

**Effect of Different Rootstocks on Success of Budding in
Nagpur Mandarin (*Citrus reticulata* Blanco.)**

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ABSTRACT

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The present investigation entitled “Effect of different rootstocks on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco.)” was carried out at the Fruits Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar during the year 2008-09. The experiment was laid out in Factorial Randomized Block Design with four treatments and five replications. One year old seedlings of different species [Rough lemon (*Citrus Jambhiri* Lush.), Rangpur lime (*Citrus limonia* Usbek), Sour orange (*Citrus aurantium* Linn.) and Carrizo (*Citrus sinensis* (L) Osbek x *Citrus trifoliata* L.)] of citrus were used as rootstock for budding of Nagpur Mandarin. The budding operation was undertaken on 15th Oct, 2008.

It was found that Sour orange had maximum bud take percentage (78.94 %). Maximum budding success (68.313 %), minimum days (54.400) required for 50 % sprouting, maximum length of scion shoot (17.98 cm), maximum plant height (34.584 cm), number of nodes/plant (1.546), number of branchlets/plants (0.054). Maximum leaf area (15.958 cm²), RWC of leaves (51.744 %) and chlorophyll content in leaves (0.194 mg/g) were observed on Rough lemon. The minimum days required (18.740 days) for first sprouting, maximum length of internodes/plant (0.296 cm), number of leaves (24.460) on scion and the maximum girth of rootstock (372.680 mm), length of longest primary root (20.218 cm), length of longest secondary root (7.648 cm) and maximum number of secondary root (29.540) were recorded in Rangpur lime.

It was found that scion of Nagpur Mandarin had vigorous performance on the Rough lemon rootstock.

1. INTRODUCTION

Citrus is the third most important fruit crop grown in India after mango and banana with production of 63.26 lakh tonnes from commensurate acreage of 7.59 lakh hectares (Anonymous 2006). Citrus trees were generally grown from seed until the mid 1800's and are still being grown from seed in certain areas of the world. Because of grave damage to orange seedling trees by *Phytophthora* foot rot, in around 1842, being particularly sensitive, the transition to the budded trees in citriculture began in most environmental conditions (Spiegel Roy and Gold Schmidt, 1996). Citrus fruits are now grown on different rootstocks all over the world due to the problem of *Phytophthora* and nematodes with certain exceptions (Broadbent and Gollnow, 1993; Broadbent and Sarooshi, 1993). Seedling trees also show a high degree of juvenility which is often associated with late bearing. To get rid of these problems, citrus scion cultivars are budded or grafted onto rootstocks propagated from seed. Thus, citrus trees are composed of two components: scion and rootstock. This combination combines the desirable attributes of the rootstock and the scion. Hence, rootstock selection is very important before the establishment of an orchard. In addition to supporting the tree in the soil, the rootstock is responsible for absorption of water and nutrients, providing storage of carbohydrate, adapting the scion to particular soil conditions and providing tolerance to some diseases. It is believed that more than 20 characteristics of scion are influenced by the rootstock. These characteristics include tree vigour and size, depth of rooting, freeze tolerance, soil adaptation, resistance /tolerance to diseases like *Phytophthora* foot rot and blight and to nematodes, and the fruit yield, size, texture, internal quality and fruit maturity (Castle, 1987). The effect of rootstock on vigour and tree size, fruit size, yield, fruit and juice quality as well as on tolerance to salt, cold and drought and biotic stresses besides on leaf mineral content in the scion has also been highlighted by Wutscher 1989.

Rootstocks need to show good and prolonged compatibility with scion varieties. They contribute largely to success and failure in citrus industry. Presently, smaller, high yielding trees are sought for closer planting, but in citrus satisfactory dwarfing rootstocks are generally not available. Practically every facet of citrus ranging from vegetative growth through to production, fruit quality and tree longevity are to be greater or lesser extent influenced by the rootstock. The factors which will carry most weight in the final choice of the rootstock in any particular case will be those which place the culture of the scion cultivars in greatest jeopardy. Each rootstock possesses some specific feature which influences different attributes of scion. The characteristic features of rootstocks under study are presented as under:

Carrizo citrange - It is a hybrid between sweet orange (Washington Navel) (*Citrus sinensis* (C) Osbeck.) and trifoliate orange (*Poncirus trifoliata* L.). It has shown tolerance to *Phytophthora* foot rot and burrowing nematode (Ford, 1964-65). Trees on this rootstock are vigorous and produce excellent crops of high quality fruit in their early years (Hutchison, 1974; Monteverde *et al.* 1988).

Rangpur lime – Trees on this stock are vigorous. It produces high yield of sweet oranges (Passos and Cundha Sabrinko, 1988). On this rootstock better quality fruits are produced than Rough lemon (Ford, 1964-65). It has been proved tolerant to soil salinity (Walker and Douglas, 1983) and susceptibility to *Phytophthora* foot rot (Carpenter and Furr, 1962).

Rough lemon – It shows high degree of nucellar embryony (Barrett and Rhodes, 1976). It produces extensive root system (Castle and Krezdorn, 1973) being vigorous in growth (Yelenosky and Young, 1977), has shown tolerance to tristeza, exocortis and xyloporosis (Wutscher, 1979) and is susceptible to citrus burrowing nematodes (O' Bannon and Ford, 1977).

Sour orange (*Citrus aurantium* L.) – Its susceptibility to tristeza virus has reduced its use (Davies and Albrigo, 1994). It is still a leading rootstock in Spain (Castle, 1987). It produces moderately vigorous tree (Hutchison, 1977). It is tolerant to *Phytophthora* foot rot (Sgvertsen *et al.*, 1983) but susceptible to citrus burrowing nematodes (O' Bannon and Ford, 1977).

In Malwa plateau region of India, especially in Jhalawar and Kota districts of Hadauti region of Rajasthan, mandarin orange finds favour among orchardists. For raising mandarin orange, use of different rootstocks is in vogue. The rootstock performing well in a particular locality may not perform that well in another locality. Hence, in present study, attempt was made to observe the performance of different rootstocks in the region so as to draw inferences regarding suitability of a particular rootstock in terms of budding performance of scion cultivar.

The experiment was carried out with following basic objectives:

- i) To study the effect of different rootstock on success of budding.
- ii) To observe influence of rootstock on growth attributes of scion.
- iii) To study the performance of rootstocks under the influence of scion cultivar.

2. REVIEW OF LITERATURE

The work done on various aspects of budding pertaining to citrus including mandarin has been reviewed and is presented suitably. However, relevant literatures on other fruit crops on the matter in context have also been incorporated wherever felt necessary to support the view as observed in present investigation.

a) Budding performance

Dubey and Singh (2003) observed significant variations in success of Mandarin and it varied from 20 % in Carrizo to 90 % to Rough lemon.

Singh (1960) pointed out that both mandarin and mosambi had better performance on Florida Rough lemon than on Karna Khatta. Karna Khatta was better for Navelencia orange.

Sharma and Sharma (1986) conducted experiment in Punjab and reported that the bud take of Kinnow on *C. jambhiri* was 98 per cent with better subsequent growth when round buds without wood were used than by using angular buds with or without wood.

Dubey and Singh (2003) in an experiment pertaining to rootstocks under foot hills conditions of Arunachal Pradesh using 'Khashi Mandarin', 'Nagpur Mandarin', 'Sikkim Mandarin' and 'Darjeeling Mandarin' reported that among the mandarins, Darjeeling Mandarin had maximum success (38.33%), whereas, final survival was found maximum in 'Nagpur Mandarin'. The 'Sikkim Mandarin' had highest scion length (20.26 cm) and diameter (5.41 mm).

Ganpathy *et al.* (1985) reported that pinched seedlings of *Poncirus trifoliata* and Rangpur lime gave higher bud take of Coorg Mandarin.

Singh *et al.* (1989) conducted experiment to observe the effect of time of budding in citrus species. They used scion of healthy mother tree of Mosambi (Orange), Santra (Mandarin), Grape fruit (*Citrus paradisi*) and Shaddock (Pummelo) and these were budded on *Citrus jambhiri* rootstock on 6 dates; 15 and 30th August, 15 and 30th September, 15th February and 15th March. They found highest per cent of bud intake (88.25 %), longest shoot (18.52 cm) and highest

number of leaves per shoot (19.75) when assessed 90 days after budding. The next best result was obtained by budding in September followed by those budded on 15 March.

