Research Article

Assessment of Stionic Relationship Among Different Rootstocks and Scion Cultivars of Sweet Orange

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Abstract | Research experiment was conducted at the PARC-Participatory Field Research Station, Tarnab, Peshawar to assess the stionic relationship among various rootstocks and scion cultivars of sweet orange (*Citrus sinensis*) to check the compatibility of three scion cultivars viz. Tarocco, Salustina, and Blood Red budded onto five rootstocks: Sour Orange, Carrizo Citrange, Australian Bigarade, Troyer Citrange and Cox Mandarin. Significant differences were observed in both rootstock and scion cultivars in term of scion height, scion diameter and bud take success. Both rootstock and scion types significantly influenced days to bud sprout, with Australian Bigarade showing the earliest sprout (25.9 days) and Cox Mandarin the latest (36.4 days). The buds of Blood Red (scion) sprouted earliest (28.9 days), while Tarocco took the longest days (33.2) to sprout. The best stionic relationship (rootstock-scion combination) was observed for scion cultivar Blood Red, budded on Australian Bigarade rootstock with 89.7%. Conversely, Tarocco budded on Sour Orange resulted in the lowest bud take success (43.4%). Scion height was also affected by rootstock and scion interaction, with Blood Red on Australian Bigarade produced the tallest scion (91.0 cm) and Tarocco on Sour Orange the shortest (51.0 cm). Scion diameter was thickest in Blood Red (8.4 cm) on Australian Bigarade and thinnest in Tarocco on Sour Orange (5.6 cm). Based on these results, Blood Red scion Budded on Australian Bigarade Rootstock is recommended for the agro-climatic conditions of Peshawar.

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Keywords | Scion, Rootstock, Stionic relationship, Bud take success, Vigour.

Introduction

In citrus production, Pakistan ranks 7th globally in terms of area and 13th in terms of production. When compared to leading citrus-producing countries like Brazil, the USA, China, and Spain, Pakistan's production is significantly lower, growing at an average annual rate of just 5%. Brazil dominates with a 35% share of the world's total citrus production, while Pakistan's share is only 1.46%. In Pakistan, citrus is cultivated on approximately 192,832 hectares, with a total annual production of 2,395,550 tonnes (FAO, 2021). The productivity and growth of citrus is largely dependent on the compatibility and performance of the rootstock-scion combination which determine the overall growth, yield, disease

resistance, and fruit quality of the grafted/budded plants. It is critical to evaluate rootstock and scion relationship in citrus as it would ultimately influence the fruit yield, fruit quality and tolerance to diseases . Rootstocks play a crucial role in determining the vigor, yield, and overall health of the grafted scion (Salman *et al.*, 2022). In citrus production, selecting an appropriate rootstock is essential for ensuring optimal growth, disease resistance, and fruit quality. The rootstock also provides the foundation for the tree, influencing the absorption of water and nutrients, tolerance to environmental stresses, and resistance to soil-borne diseases, while the scion determines the fruit characteristics (Salih and Al-Jeboory, 2023).

The stionic relationship between rootstock and scion is complex and varies across different cultivars. The selection of an appropriate rootstock is crucial for growth vigor, bud take success, and fruit production (Baron *et al.*, 2019). Different rootstocks impart varying degrees of influence on scion performance, which can be seen in the differences in bud sprout time, scion height and scion diameter. Sweet orange cultivation is challenged by factors such as soil type, disease susceptibility, and climate variations, which can be mitigated through the careful selection of rootstocks. The choice of rootstock not only affects the growth and yield but also the long-term sustainability of the orchard (Faria-Silva *et al.*, 2020).

This study aims to assess the stionic relationships between different rootstocks and scion cultivars of sweet orange, focusing on their interactive effects on key growth parameters such as bud sprout time, bud take success, scion height, and scion diameter. By identifying the most compatible combinations, this research seeks to provide practical recommendations for citrus growers, helping them to enhance the productivity and quality of their citrus orchards.

Materials and Methods

The study was conducted at the PARC-Participatory Field Research Station, Tarnab, Peshawar, in the year 2023-24. One year old seedlings of four different rootstocks namely: Sour Orange, Carrizo Citrange, Australian Bigarade, Troyer Citrange and Cox Mandarin were used for budding of three sweet orange scion cultivars Tarocco, Salustina, and Blood Red. Five (05) plants per treatment and three replications constituted the experimental material for taking data of various attributes under study using randomized complete block design. The budded plants were monitored for various growth parameters, including days to bud sprout, bud take success percentage, scion height, and scion diameter. Days to bud sprout were counted when 50% of buds sprouted. Bud take success percentage was determined by counting survived sprouted scion seedlings after one month of budding.

