| Murcott | 2.53 | 2.86 | 10.80$^{b}$ | 1.80 | 1.64 | 2.7 | 2.10$^{c}$ | 2.33 | 6.5 | 2.10$^{c}$ | 2.60 | 7.5$^{c}$ |
| Fairchild | 2.50$^{c}$ | 3.19 | 13.30$^{a}$ | 2.50$^{a}$ | 2.57 | 9.0$^{b}$ | 2.19$^{c}$ | 2.77 | 9.6$^{c}$ | 2.45$^{b}$ | 2.77 | 9.8$^{b}$ |
| Fremont | 2.10 | 2.24 | 5.50$^{c}$ | 2.60$^{a}$ | 1.80 | 4.6$^{c}$ | 2.50$^{b}$ | 2.56 | 9.3$^{c}$ | 1.85$^{c}$ | 2.26 | 4.90 |
| Pearl Tangelo | 2.60$^{b}$ | 3.09 | 13.00$^{a}$ | 2.30$^{b}$ | 2.62 | 8.6$^{b}$ | 2.60$^{a}$ | 2.77 | 11.3$^{b}$ | 2.18$^{c}$ | 2.39 | 6.50$^{c}$ |
| W Murcott | 2.55 | 2.63 | 9.20$^{c}$ | 2.28$^{c}$ | 2.41 | 7.2$^{c}$ | 2.05$^{c}$ | 2.17 | 5.8 | 2.29$^{b}$ | 2.40 | 6.9$^{c}$ |
| Kinnow | 3.13$^{a}$ | 2.91 | 14.6$^{a}$ | 3.00$^{a}$ | 2.78 | 12.6$^{a}$ | 2.68$^{a}$ | 2.38 | 8.6$^{c}$ | 3.50$^{a}$ | 2.52 | 11.7$^{a}$ |
| C.D. ($p \geq 0.05$) Interaction | 0.38 | 0.17 | 1.79 | | | | | | | | | |

**Table 2. Scion girth, stock girth and stock/scion ratio of various scion cvs. of mandarin budded over diff. rootstocks.**

| Cultivars | Name of Root stock | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volkamer Lemon | | | Rangpur Lime | | | X-639 | | | Rough Lemon | | |
| | Scion girth | Rootstock girth | Stock/Scion ratio | Scion girth | Rootstock girth | Stock/Scion ratio | Scion girth | Rootstock girth | Stock/ Scion ratio | Scion girth | Rootstock girth | Stock/ Scion ratio |
| Daisy | 21.1$^{b}$ | 28.8 | 1.4 | 18.8$^{a}$ | 23.9 | 1.3 | 18.6$^{a}$ | 21.5 | 1.2 | 19.9$^{b}$ | 25.7 | 1.3 |
| Michal | 26.8$^{a}$ | 33.7 | 1.3 | 19.6$^{a}$ | 24.8 | 1.3 | 21.6$^{a}$ | 27.5 | 1.3 | 22.5$^{a}$ | 29.5 | 1.3 |
| Murcott | 21.2$^{b}$ | 31.2 | 1.5 | 18.0$^{b}$ | 21.3 | 1.2 | 18.7$^{a}$ | 21.1 | 1.1 | 20.6$^{a}$ | 25.6 | 1.3 |
| Fairchild | 19.8$^{c}$ | 30.3 | 1.5 | 19.0$^{a}$ | 21.2 | 1.1 | 19.9$^{a}$ | 21.7 | 1.1 | 18.9$^{c}$ | 24.3 | 1.3 |
| Fremont | 21.1$^{b}$ | 27.2 | 1.3 | 19.5$^{a}$ | 21.4 | 1.1 | 19.5$^{a}$ | 25.2 | 1.3 | 20.7$^{a}$ | 28.6 | 1.4 |
| Pearl Tangelo | 21.8 | 27.4 | 1.3 | 18.2$^{b}$ | 22.4 | 1.2 | 19.9$^{a}$ | 23.8 | 1.2 | 19.3$^{b}$ | 26.6 | 1.4 |
| W Murcott | 24.3$^{b}$ | 31.9 | 1.3 | 19.5$^{a}$ | 23.9 | 1.3 | 19.8$^{a}$ | 26.0 | 1.3 | 17.9$^{c}$ | 25.2 | 1.4 |
| Kinnow | 20.9$^{b}$ | 28.6 | 1.4 | 21.0a | 24.8 | 1.2 | 18.9$^{a}$ | 25.5 | 1.3 | 21.4$^{a}$ | 30.4 | 1.4 |
| C.D. ($p \geq 0.05$) Interaction | 2.3 | NS | NS | | | | | | | | | |

duration (28 d) whereas it was at par with Fremont. It was significantly followed next to Pearl Tangelo (26 d). Minimum flower duration was noted in the case of Daisy (19 d). W Murcott showed 31 d when budded over X-639 rootstock which is significantly followed by other cultivars under investigation viz. Fairchild, Fremont and Pearl Tangelo. Minimum days were recorded in the case of Michal (22 d). In the case of Michal, budded over Rough lemon showed the significantly highest duration (36 d) was followed by other cultivars like W Murcott, Pearl Tangelo, and Murcott (each with 33, 33, and 34, respectively) whereas, Daisy recorded the least flower duration of 22 d. A study also reported variation concerning flower initiation to cessation (18 to 25 d) in different Pummelo cultivars under subtropics of Punjab (Baswal *et al,* 2018). Whereas, flowering duration varied from 14 to 28 d in seventeen rough lemon strains under sub-tropical conditions of Punjab (15).