Mukherjee and Singh (1966) found the effect of season of budding of sweet orange (*Citrus sinensis*) and observed that October was the best time for budding under Delhi condition.

Stevenson (1974) reported that 'T' budding gave 87 per cent success in citrus species.

Joalka (1986) in an experiment pertaining to the method and time of budding on bud take in Kinnow Mandarin found the maximum bud take (90 per cent) of Kinnow on *Citrus jambhiri* during May under Palampur (H.P.) condition.

Son and Kapadia (1984) observed that bud take, sprouting and bud survival of *Citrus sinensis* and *Citrus reticulata* on *Citrus karna* were highest during February under Udaipur condition.

b) Growth attributes

Bajwa and Nagpal (1955) observed that Karna Khatta imparted greater vigour to Marsh Seedless grapefruit plants in the nursery stage, but the relative rate of growth was lower than on Rough lemon. Later on, Rough lemon proved to be vigorous as compared to Karna Khatta. The growth rate was very low on sweet lime and citron.

Bhullar and Nauriyal (1974 and 1975) found that Blood Red trees on Rough lemon were more vigorous than on other rootstocks.

Dhillon *et al.* (1981) reported Blood Red and Mosambi as more vigorous on Rough lemon than on Troyer.

Hutchison (1977) noted that trees budded on Sour orange were somewhat slower growing than those on Rough lemon, but it produced a tree of moderate vegetative vigour and size.

Jalilop *et al.*, (1986) noted that pre-bearing performance of Kinnow under rainfed condition was better on Rough lemon, Troyer and Rangpur lime than on Trifoliate orange and Cleopatra mandarin.

Sweet lime rootstock was found to be best with regard to vigour, precocity, yield, fruit weight, TSS/acid ratio and immunity to collar rot (Singh 1996).

Singh and Nagpal (1954) found Rough lemon as vigorous rootstock for Blood Red Malta.

Singh (1960) reported that the growth of Sangtra and Srinagar Mandarins were more vigorous on Florida Rough Lemon than that on Karna Khatta. Likewise, Mosambi also performed better on Florida Rough Lemon. The Valencia trees exhibited better growth on Karna Khatta.

Hutchison (1977) found that tree budded on sour orange were slow growing than those on Rough lemon, but it produced a tree of moderate vegetative vigour and size.

Sonker *et al.* (2004) studied growth parameters of acid lime on 19 stionic combinations under Central Indian conditions. They found that the acid lime seedling Schaub Rough Lemon, Troyer Citrange (Chethalli), CHES Rough lemon and Cleoptra Mandarin (Texas) were the vigorous rootstocks and dwarfing effect there of on growth was recorded in acid lime budded on strain of Cleopatra Mandarin (Coorg) rootstock.

Chaudhari *et al.*, (1974) found that Rangpur lime as the best rootstock for vigor, health and productivity for Mandarin.

Singh *et al.*, (1978) observed rootstocks of Sohsarkar (*C. karna*) vigours followed by Troyer and *Carrizo citrange* which were medium in growth habit and the least growth of Mosambi was there on Trifoliate orange.

Ford (1964-65) observed that the tree budded on Rangpur lime was vigorous in growth similar to the trees produced on Rough lemon. It produced large trees with minimum cold tolerance, high yield and large fruit size. Fruit quality was slightly better than tree produced on Rough lemon. Further, he reported that the trees budded on Rough lemon rank at or near the top in vigour of growth and size of trees produced when compared with trees on other rootstocks. Yield was maximum and fruit size was also maximum with thick and poor quality of juice on this rootstock.

Crescimanno *et al.* (1981) ; Hutchison (1974) ; Monteverde *et al.* (1988) reported Carrizo citrange as the excellent rootstock for performance of young trees. Trees on this rootstock were vigorous in growth habit.

Jawanda and Mehrotra (1974) found that Jhatti Khatti and Karna Khatta showed higher vigour than other rootstocks. They further reported that Jatti Khatti excelled all other rootstocks in imparting vigour followed by Karna Khatta, Troyer and Carrizo.

Mehrotra *et al.* (1984) found vigorous nature of Jatti Khatti and trees on it were heavy yielder.

Singh and Singh (1942) noted Karna Khatta followed by Jatti Khatti as vigorous, sweet lime as dwarfing irrespective of scion varieties budded on these rootstocks. Malta Local was vigorous on Nasnaran whereas, Sangtra was dwarf on it. Malta Local and grapefruit were dwarf on citron rootstock.

Aiyappa *et al.* (1974) noted that Cleopatra, Troyer and Australian trifoliolate were good rootstocks for mandarin as far as growth and production were concerned.

Chohan *et al.* (1978) under Abohar condition found that Kinnow showed vigorous growth on Jatti khatti and on Karna Khatta than on Troyer and Carrizo rootstocks.

In an observation Italian 76 was observed as the best rootstock for Vanilla orange with regards to vigour as evident by stock girth and scion height (Prasad 1967).

c) Leaves parameter

In a trail Singh and Dass (1999) found that Rangpur lime exhibited maximum canopy of Mandarin while on Carrizo the canopy volume was the lemon.

Cruz *et al.* (2007) conducted a study on evaluation of leaf water potential on the mandarin orange. They found the leaf water potential of citrus decreased under conditions of high temperature.

Gibbs (1971) reported maximum water content in leaves near sunrise and its decreased during the morning and midday.

Malik and Srivastava (1980) reported co-relation of leaf area with the rate of transpiration in the plant growth. The role of leaves in affect transparent has also been highlighted by Brown (2008). He further pointed out the influence of leaf area on photosynthesis a primary mechanism of nourishment and ultimately growth in plant.

d) Rootstock performance

Castle and Krezdorn (1973) found extensive root system in Rough lemon sometimes reaching a depth of 4-6 m in deep sands. They also reported the drought tolerance attribute of Rough lemon.

Vigorous and spreading growth habits of root system of Rough lemon have also been reported by Castle and Youtsey (1977) and, Savage *et al.* (1945).

Das (1948) considered Rough lemon as the best rootstock for Sweet oranges and Sour orange was next to it.

Singh (1962) noted that Italian-76 was most suitable rootstock for Mandarin and fruits excelled in vigour and vitamin C content when budded over it.

Singh (1963) observed Karna Khatta as better rootstock than Trifoliate orange for mandarin.

Castle and Youtsey (1977) found that Rangpur lime has a more prominent lateral root system composed of fewer thicker and longer roots.

Rangpur lime was promising rootstock for Mosambi (Chohan and Kumar 1983).

Ram *et al.*(1999) reported the lowest shoot : scion ratio in lime plants raised at Rangpur lime rootstock.

It was observed that Sour orange had vigorous and, spreading root system characterized by an abundance of lateral and feeder roots (Castle and Youtsey, 1977).

Castle and Youtsey, (1977) noted that Carrizo citrange, has a poor root system development. The root system consisted of a prominent tap root, but only a small number of feeder and lateral roots were there in the plants.

Kumar and Ganapathy (1992) in a trail on suitability of rootstocks for sweet orange cv. Mosambi, grown in the Chotanagpur region of Bihar, reported *Carrizo citrange* followed by Rough lemon and *Troyer citrange* as the best rootstocks.

Troyer and Jatti Khatti shown to be good rootstock (Chohan and Kumar 1986) for Nagpur Mandarin.

Jatti Khatti proved to be most vigorous rootstock for Blood Red sweet orange followed in order by Cleopatra, Karna Khatta, Troyer, Carrizo, Rangpur lime and Citrumelo (Chohan *et al.*, 1982).

3. MATERIALS AND METHODS

The present investigation entitled “Effect of different rootstocks on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco)” was conducted during the year 2008-09 at the Instructional Farm, Department of Fruit science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar. The details of techniques followed and materials used during the course of study are described below:

3.1 Climate and weather

Zone-V (Humid South Eastern Plain)

District Jhalawar extends over 6.32 lac hectares area among 23⁰4' to 24⁰52' N latitude and 75⁰29' to 76⁰56' E- Longitude in South Eastern Rajasthan. Agro-climatically, the district falls in zone V known as Humid South Eastern Plain .About 84.22 per cent population is rural whose main occupation is agriculture and its related activities. Average rainfall in the region is 954.7 mm. Maximum temperature range in summer is 43⁰-48⁰c and minimum 1⁰-2.6⁰ c during winter (Table 3.1 and fig.3.1). Agriculture and forest land occupy 73.5 per cent and 18.77 per cent area, respectively in the district.