Budding was performed using the standard budding technique, with careful selection of healthy and disease-free rootstock and scion materials.The collected data were analyzed using Statistix 8.1 software to determine the significance of the studied attributes. LSD (Least Significant Difference) test at $P \leq 0.05$ was applied for mean comparison (Steel and Torrie, 1980).

Results and Discussion

Days to bud sprout

Data concerning days to bud sprout is shown in Table 1. Both rootstock (R) and scion (S) significantly affected days to bud sprout while interaction (SxT) was non significant. Data regarding different rootstocks, Australian Bigarade resulted in earliest bud sprout (25.9 days) followed by Carrizo Citrange

Table 1: *Days to bud sprout as affected by various sweet orange rootstocks and scion cultivars:*

Scion	Rootstocks					
	Sour orange	Carrizo citrange	Australian bigarrade	Troyer citrange	Cox mandarin	Mean
Tarocco	38.7	29.5	27.7	33.9	36.3	33.2 c
Salustina	35.5	28.4	25.4	31.7	34.4	31.1 b
Blood red	35.1	27.1	24.5	28.5	29.3	28.9 a
Mean	36.4 e	28.3 b	25.9 a	31.4 c	33.4 d	

LSD value for rootstock at P ≤ 0.05 = 1.53
LSD value for scion at P ≤ 0.05 = 1.55
Means followed by similar letters are statistically at par with each other at p ≤ 0.05

(28.3 days) while late bud sprouting was noted in Cox Mandarin (36.4 days). Similarly, regarding various scion cultivars, earliest bud sprout was observed in Blood Red (28.9 days), followed by Salustina (31.2 days), whereas highest number of days were take by Tarocco (33.2) (Figure 1).

Earlier bud sprouting in Australian Bigarade rootstock and Blood Red scion can be attributed to the successful union between stock and scion. These results align with findings of Rehman *et al.* (2017) in sweet orange, as well as Verma *et al.* (2010) in grapes. This early sprouting may be due to favorable temperature that promote active cellular processes at the union site, enabling faster vascular connections between the xylem and cambium tissue of the scion, thus encouraging earlier bud sprouting (Hartmann *et al.*, 2002). The findings of Baloda *et al.* (2016) in jamun further support these results.

Bud take success (%)

Data regarding bud take success is given in Table 2. Rootstock, scion and their interaction significantly affected bud take success in sweet orange plants. Data revealed that the highest bud take success (83.6%) was recorded for Australian Bigarade plants followed by Troyer Citrange (79.1 %) which was at par with that of Carrizo citrange (77.3 %), while Sour Orange resulted in the lowest bud take success (55.8%). Pertaining different scion cultivars, bud take success was highest (84.0%) in case of Blood Red while lowest values (63.2%) were recorded for Tarocco. Regarding various interactions, Blood Red when budded on Australian Bigarade plants recorded the highest bud take success (89.7%) wherease Tarocco when budded on Sour orange gave the lowest bud take success (43.4%) (Figure 2).

Table 2: *Bud take success (%) as affected by various sweet orange rootstocks and scion cultivars:*

Scion	Rootstocks					
	Sour orange	Carrizo citrange	Australian bigarrade	Troyer citrange	Cox mandarin	Mean
Tarocco	43.4	65.0	74.7	69.9	62.8	63.2 c
Salustina	49.3	79.1	86.5	80.4	69.8	73.0 b
Blood red	74.9	87.9	89.7	86.9	80.6	84.0 a
Mean	55.8 d	77.3 b	83.6 a	79.1 b	71.1 c	

LSD value for rootstock at P ≤ 0.05 = 3.23
LSD value for scion at P ≤ 0.05 = 2.04
LSD value for interaction at P ≤ 0.05 = 4.56
Means followed by similar letters are statistically at par with each other at p ≤ 0.05