### Days required for fruit set

The data revealed the days required for the fruit set. A non-significant results were recorded in case of various rootstocks, during the course of study. However, Pearl Tangelo took the least days (6 d) for the fruit set. Next to it, Murcott (7 d) while in Kinnow it was observed as 8 d when budded over Volkamer lemon (rootstock). Likewise, when

**Table 3. Flower initiation (particular point of time) of various scion cvs. of mandarin budded over different rootstocks**

| Cultivar | Name of Root stock | | | |
|---|---|---|---|---|
| | Volkamer Lemon | Rangpur Lime | X-639 | Rough Lemon |
| | Flower initiation | Flower initiation | Flower initiation | Flower initiation |
| Daisy | 7th March | 26thFeb | 25th Feb | 20th Feb |
| Michal | 24th Feb | 24th Feb | 19th Feb | 19th Feb |
| Murcott | 25th Feb | 23rd Feb | 23rd Feb | 17th Feb |
| Fairchild | 18th Feb | 22nd Feb | 19th Feb | 17th Feb |
| Fremont | 14th Feb | 17th Feb | 17th Feb | 9th Feb |
| Pearl Tangelo | 9th Feb | 5th Feb | 6th Feb | 4th Feb |
| W/Murcott | 22nd Feb | 21st Feb | 23rd Feb | 18th Feb |
| Kinnow | 1st March | 1st March | 2ndMarch | 26th Feb |

**Table 4. Flower duration, days required for fruit setting and setting to maturity of various scion cvs. of mandarin budded over different rootstocks**

| Cultivars | Name of Root stock | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volkamer Lemon | | | Rangpur Lime | | | X-639 | | | Rough Lemon | | |
| | Flower duration (d) | Fruit setting (d) | Setting to maturity (d) | Flower duration (d) | Fruit setting (d) | Setting to maturity (d) | Flower duration (d) | Fruit setting (d) | Setting to maturity (d) | Flower duration (d) | Fruit setting (d) | Setting to maturity (d) |
| Daisy | 18.0 | 8.00 | 225.3 | 19.0 | 9.00 | 235.3 | 24.0c | 10.0 | 232.7 | 22.0 | 7.00 | 222.3 |
| Michal | 26.0 | 10.0 | 260.3 | 25.0[c] | 8.00 | 267.7 | 22.0 | 14.0 | 275.7 | 36.0[a] | 7.30 | 253.7 |
| Murcott | 27.0 | 7.00 | 319.7 | 25.0[c] | 9.30 | 321.7 | 26.0[b] | 12.0 | 330.3 | 33.0[b] | 8.30 | 317.7 |
| Fairchild | 33.0[b] | 12.0 | 269.3 | 25.0[c] | 9.00 | 278.0 | 27.0[b] | 7.30 | 283.0 | 32.0[c] | 8.00 | 271.3 |
| Fremont | 34.0[a] | 10.0 | 281.7 | 28.0[a] | 10.0 | 294.7 | 27.0[b] | 9.00 | 304.7 | 31.0 | 10.0 | 284.3 |
| Pearl Tangelo | 29.0 | 6.00 | 333.3 | 26.0[b] | 6.00 | 340.7 | 27.0[b] | 7.30 | 346.7 | 34.0[b] | 8.30 | 327.7 |
| W Murcott | 31.0[c] | 8.00 | 327.0 | 28.0[a] | 9.00 | 325.3 | 31.0[a] | 9.00 | 332.3 | 33.0[b] | 9.30 | 318.3 |
| Kinnow | 27.0 | 8.00 | 310.3 | 25.0[c] | 9.00 | 316.0 | 24.0[c] | 5.00 | 323.3 | 26.0 | 12.0 | 313.0 |
| C.D. (p≥0.05) Interaction | 1.40 | NS | NS | | | | | | | | | |

Rangpur lime was used as rootstock, minimum days were noted in the case of Pearl Tangelo (6 d) followed by Michal (8 d). However, the highest number of days were recorded in Michal (14 d), and minimum days in Kinnow (5 d) budded over X-639. Days were maximum in the case of Kinnow (12 d, longest time) when budded over Rough lemon while time was least in Daisy (7 d), followed by Michal (7.30 d). Overall, Daisy took minimum days in fruit setting.