Major Kharif crops of the district are soybean, maize and pulses. While in rabi wheat, mustard, coriander and garlic are main crops. The district has attained premier position in cultivation of mandarin orange. In the district about 14 thousand ha area is under the cultivation of mandarin and the total production is 89.9 thousand tonnes. (Anonymous, 2004-05)

3.2 Soil condition

In order to assess the physico-chemical properties of the experimental soil, the soil samples were drawn randomly from different spots in the nursery at a depth should be 0-15 cm before the commencement of the experiment. A representative sample was prepared and subjected to mechanical, physical and chemical analyses. The detail of soil properties as observed is presented ahead.

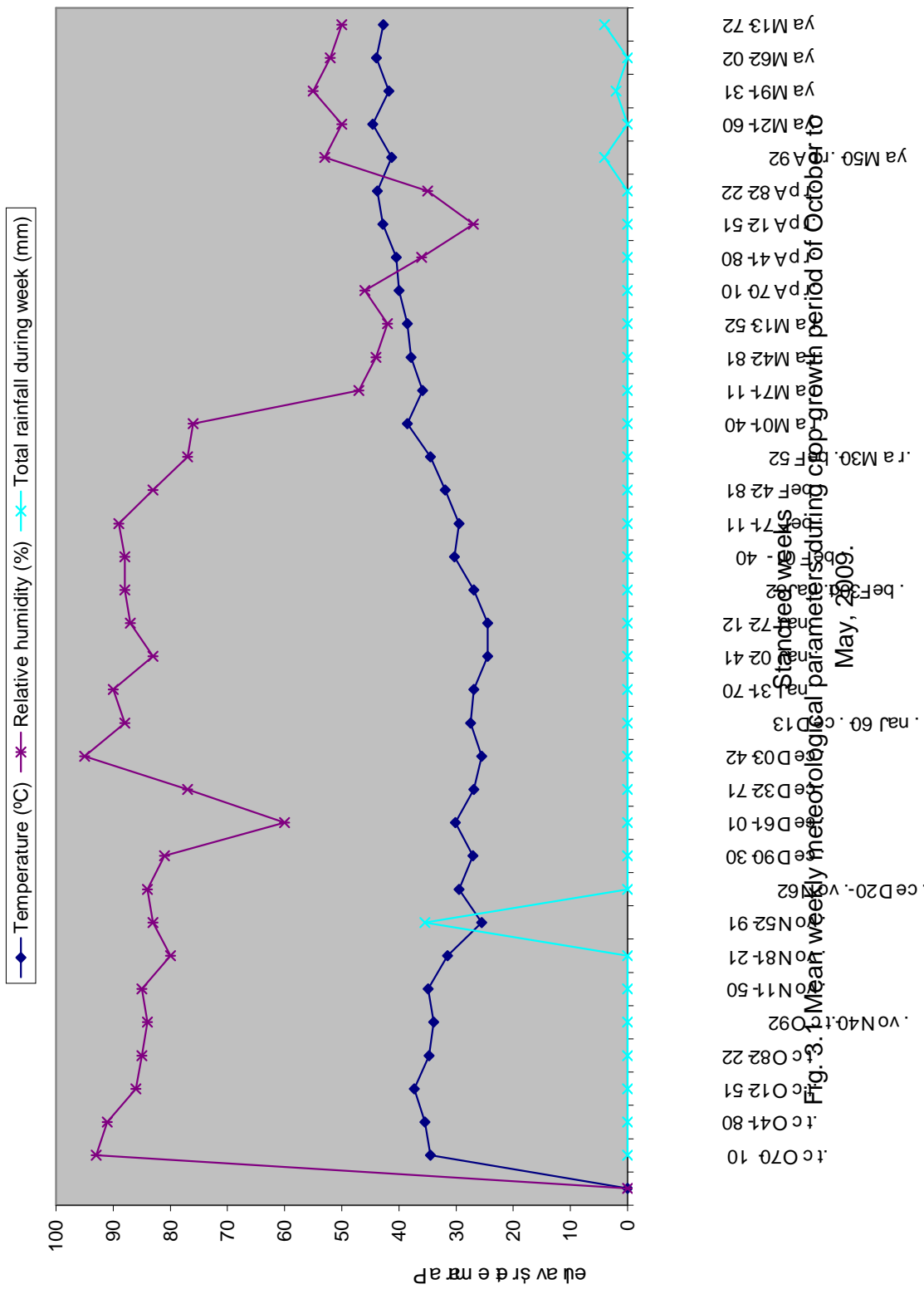
Table 3.1: Mean weekly meteorological parameters during budding period

of October, 2008 to May, 2009.

Standard week Number	Duration	Temperature (°C)		Relative humidity (%)		Total rainfall during week (mm)
		Max.	Min.	Max.	Min.	
39	01 -07 October	34.50	23.5	93	66	0
40	08-14 October	35.50	22.5	91	51	0
41	15-21 October	37.30	25.5	86	40	0
42	22-28 October	34.70	16.9	85	44	0
43	29 Oct.-04 Nov.	33.90	16.9	84	40	0
44	05-11 November	34.90	16.3	85	31	0
45	12-18 November	31.50	16.9	80	36	0
46	19-25 November	25.50	16.9	83	73	35.5
47	26 Nov.- 02 Dec.	29.50	12.5	84	34	0
48	03-09 December	27.10	13.9	81	55	0
49	10-16 December	30.10	15.3	60	34	0
50	17-23 December	26.90	15.5	77	46	0
51	24-30 December	25.50	9.9	95	45	0
52	31 Dec. -06 Jan.	27.50	10.9	88	42	0
1	07-13 January	26.90	11.5	90	57	0
2	14-20 January	24.50	14.5	83	42	0

3	21-27 January	24.50	14.2	87	62	0
4	28 Jan. to 03 Feb.	26.90	11.5	88	39	0
5	04 - 10 February	30.30	11.9	88	29	0
6	11-17 February	29.50	12.9	89	50	0
7	18-24 February	31.90	14.5	83	34	0
8	25 Feb.-03 March	34.50	17.5	77	38	0
9	04-10 March	38.50	17.9	76	24	0
10	11-17 March	35.90	19.5	47	22	0
11	18-24 March	37.90	18.17	44	18	0
12	25-31 March	38.57	21.4	42	24	0
13	01-07 April	39.98	22.07	46	12	0
14	08-14 April	40.44	21.14	36	10	0
15	15-21 April	42.80	24.01	27	7	0
16	22-28 April	43.75	26.02	35	12	0
17	29 Apr. -05 May	41.30	25.08	53	18	4
18	06-12 May	44.58	25.01	50	19	0
19	13-19 May	41.75	26.47	55	19	2
20	20-26 May	43.92	27.52	52	20	0
21	27-31 May	42.72	24.48	50	19	4

Source: Meteorological Department , Govt. of Rajasthan, Jhalawar, 2008-2009.



3.2: Physico-chemical properties of soil of the experimental field (2008-09)

Table

Fig. 3.1 Mean weekly meteorological parameters during crop-growth period of October to May, 2009.