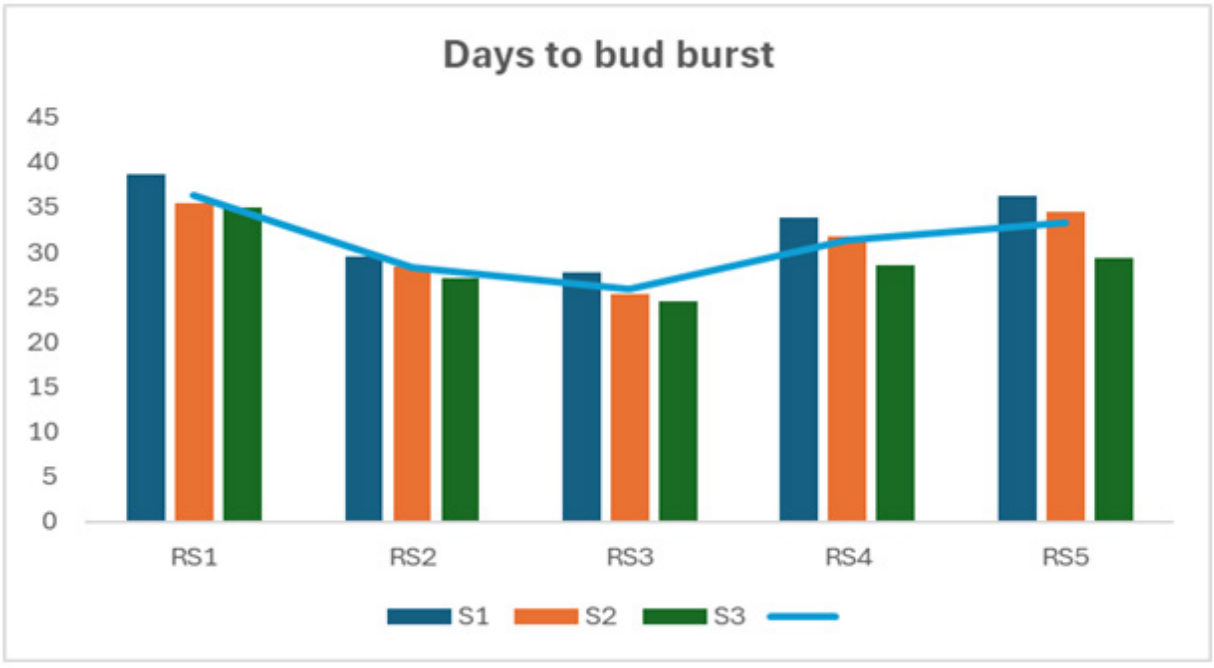

Figure 1: *Days to bud sprout as affected by different rootstocks and scion cultivars*

Table 3: *Scion height (cm) as affected by various sweet orange rootstocks and scion cultivars:*

Scion	Rootstocks					
	Sour orange	Carrizo citrange	Australian bigarrade	Troyer citrange	Cox mandarin	Mean
Tarocco	51.0	62.8	73.9	68.5	55.2	62.3 c
Salustina	53.9	65.4	84.5	72.7	58.4	67.0 b
Blood red	61.8	81.3	91.0	85.8	74.9	79.0 a
Mean	55.6 e	69.9 c	83.1 a	75.7 b	62.8 d	

LSD value for rootstock at P ≤ 0.05 = 3.72
LSD value for scion at P ≤ 0.05 = 1.95
LSD value for interaction at P ≤ 0.05 = 4.37
Means followed by similar letters are statistically at par with each other at p ≤ 0.05

Table 4: *Scion diameter (cm) as affected by various sweet orange rootstocks and scion cultivars:*

Scion	Rootstocks					
	Sour orange	Carrizo citrange	Australian bigarrade	Troyer citrange	Cox mandarin	Mean
Tarocco	5.1	5.7	6.5	5.4	5.4	5.6 c
Salustina	6.7	7.1	8.2	7.3	6.8	7.2 b
Blood red	7.5	8.8	9.1	8.5	7.9	8.4 a
Mean	6.5 c	7.2 b	7.9 a	7.1 b	6.7 c	

LSD value for Rootstock at P ≤ 0.05 = 0.38
LSD value for Scion at P ≤ 0.05 = 0.24
Means followed by similar letters are statistically at par with each other at p ≤ 0.05

Bud take success is closely linked to the compatibility between the rootstock and scion, which enhances the cambium layer bonding and promotes healing. Successful bud take depends on rootstock-scion relationship as well as optimal environmental conditions, including appropriate temperature, humidity, and water levels (Hartmann *et al.*, 2011). The availability of sufficient sap from the scion and stock promotes rapid healing at the bud union, resulting in a swollen bud that achieves better growth and a higher success of bud take. Proper alignment of the cambial layers in the stock and scion also plays a crucial role; close cambial alignment at the time of grafting encourages rapid bud union formation (Thokchom *et al.*, 2019).

Scion height (cm)

Data regarding scion height of sweet orange plants is provided in Table 3. Rootstock, scion and their interaction significantly affected scion height. In case of rootstocks, scion height was maximum (83.1 cm) for plants budded on Australian Bigarade rootstock while minimum value (55.6 cm) was recorded when plants were budded on Sour orange. Regarding Scion cultivars, Tallest scion plants (79.0 cm) were produced when Blood Red was used as a scion cultivar while shortest scions plants (62.3 cm) resulted in Tarocco. Interactions showed that scion height was maximum (91.0 cm) when Blood Red was budded on Australian Bigarade and minimum value (51.0 cm) for scion height was observed in Tarocco plants budded on Sour orange (Figure 3).

Increased scion height Blood Red budded on Australian Bigarade may be attributed to the better allocation of food and nutrients allocation due to a successful union. Lewis and Alexander, (2008) also recorded similar results that the height growth of a grafted plant is largely determined by the vigor of the scion wood, along with adequate water, food, and nutrient availability, and a successful bud union. These factors are deciding factors in promoting vertical growth, allowing the scion to reach optimal height. It was also demonstrated through results that the combination of cultivar and rootstock has a significant impact on plant height (Ahmed *et al.*, 2013).