**Days taken for fruit maturity**

Among various rootstocks, significant differences were seen regarding the number of days taken from fruit set to maturity. When Daisy cultivar was budded over Volkamer lemon rootstock showed that minimum days (225.3 d) for fruit maturity followed by Michal. At the same time when Rangpur lime was budded over with the same cultivar (Daisy), it exhibited a minimum

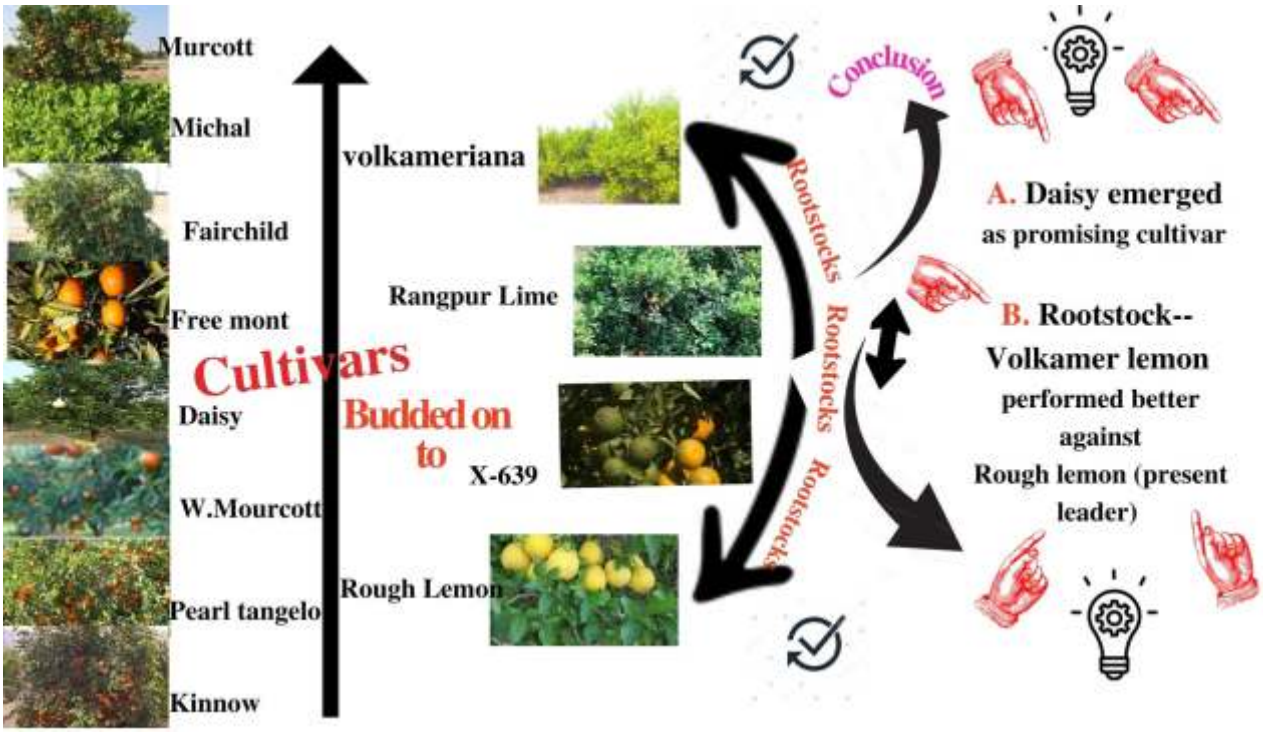


**Fig 1. Summary and conclusion of research experiment**

number of days for fruit maturity *i.e.,* 235.3 while it was followed by Michal (267.7 d). But this cultivar took the least number of days for fruit maturity when budded over X-639 and Rough lemon rootstock (232.7 and 222.3 d, respectively). A study assessed performance of Fremont mandarin on different rootstocks under Indian conditions and revealed that fruit maturity of Fremont was earliest on Pectinifera rootstock, while it was deferred on other rootstocks like Rough lemon and Karna khatta (16).

## CONCLUSO N

It was concluded that for vegetative, blooming, and fruit setting behavior, Daisy, Murcott, and W Murcott emerged as promising cultivars for the climatic conditions of Punjab and may be utilized as an alternative to Kinnow mandarin and to break monoculture in the future. Volkamer lemon and X-639 performed best among rootstocks and can replace the existing rootstock, Rough lemon. Above all, there was a lot of variation in the pairings of cultivars and rootstocks. Daisy and Murcott cultivars budded on Volkamer lemon rootstock, followed by X-639 rootstock, produced the best stionic combinations (Fig 1). These combinations have the potential to replace the existing Kinnow and Rough lemon monoculture. This included study on evaluating the performance of other systems. This envisages research on evaluating the performance of other citrus species to diversify varietal wealth along with increasing productivity, variety diversity for fruit maturity, and quality etc. will be the crucial concerns of variety improvement and breeding in the future. Many potential exotic citrus species/varieties have been introduced in India and some of them have been well adapted, having good potential to be cultivated on a larger scale. But initial screening, characterization of germplasm, evaluation, and potential against biotic and abiotic stresses for future utilization for improvement is recommended.

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