Standard weeks

ya M13 72
ya M62 02
ya M91 31
ya M21 60
ya M50 1A92
pa A82 22
pa A12 51
pa A41 80
pa A70 10
pa A13 52
pa A42 81
pa A71 11
pa A01 40
pa A30 52
pa F42 81
pa F71 11
pa F01 40
pa F30 52
pa F72 12
pa F02 41
pa F31 70
pa F60 13
pa F90 42
pa F32 71
pa F61 01
pa F90 30
pa F20 62
pa N52 91
pa N81 21
pa N11 50
pa N40 1092
pa N82 22
pa N12 51
pa N41 80
pa N70 10

Properties	Values	Method employed
(A) Mechanical compositions		
1. Sand (%)	23.1	International pipette method
2. Silt (%)	37.2	International pipette method
3. Clay (%)	39.6	International pipette method
(B) Physical properties		
1. Bulk density (Mg m^{-3})	1.40	Core sampler method (Piper, 1950)
2. Particle density (Mg m^{-3})	2.65	Black (1965)
3. Porosity (%)	43.2	Black (1965)
(C) Chemical properties		
1. Organic carbon (%)	0.58	Walkley and Black (1934)
2. Available Nitrogen (kg ha^{-1})	324	Alkaline KMnO_4 (Subbiah and Asija)
3. Available phosphorus ($\text{P}_2\text{O}_5 \text{ kg ha}^{-1}$)	20.81	Olsen's method (Olsen et al., 1954)
4. Available Potassium ($\text{K}_2\text{O kg ha}^{-1}$)	298	Flam photometer method (Metson, 1956)
5. EC ($\text{dsm-1 at } 25^{\circ}\text{c}$)	0.98	Using solubridge (Jackson, 1973)
6. pH (1:2: Soil: water suspension)	7.6	Potentiometric Method using pH meter (Jackson, 1973)

The Soil of experimental site was clay loam in texture (Black cotton), normal in reaction and medium in respect to nitrogen, phosphorus and potassium.

3.3 Plant materials

3.3.1 Rootstocks

One year old plants of Rough lemon (*Citrus jambhiri* Lush), Rangpur lime (*Citrus limonia* Usbek), Sour Orange (*Citrus aurantium* Linn) and Carrizo (*Citrus sinensis* (C) Osbeck x *Citrus trifoliata* L.) were used as rootstocks. The plants were grown at the Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalrapatan, Jhalawar. For the experiment, total 200 plants were selected from different rootstocks to record various observations pertaining to the study.

3.3.2 Scion

Latent buds of current season growth were utilized as scion

- Scion species : *Citrus reticulata* Blanco
- Scion cultivar : Nagpur Mandarin

3.4 Other detail of the experiment

- Age of rootstock : 12 Months
- Type of liner seedling production : Bed grown plants
- Total treatments : 4
- Unit plant per treatment : 10
- No. of replications :5
- No. of plants under study : $4 \times 10 \times 5 = 200$ Plants
- Experimental design : Randomized Block Design(RBD)
- Time of budding: October, 2008
- Method of budding : “T” budding

3.5 Observations recorded

3.5.1 Budding performance

i) Bud take percentage (%)

It was recorded on the basis of number of buds manifested swelling on a particular rootstock. Total number of buds sprouted, whether survived further or not, constituted the observation. The number of sprouted buds in different treatments was recorded in order to calculate the percentage of bud take. The per cent bud take was calculated after 10 days of budding operation. Ten plants selected randomly in each replication, were tagged for recording various characteristics at 30 days interval.

ii) Days required for first sprouting

All the budlings (grafts) were watched regularly and date on which first bud sprouted was recorded.

iii) Days required for 50 per cent sprouting

The data on which 50 per cent buds on each rootstock sprouted was recorded to make the observation.

iv) Budding success (per cent)

The sprout which continued surviving till one month after completion of sprouting of entire plants under study were included to record budding success per cent.

3.6 Growth attributes

3.6.1 Stem parameter

v) Length of scion shoot (cm)

The length of new shoot was measured with the help of a meter scale.

vi) Diameter of scion (mm)

The diameter of the new shoot was measured with the help of vernier caliper. It was measured at the very base of its sprouting near the bud union.

vii) Plant height (cm)

The height of the plant was measured from the level of soil surface to the highest tip of the plant with the help of a meter scale.

viii) Number of nodes

It was recorded time to time by counting the number of nodes of entire plant.

ix) Length of internodes

The length of internodes was measured between length of two nodes with the help of a meter scale.

x) Branchlets / plants

The number of branch lets/plant was counted at 30 days interval after sprouting of bud and till the cessation of growth by May.

All the stem parameter and were recorded at monthly interval right from initiation of scion growth till cessation of growth of the spring flush by the first week of May.

3.7 Leaves parameter

xi) Leaf area (cm²)

For measuring leaf area, three fully grown leaves from new growth emerged during respective observation period were randomly selected each month from each treatment and average leaf area was observed with the help of a leaf area meter.

xii) Number of leaves on scion

Leaves emerging from the newly sprouted scion shoot were counted. Total number of leaves present on the scion shoot during a particular month was observed to record the data.

xiii) Perimeter of leaves

The same leaves as used for recording leaf area were used to measure perimeter. Total number of leaves present on the scion shoot during a particular month was observed to record the data.

xiv) Water potential of leaves (MPa)

The water potential of leaves was recorded at periodic intervals (15 days interval) using Water Potential system, WESCOR, USA. For this purpose, the leaf samples of different rootstocks were taken in polythene bags and were put in the ice box. The leaf samples were then brought to the laboratory and were estimated using Dew point, Water Potential system.

xv) RWC of leaves (%)

To calculate RWC following observation were made-

A) Fresh weight of leaves

Three fully grown leaves were randomly selected at 15 days interval in each treatment and fresh weight was recorded with the help of an Electronic balance and average weight was calculated.

B) Turgid weight

To measure the turgid weight of leaves, the leaves selected for fresh weight were dipped in distilled water for 24 hours and their turgid weight was recorded with the help of an Electronic balance and average weight was calculated.

C) Dry weight of leaves

The leaves which were selected for turgid weight were dried in oven at 60⁰c for 24 hrs. After drying, the dry weight of leaves was recorded with the help of electronic balance and average was made. RWC (%) was calculated by using following formula.

$$RWC (\%) = \frac{FW-DW}{TW-DW} \times 100$$

Where-

FW=Fresh weight

DW=Dry weight

TW=Turgid weight

xvi) Chlorophyll content

Chlorophyll content was measured as per method as suggested by Sadasivam and Manickam (1997). The details of procedure followed are mentioned here as under:

- 1 g. of finely cut leaves was weighted and ground using 20 ml volume of 80 % acetone into a clean mortar.
- The sample was centrifuged (5000 rpm for 5 min.) and the supernatant was transferred to a 100 ml volumetric flask
- The process of centrifuging was repeated until the appearance of colourless residue. The mortar and pestle was washed thoroughly with 80 % acetone to get the clear extract of leaves
- The volume was made up to 100 ml with 80 % acetone
- The absorbance of the solution was read at 64, 663 and 652 nm against the blank solution of 80 % acetone
- The amount of chlorophyll present in the extract was calculated using the following equations-

Chlorophyll (a) mg/g tissue=

$$12.7(A_{663}) - 2.69 (A_{645}) \times V/1000 \times W$$

Chlorophyll (b) mg/g tissue=

$$22.9(A_{645}) - 4.68(A_{663}) \times V/1000 \times W$$

Total Chlorophyll mg/g tissue=

$$20.2(A_{645}) - 8.02 (A_{663}) \times V/1000 \times W$$

Where-

A= Absorbance at specific wavelength

V=Final volume of chlorophyll extract in 80% acetone

W=Fresh weight of tissue extracted

Analysis for chlorophyll content was made at 15 days interval commencing for 15 Feb, 2009 till 1 May, 2009.

C) Rootstock performance

xvii) Girth of rootstock (mm)

For measuring the girth of rootstocks, the plants were marked at a broader point. Initial girth of rootstock was measured separately by using digital vernier caliper at 0 days of budding. It was again recorded after 8 month of budding interval.

xviii) Length of longest primary root (cm)

It was measured with the help of a meter scale. To record it, the length of the longest primary root, soil up to 50 cm depth from ground level was excavated.

xix) Length of longest secondary roots (cm)

To record, the length of the longest secondary root, soil up to 50 cm depth from ground level was excavated. The length was measured using a meter scale.

xx) Number of secondary roots

The number of second order roots were counted to record the observation.

xxi) Root: shoot ratio

The weight of root and shoot were recorded separately and their ratio was calculated. To observe weight of root, the soil up to 50 cm depth from ground level was excavated.

All the parameters pertaining to rootstock performance were recorded at 0 days of budding after detopping rootstock portion above matrix and also after 8 month of budding.

3.9) Statistical analysis

The data pertaining to various investigations on growth and development of budding plants were subjected to statistical analysis following RBD as per method as suggested by Fisher (1950). The significance of various treatment effects was judged with the help of “F” value (test) at 5% level of significance. The critical difference was calculated to assess the significant differences between treatment means.