Scion diameter (cm)

Data pertaining to scion diameter of sweet orange plants is given in Table 4. Both rootstock and scion significantly influenced scion diameter. Regarding rootstocks, thickest scions stems (7.9 cm) resulted in Australian Bigarade and lowest scion diameter (6.5 cm) was noted for Sour orange rootstock which was

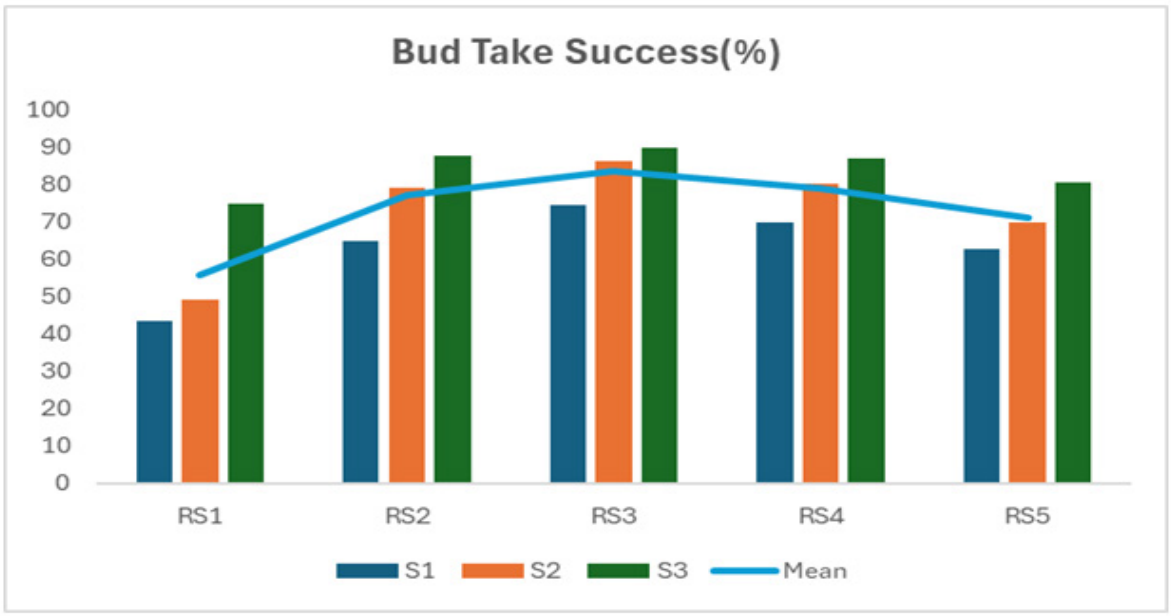

Figure 2: *Bud take success (%) as affected by different rootstocks and scion cultivars*

Figure 3: *Scion height (cm) as affected by different rootstocks and scion cultivars*

significantly at par with that of Cox Mandarin (6.7 cm). According to various scion cultivars, highest scion diameter (8.4 cm) was observed in Blood Red plants while lowest (5.6 cm) was recorded in Tarocco (Figure 4).

With a favorable rootstock-scion relationship, the nutrients and photosynthates within both the scion and rootstock are efficiently distributed to the buds on the scion wood. This balanced distribution ensures that a controlled amount of resources reaches each branch, supporting the vascular cambium's activity in moderate secondary growth of each shoot (Lewis and Alexander, 2008). Conversely, when the rootstock-scion relationship is not optimal, the rootstock tends to monopolize the photosynthates and assimilates. This exclusive allocation encourages the vascular cambium to proliferate rapidly, producing numerous cells outwardly between the wood (xylem) and the bark (phloem, cortex, and periderm). As a result, this excess allocation drives vigorous outward growth, manifesting as enhanced secondary growth in the

plant (Kumar, 2009).

Figure 4: *Scion diameter (cm) as affected by different rootstocks and scion cultivars*

Conclusions and Recommendations

It was concluded that Blood Red Budded on Australian Bigarade roostock resulted in early bud sprouting, highest bud take success, scion height and scion diameter and hence are recommended for the agro-climatic conditions of Peshawar.

Novelty Statement

This research study explores the influence of different sweet orange scion cultivars and rootstocks on key growth parameters. It provides insights into stionic relationships and the importance of rootstock choice in improving citrus nursery plants production.

Author's Contribution

Gulzar Ullah: Conducted the experiment, data collected and analyses, writeup of the manuscript
Riaz Alam: Planned the experiment, Supervision, conceptualization

Generative AI and AI-assisted technology statement
The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in this manuscript.

Conflict of interest
The authors have no conflict of interest.

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