4. EXPERIMENTAL RESULTS

The results of the experiment entitled "Effect of different rootstocks on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco.)" conducted at the Instruction Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalrapatan, Jhalawar during the year 2008 - 2009 are presented in this chapter. To make the presentation clear pertinent tables and graphs associated with different observations have been included suitably in the chapter. The relevant analysis of variances has been presented under Appendices.

4.1. Bud take percentage (%)

The data mean percentage of bud take and emergence of new shoots as affected by rootstocks have been presented in the Table 4.1.1 and through Fig. 4.1.1. It is clear from the presentation that maximum bud take (78.939 %) was there on Sour orange. It was at par with Rough lemon (73.626 %) and Rangpur lime (69.045). The minimum per cent of bud take was observed in Carrizo (27.894 %).

4.2. Days required for first sprouting

Data with regard to number of days taken for first sprouting are presented in Table 4.2.1 and depicted through Fig. 4.2.1. The data reveal that different rootstocks had significant effect on number of days taken to first sprouting. The scion budded on Rangpur lime rootstock required significantly minimum days in first sprouting i.e. 18.740 days after budding while, it took maximum number of days (46.200 days) when budded on the rootstock Carrizo.

4.3. Days required for 50% sprouting

It is evident from the Table 4.3.1 and Fig. 4.3.1 that different rootstocks extended significant effect on days required for 50 % sprouting of scion. The Rough lemon and Rangpur lime both took minimum number of days (54.400 days) for 50% sprouting than Sour orange (59.680 days). Carrizo took maximum days (177.000) for 50 % sprouting. However, the days required for 50 % sprouting under Sour orange (59.680 days) was statistically at par with both Rough lemon (54.400 days) and Rangpur lime (54.400 days).

4.4. Budding success (%)

The data presented in Table 4.4.1 and Fig. 4.4.1 indicate the rate of budding success in Nagpur Mandarin over different rootstocks. Through Rough lemon (68.313 %) and Sour orange (66.687 %) were at par in offering budding success, the value was higher on formal rootstock. Least success of budding (27.894 %) was recorded on Carrizo which was merely 46.920 % in comparison to Rangpur lime on which the budding success was 59.447 %.

4.5. Length of scion shoot (cm)

The data regarding length of Scion shoot (cm) are shown in Table 4.5.1 and through Fig. 4.5.1. The data exhibited that both the factors of rootstock and period and their interactions showed significant effect of scion shoot. At the termination of observations during May, maximum length of scion shoot (17.978 cm) was recorded on Rough lemon followed Sour orange (15.362 cm) and Rangpur lime (14.320 cm) while minimum length of scion shoot was found on Carrizo (3.594 cm).

4.6. Diameter of scion shoot (mm)

The diameter of scion shoot affected significantly by different rootstocks (Table 4.6.1, Fig. 4.6.1). Excepting January, irrespective of periods of observation, the maximum diameter (17.492 mm) of scion shoot by the end of May was observed on the rootstock Rough lemon. The minimum diameter (4.710 mm) of scion shoot during May was observed on the rootstock Carrizo. The interaction effect of rootstock and period was found to be significant.

4.7. Plant height (cm)

The perusal of data presented in Table 4.7.1 and depicted through Fig. 4.7.1 clearly shows that both the factors of rootstock and period and their interactions had significant effect on height of Nagpur Mandarin plant. On an average, on Rough lemon rootstock, the plant had significantly maximum height (34.584cm) by the end of observation period (May). It was followed by Sour orange (31.666 cm) and Rangpur lime (29.764 cm) during the same period. However, at Carrizo rootstock, the plant had in minimum height (9.768 cm) during May.

4.8. No. of nodes

The data on number of nodes are presented in Table 4.8.1 and depicted through Fig. 4.8.1. The data manifests that both the factors of rootstock, period and their interaction had significant effect on number of nodes. On an average, the total number of nodes were found significantly higher in plants budded on Rough lemon (1.546) and it was minimum in Carrizo (0.080) by the end of observation during May.

4.9. Length of internodes (cm)

Among different treatment, Rangpur lime showed significantly maximum length of internode (0.296 cm) followed by Rough lemon (0.238 cm) and minimum length of internode was found in Carrizo (0.004 cm) (Table 4.9.1 and Fig. 4.9.1) by the end of observations period (May).

4.10. Number of branchlets/plant

Significantly maximum branchlets/plant (0.054) was recorded in plant budded on Rough lemon while minimum (0.004) was observed in Carrizo by the end of observation in May (Table 4.10.1 and Fig. 4.10.1). The interaction effect of rootstock and period was found to be significant.

4.11. Number of leaves on scion

The data presented in Table 4.11.1 and depicted through Fig. 4.11.1 show that the both the factors of rootstock, period and their interaction had a significant effect on number of leaves on scion. There was progressive increase in number of leaves on scion during different periods budded on different rootstocks. The maximum number of leaves on scion during May was recorded on Rangpur lime (24.460) followed by Rough lemon (17.842), Sour orange (15.644) and Carrizo (6.846). The same trend was observed on these rootstocks irrespective of the period.

4.12. Leaf area (cm²)

The data on leaf area (cm²) as influenced by rootstocks, periods and their interaction in Nagpur Mandarin are presented in Table 4.12.1 and depicted through Fig. 4.12.1.

A perusal of data reveals that leaf area increased with advancement of observation period during February to May. At the end of observation during May, the maximum leaf area (15.958 cm²) was observed in Rough lemon, which was significantly higher over other treatments. The minimum leaf area (8.524 cm²) was recorded on Carrizo rootstock by the end of period (May).

4.13. Perimeter of leaves (cm)

The data on perimeter of leaves (cm) on different rootstock are presented in Table 4.13.1 and depicted through Fig. 4.13.1. The data into the Table 4.13.1 reveal that perimeter of leaves increased with advancement of periods of observation from February to May. The maximum perimeter of leaves (15.06 cm) was observed at Rough lemon rootstock followed by Rangpur lime (13.918 cm), Sour orange (12.922 cm) and minimum (10.294 cm) was recorded at Carrizo rootstock. The interaction of rootstock and period had significant effect on perimeter of leaves.

4.14. Water potential of leaves (-Mpa)

The data on water potential of leaves (-Mpa) on different rootstocks in Nagpur Mandarin are presented in Table 4.14.1 and depicted through Fig. 4.14.1.

There was significant difference in water potential at different rootstocks except at Rough lemon during April and May. The interaction of rootstock and period was also significant. It appears that the data didn't show any definite patterns of change during different period of observations. During May, the minimum water potential of leaves (-0.500 Mpa) was observed at Carrizo, which was significantly lower over all other rootstocks. The maximum water potential (-0.140 Mpa) was recorded on Rough lemon rootstock.

4.15. Relative water content of leaves (RWC) (%)

The data on RWC of leaves (%) at different rootstocks during different periods of observations in Nagpur Mandarin are presented in Table 4.15.1 and depicted through Fig. 4.15.1. RWC expressed decreasing trend during different successive periods of observations except at Sour orange during February to March where there was a rise in RWC over preceding period of observation. However, the rate of decrease in RWC of leaves was significantly different at different rootstock during different periods of observations. Further, during May, the maximum RWC of leaves (51.744 %) was observed at Rough lemon, which was significantly higher over all other rootstocks. The minimum RWC of leaves

(44.238 %) was recorded at Sour orange. The interaction effect of rootstock and period was found to be significantly different.

4.16. Chlorophyll content

The data on chlorophyll content budded at different rootstocks during different periods of observations in Nagpur Mandarin are presented in Table 4.16.1 and depicted through Fig. 4.16.1. The chlorophyll content of leaves at different rootstocks didn't show any definite trend of change during different period of observations. However, there was a reduction in its content at different rootstocks during February till March. During May, the maximum chlorophyll content (0.194 mg/g) in leaves was noted at Rough lemon rootstock which was significantly higher than all other rootstocks. The minimum chlorophyll (0.054 mg/g) was noted at Rangpur lime rootstock during May. The interaction effect of rootstock and period was found significant in affecting chlorophyll content in leaves.

4.17. Girth of rootstock (mm)

The data pertaining to increase in rootstock girth in different rootstock have been presented in Table 4.17.1 and depicted through Fig. 4.17.1. A perusal of data indicate that rootstock girth increased with successive periods of observations from 0 days of budding till the observation recorded during the month of May on all the rootstocks. However, the rate of increase on rootstock (mm) was significant. The maximum girth of rootstock (37.268 mm) in May was observed at Rangpur lime. It was significantly higher over all other rootstocks. The minimum girth of rootstock was noted in Carrizo (19.120 mm) after 8 month of budding during May. The rootstock, period and their interaction had significant effect on girth of plant.

4.18. Length of longest primary root (cm)

The data on length of longest primary root (cm) after 0 and 8 months of budding in Nagpur Mandarin are presented in Table 4.18.1 and depicted through Fig. 4.18.1. A perusal of data reveals that the length of primary root increased from 0 days after budding to the end of observations period after 8 months of budding. The maximum length of primary root (20.218 cm) was observed in Rangpur lime. The minimum length of longest primary root (14.394 cm) was recorded in Carrizo after 8 months of budding. The rootstock, period and their interaction were found significant in respect to length of the primary root.

4.19. Length of longest secondary root (cm)

The data on length of longest secondary root (cm) at 0 days of budding and after 8 months of budding are presented in Table 4.19.1 and depicted through Fig. 4.19.1. A perusal of data reveals that the length of secondary roots increased from 0 days of budding to the end of observations period after 8 months of budding. The maximum length of secondary roots (7.648 cm) was observed in Rangpur lime which was significantly higher over all other rootstocks. The minimum length of longest secondary roots (3.310 cm) was recorded at Carrizo after 8 months of budding.

4.20. Number of secondary roots (cm)

The data on number of secondary roots (cm) as observed in different rootstocks during at 0 day of budding and after 8 months of budding are presented in Table 4.20.1 and depicted through Fig. 4.20.1. The critical evaluation of data reveals that number of secondary roots increased with successive advancement of growing period. After 8 months of budding, the maximum number of secondary roots was in Rangpur lime (29.54 cm) after 8 months after budding. Minimum (26.318 cm) was recorded in Carrizo after 8 months of budding. The effect was significant irrespective of the rootstock, periods and their interaction were found significant.

4.21. Root: Shoot ratio

The data on Root: Shoot ratio at 0 day of budding and after 8 months after budding are presented in Table 4.21.1 and depicted through Fig. 4.21.1. A perusal of data highlights that root: shoot ratio increased from 0 days of budding to the culmination of experiment after 8 months of budding. After 8 months of budding, the maximum root: shoot ratio (50.552) was observed in Carrizo. The minimum root: shoot ration (32.004) was noted in Rough lemon after 8 months of budding.

Table 4.1.1: Effect of different rootstocks on bud take percentage (%) during post budding period in Nagpur Mandarin

Rootstocks	Bud take percentage
Rough lemon	73.626 (90.000)
Rangpur lime	69.045 (84.000)
Sour orange	78.939 (94.000)
Carrizo	27.894 (22.000)
SEm_±	4.5867
CD at 5%	14.1330

Note: Figures in parentheses indicate angular transformed value

Table 4.2.1: Effect of different rootstocks on days required for first sprouting during post budding period in Nagpur Mandarin

Rootstocks	Days required for first sprouting
Rough lemon	21.000
Rangpur lime	18.740
Sour orange	25.880
Carrizo	46.200
SEm_±	0.473
CD at 5%	1.459

Table 4.3.1: Effect of different rootstocks on days required for 50% sprouting during post budding period in Nagpur Mandarin

Rootstocks	Days required for 50% sprouting
Rough lemon	54.400
Rangpur lime	54.400
Sour orange	59.680
Carrizo	177.000
SEm_±	1.422
CD at 5%	4.384

Table 4.4.1: Effect of different rootstocks on budding success (%) during post budding period in Nagpur Mandarin

Rootstocks	Budding success (%)
Rough lemon	68.313 (86.000)

Rangpur lime	59.447 (74.000)
Sour orange	66.687 (84.000)
Carrizo	27.894 (22.000)
SEm±	6.002
CD at 5%	8.415

Note: Figures in parentheses indicate angular transformed value

Table 4.5.1: Effect of different rootstocks on length of scion shoot (cm) during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	8.032	12.062	14.532	16.922	17.978
Rangpur lime	8.046	9.458	13.108	13.707	14.320
Sour orange	8.030	9.388	13.800	14.372	15.362
Carrizo	0.000	0.000	0.000	3.184	3.594
	SEm±	CD at 5%			

Rootstocks (R)	0.146	0.411	
Period (P)	0.163	0.459	
R x P	0.326	0.919	

Table 4.6.1: Effect of different rootstocks on diameter of scion shoot (cm) during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	7.760	12.656	16.180	17.100	17.492
Rangpur lime	9.860	10.960	11.920	12.260	12.564
Sour orange	9.200	14.980	16.680	17.510	18.064
Carrizo	0.000	0.000	0.000	4.148	4.710
	SEm_±	CD at 5%			
Rootstocks (R)	0.116	0.328			
Period (P)	0.130	0.367			
R x P	0.260	0.734			

Table 4.7.1: Effect of different rootstocks on plant height (cm) during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	22.684	27.134	32.260	33.524	34.584
Rangpur lime	17.600	20.018	27.234	29.028	29.764
Sour orange	19.800	22.942	30.256	31.504	31.666
Carrizo	0.000	0.000	0.000	8.910	9.768
	SEm±	CD at 5%			
Rootstocks (R)	0.239	0.675			
Period (P)	0.268	0.755			
R x P	0.536	1.510			

Table 4.8.1: Effect of different rootstocks on number of nodes during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	0.500	0.520	1.540	1.546	1.546
Rangpur lime	0.780	0.900	0.920	0.940	0.940
Sour orange	0.020	0.040	0.092	0.120	0.180
Carrizo	0.000	0.000	0.000	0.040	0.080

	SEm±	CD at 5%	
Rootstocks (R)	0.040	0.114	
Period (P)	0.045	0.128	
R x P	0.090	0.256	

Table 4.9.1: Effect of different rootstocks on length of internodes (cm) during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	0.204	0.214	0.234	0.238	0.238
Rangpur lime	0.018	0.068	0.088	0.112	0.296
Sour orange	0.000	0.000	0.010	0.012	0.014
Carrizo	0.000	0.000	0.000	0.004	0.004
	SEm±	CD at 5%			
Rootstocks (R)	0.024	0.069			
Period (P)	0.027	0.077			
R x P	0.055	0.154			

Table 4.10.1: Effect of different rootstocks on branchlets/plant during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	0.000	0.004	0.054	0.054	0.054
Rangpur lime	0.018	0.020	0.020	0.020	0.020
Sour orange	0.000	0.000	0.050	0.050	0.050
Carrizo	0.000	0.000	0.000	0.004	0.004
	SEm_±	CD at 5%			
Rootstocks (R)	0.003	0.008			
Period (P)	0.003	0.010			
R x P	0.007	0.019			

Table 4.11.1: Effect of different rootstocks on number of leaves on scion during post budding period in Nagpur Mandarin

Rootstocks	Period				
	January	February	March	April	May
Rough lemon	6.464	9.640	17.034	17.564	17.842
Rangpur lime	10.040	12.450	24.408	24.454	24.460

Sour orange	8.468	9.624	14.832	15.044	15.644
Carrizo	0.000	0.000	0.000	6.458	6.846
	SEm±	CD at 5%			
Rootstocks (R)	0.365	1.030			
Period (P)	0.408	1.151			
R x P	0.817	2.303			

Table 4.12.1: Effect of different rootstocks on leaf area (cm²) during post budding period in Nagpur Mandarin

Rootstocks	Period					
	15 February	1 March	15 March	1 April	15 April	1 May
Rough lemon	13.128	14.292	15.044	15.726	15.914	15.958
Rangpur lime	7.756	8.470	8.860	9.030	9.472	9.510
Sour orange	8.794	9.258	9.852	9.854	10.454	10.440
Carrizo	0.000	0.000	0.000	7.756	8.442	8.524
	SEm±	CD at 5%				
Rootstocks (R)	0.087	0.244				
Period (P)	0.097	0.273				
R x P	0.194	0.547				

Table 4.13.1: Effect of different rootstocks on perimeter of leaves (cm) during post budding period in Nagpur Mandarin

Rootstocks	Period					
	15 February	1 March	15 March	1 April	15 April	1 May
Rough lemon	12.374	12.844	13.454	14.042	14.266	15.060
Rangpur lime	11.782	11.870	13.034	13.064	13.744	13.918
Sour orange	10.348	11.164	11.720	12.354	12.824	12.922
Carrizo	0.000	0.000	0.000	9.052	9.720	10.294
	SEm_±	CD at 5%				
Rootstocks (R)	0.087	0.246				
Period (P)	0.097	0.275				
R x P	0.195	0.550				

Table 4.14.1: Effect of different rootstocks on water potential of leaves (-MPa) during post budding period in Nagpur Mandarin

Rootstocks	Period					
	15 February	1 March	15 March	1 April	15 April	1 May
Rough lemon	0.520	0.220	0.500	0.260	0.180	0.140
Rangpur lime	0.480	0.420	0.640	0.360	0.340	0.460

Sour orange	0.480	0.048	0.300	0.200	0.320	0.240
Carrizo	0.000	0.000	0.000	0.520	0.440	0.500
	SEm_±	CD at 5%				
Rootstocks (R)	0.021	0.060				
Period (P)	0.024	0.068				
R x P	0.048	0.136				

Table 4.15.1 Effect of different rootstocks on relative water content (RWC) of leaves (%) during post budding period in Nagpur Mandarin

Rootstocks	Period					
	15 February	1 March	15 March	1 April	15 April	1 May
Rough lemon	69.445 (87.654)	57.984 (71.886)	57.334 (70.986)	57.359 (70.906)	55.816 (68.432)	51.744 (61.886)
Rangpur lime	61.359 (77.016)	60.928 (76.716)	51.874 (61.816)	51.964 (62.766)	50.365 (59.300)	46.886 (53.288)
Sour orange	58.767 (73.098)	64.842 (81.910)	55.621 (68.112)	54.799 (66.766)	51.770 (61.704)	44.238 (48.670)
Carrizo	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-	52.052 (62.180)	50.304 (59.204)
	SEm_±	CD at 5%				
Rootstocks (R)	0.281	0.790				
Period (P)	0.314	0.884				
R x P	0.629	1.768				

Note- the figures in the parentheses indicate the angular transformed values.

Table 4.17.1: Girth (mm) of rootstocks during post budding period in Nagpur

Mandarin

Rootstocks	Girth (mm)	
	0 Days of budding	After 8 months of budding
Rough lemon	5.214	31.800
Rangpur lime	4.736	37.268
Sour orange	4.620	34.076
Carrizo	3.500	19.120
	SEm_±	CD at 5%
Rootstocks (R)	2.573	7.456
Period (P)	2.877	8.336
R x P	5.755	16.672

Table 4.18.1: The length of the longest primary root (cm) of rootstock during post budding period in Nagpur Mandarin

post budding

Rootstocks	Length of longest primary root	
	0 Days of budding	After 8 months of budding
Rough lemon	8.438	18.456
Rangpur lime	7.560	20.218
Sour orange	9.160	19.392
Carrizo	9.320	14.394

	SEm±	CD at 5%
Rootstocks (R)	0.050	0.146
Period (P)	0.056	0.056
R x P	0.112	0.112

Table 4.19.1: The length of the longest secondary root (cm) of rootstock during post budding period in Nagpur Mandarin

Rootstocks	Length of longest secondary root	
	0 Days of budding	After 8 months of budding
Rough lemon	2.442	5.550
Rangpur lime	2.450	7.648
Sour orange	3.260	6.590
Carrizo	2.356	3.310
	SEm±	CD at 5%
Rootstocks (R)	0.052	0.153
Period (P)	0.059	0.171
R x P	0.118	0.342

Table 4.20.1: The number of secondary roots in rootstock during post budding period in Nagpur Mandarin

Rootstocks	Number of secondary root	
	0 Days of budding	After 8 months of budding
Rough lemon	6.324	24.346
Rangpur lime	7.190	29.540
Sour orange	5.290	27.256
Carrizo	4.424	26.318
	SEm_±	CD at 5%
Rootstocks (R)	0.051	0.149
Period (P)	0.057	0.166
R x P	0.115	0.333

Table 4.21.1: The root: shoot ratio in plants during post budding period in Nagpur Mandarin

Rootstocks	Root: shoot ratio	
	0 Days of budding	After 8 months of budding
Rough lemon	30.221 (25.340)	32.004 (28.100)
Rangpur lime	45.917 (51.600)	46.778 (53.100)

Sour orange	48.274 (55.700)	49.477 (57.780)
Carrizo	46.193 (55.080)	50.552 (59.600)
	SEm_±	CD at 5%
Rootstocks (R)	0.250	0.724
Period (P)	0.279	0.810
R x P	0.559	0.620

Note: Figures in parentheses indicate angular transformed value

5. DISCUSSION

The present investigation entitled **“Effect of different rootstocks on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco.)”** was carried out at Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalrapatan, Jhalawar during the year 2008-09.

The observations were recorded on the different aspects such as budding performance – bud take percentage, days required for first sprouting, days required for 50% sprouting, budding success (%); growth attributes i.e.- length of scion shoot (cm), diameter of scion (mm), plant height (cm), number of nodes, length of internode, branchlets/plant and leaves parameters i.e.- number of leaves on scion, leaf area (cm²), perimeter of leaves, water potential of leaves (MPa), RWC of leaves (%), chlorophyll content (mg/g) and on rootstock performance i.e.- girth of rootstock (mm), length of longest secondary roots (cm), number of secondary roots and root : shoot ratio. In the preceding chapter, many significant variations were observed due to effect of different treatments, which are discussed in the chapter in the light of findings as observed on different rootstocks.

A. Budding performance

Different rootstocks affected bud take (%), days required for first and 50 % sprouting and budding success significantly. As far as budding performance is concerned, the maximum bud take percentage (78.94 %) was recorded on Sour orange and minimum (27.89 %) on Carrizo. This might be due to rapid complete union of xylem and cambium tissue of the scion and rootstock favouring closer matching of the scion tissue to the rootstock stem helping in callus tissue differentiation into new cambium tissue (Hartmann *et al.*, 1997; Janick 1982). The low bud – take percentage as observed on Carrizo might be due to low sap flow (Hartmann *et al.*, 1997). Similar reason may be ascribed for better budding success in Rough lemon. The minimum days required for 50 % sprouting both on Rangpur lime and Rough lemon was 54.4 days. However, the days required for first sprouting and 50 % sprouting were recorded as 46.2 and 177 days respectively on Carrizo. Maximum success in budding was recorded on Rough lemon (68.313 %) and minimum in Carrizo (27.894 %).

Present findings are in consonance to the findings as recorded by Shinde *et al.* (1997). They recorded variation in bud take of Sour orange on different rootstocks and also on survival (%) when budded on different rootstocks. Ganpathy *et al.* (1985) reported higher bud take of Coorg Mandarin on Rangpur lime. Joalka (1986) found the maximum bud take (90 per cent) of Kinnow on Rough lemon

(*Citrus jambhiri*) under Palampur condition. Sharma and Sharma (1986) reported the bud take to the tune of 98 per cent of Kinnow on Rough lemon (*Citrus jambhiri*) with better subsequent growth.

B. Growth attributes

The length and diameter of scion shoot of the bud formed are one of main parameters in judging the success of budding. The length and diameter of newly emerged shoot were found to be significantly affected by rootstock. As regards to the effect of rootstocks on the length and diameter of newly emerged shoot, it was observed that scion shoot showed significantly higher length (17.98 cm) on Rough lemon while maximum diameter (18.06 mm) of scion shoot was noted on Sour orange. Minimum length (3.59 cm) and diameter of scion shoot (4.71 mm) were recorded on Carrizo. Lallan Ram *et al.* (2002) found variation in growth of scion in Nagpur Mandarin budded on different rootstocks. Mishra and Singh (1991) reported that scion length was significantly influenced by different rootstocks. Dubey and Singh (2003) reported greater scion length in Khasi mandarin *Tayum sile* rootstocks on it was Karna khatta in Nagpur Mandarin (19.00 cm), which did not show significant edge over *Tayum sile* (18.67 cm). The Rough lemon had maximum scion length for Darjeeling mandarin (29.88) and Sikkim mandarin (29.75 cm). The higher length of scion shoot under Rough lemon may be due to quick and strong formation of union between the rootstock and bud (Skene *et al.*, 1983) and subsequently due to greater utilization of nutrients by sprouted shoot. The data on plant height, number of nodes, number of branchlets/plants and length of internodes were significantly affected by different rootstocks. On an average, Rough lemon produced maximum plant height (34.58 cm), number of nodes (1.55) and branchlets/plant (0.054). But, the length of internodes was maximum on Rangpur lime (0.296 cm). Minimum plant height, number of nodes, branchlets/plant and length of internodes were recorded on Carrizo, where were 9.76 cm, 0.080, 0.004 and 0.004 respectively.

Maximum plant height, number of branchlets/plant on Rough lemon may be due to its vigorous nature in comparison the other rootstocks facilitating greater absorption of nutrients and water from soil. The vigorous attributes of Rough lemon (*Citrus jambhiri*) has also been reported by Castle and Youtsey (1977), Savage *et al.*, (1945) and Bal (2006).

C. Leaf Parameters

Like shoot length and diameter, number of leaves and other leaf parameters were also affected significantly by rootstocks. The maximum number of leaves on scion, and higher chlorophyll content (mg/g) on leaves were recorded on Rangpur lime which were 24.46, 0.568 mg/g, respectively. The maximum higher water potential of leaves (-0.14MPa), leaf area (15.96 cm²), perimeter of leaves (15.06

cm) and RWC percentage (51.74 %) in leaves were observed on Rough lemon, which were significantly higher over other rootstocks. It may be due to better potency of Rough lemon to absorb and translocate nutrients besides its better photosynthetic ability as appears deceptively from more number of leaves on the rootstock. The role of leaves in photosynthetic production has been highlighted by Sestak (1981).

Significant variation in height, number of leaves, length of nodes and number of nodes were noted with advancement of growing periods. It may be due to ongoing development process accounting to cell division, expansion and differentiation governing size, shape and structure of plants (Taiz and Zeiger 2002). The discernible positive correlation of number of nodes, length of nodes and number of leaves with height may be explained in the light of photosynthetic production and consequently the energy generation. The role of energy in regulation of growth has been narrated by Singh (2005). The minimum number of leaves (6.85) on scion, leaf area (8.52cm²), water potential of leaves (-0.50 MPa) and perimeter of leaves (10.29 cm²) were recorded on Carrizo. The minimum RWC was observed on Sour orange (44.24%) and that the chlorophyll content on Rough lemon (0.042 mg/g).

These may be explained in the light of different growth behavior of rootstock as discussed earlier. The results obtained are in accordance with the earlier findings as highlighted by Dubey and Singh (2003).

The maximum RWC of leaves (%) was recorded on Rough lemon and minimum on Sour orange. It may be linked to stomatal conductance. Higher the stomatal conductance lower the RWC. Loss of water owing to increased stomatal conductance may be ascribed behind less RWC on Sour orange. The loss of water from leaves stomatal conductance has been highlighted by Mallik and Srivastava (1979). The maximum RWC in Rough lemon leaves might be due to inherent character of this species, as it is a vigorous (Singh *et al.*, 2009, Rajput and Singh, 1985) both in term of water and nutrient absorption rootstock as compared to sour orange, Carrizo and Rangpur lime rootstocks which are lazy rootstocks during early growth as compared to Rough lemon.

The maximum chlorophyll content was found on Rough lemon and minimum on Rangpur lime during May. It may be due to differential of synthesis and degradation of chlorophyll in these rootstocks. More photo-oxidation of the Chlorophyll pigment on Rangpur lime may be ascribed to minimum chlorophyll content of this pigment in the shoot grown on this rootstock. The oxidative degradation of chlorophyll has been highlighted by (Richmond and Lang, 1957; Fletcher, 1977; Thiamann, 1980). Further, the high activity of enzyme chlorophyllase may also be attributed to less chlorophyll content in the leaves on shoot grown on Rangpur lime. The role of chlorophyllase in degrading chlorophyll has been highlighted by (Kuroki *et al.*, 1981; Puroid and Barmere, 1981).

D. Rootstock performance

As observed, the girth of rootstock (mm), length of longest primary root (cm), length of longest secondary root (cm), number of secondary roots and root : shoot ratio were significantly affected by different rootstocks as presented under (Table 4.17.1 to 4.21.1).

The maximum girth of rootstock (37.268mm), length of longest primary root (20.22 cm), length of longest secondary root (7.648 cm) and number of secondary roots (29.54) were observed after 8 months of budding on Rangpur lime and minimum on Carrizo rootstock.

In case of root: shoot ratio, maximum ratio of (50.55) after 8 months of budding was observed on Carrizo and minimum root: shoot ratio of 32.004 was found on Rough lemon. Such findings may be due to varying growth behavior of different rootstocks. The results obtained are in accordance with the earlier finding as narrated by Castle and Youtsey (1973) ; Lallan Ram *et al.* (2002); Mishra and Singh (1991) as have been explained under foregoing growth attributes.

6. SUMMARY

The experiment entitled "Effect of different rootstock on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco.)" was conducted during the year 2008-09 at the Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalrapatan, Jhalawar. The results obtained in the preceding chapter have been summarized below:

6.1 Budding Performance:

The Bud take percentage (%), Days required for first sprouting, Days required for 50 per cent sprouting and budding success (%) were significantly influenced by different rootstocks. The maximum bud take per cent (78.393%) of scion was on Sour orange, minimum days required for first sprouting (18.74 days) was there on Rangpur lime. Rough lemon and Rangpur lime had non-significant edge on days required for 50 per cent sprouting. The maximum budding success (68.313%) was recorded in Rough lemon. Minimum percentage of bud take (27.894%), maximum days required for first sprouting and 50% sprouting (46.20 days and 177.00 days respectively) and minimum budding success (27.894%) were recorded on Carrizo.

6.2 Growth attributes

6.2.1 Stem Parameter

The length of scion shoot (cm), diameter of scion (mm), plant height (cm), number of nodes, length of internodes (cm), branchlets/plants were significantly influenced by different rootstocks. The maximum length of scion shoot (17.97 cm), plant height (34.58 cm), number of nodes (1.55) and branchlets/plant (0.054) were recorded on Rough lemon and maximum diameter of scion shoot was observed on Sour orange. However, the maximum length of internode was recorded on Rangpur lime (0.296 cm). Minimum length of scion shoot (3.594 cm), plant height (9.768 cm), number of nodes (0.080), branchlets/plant (0.004), diameter of scion shoot (4.71 mm) and length of internode (0.004 cm) were recorded on Carrizo.

6.2.2 Leaves Parameter

The number of leaves on scion, leaf area (cm²), perimeter of leaves (cm), water potential of leaves (-Mpa), RWC of leaves (%), and chlorophyll content (mg/g) were significantly

influenced by different rootstocks. The maximum number of leaves on scion (24.46), and chlorophyll content (0.568 mg/g) were observed on Rangpur lime. The maximum leaf area (15.958 cm²), leaf perimeter (15.06 cm) and RWC in leaves (51.74%) were observed on Rough lemon. Minimum number of leaves on scion (6.85), leaf area (8.52 cm²), perimeter of leaf (10.29 cm) were observed on Carrizo. The minimum RWC of leaves (44.24%) and chlorophyll content were found in Sour orange and Rough lemon (0.042 mg/g) respectively.

6.2.3 Rootstock performance

The girth of rootstock (mm), length of longest primary root (cm), length of longest secondary root and root: shoot ratio were significantly different from each other. The maximum girth of rootstock (37.268 mm), length of longest secondary root (7.648 cm) and number of secondary roots (29.54) were observed in Rangpur lime after 8 months of budding and maximum root: shoot ratio (50.55) was observed in Carrizo after 8 months of budding. The minimum girth of rootstock (19.120 mm) length of longest primary root (14.39 cm), length of longest secondary root (3.310 cm) and number of secondary roots (20.32) were recorded on Carrizo after 8 months of budding.

7. CONCLUSION

On the basis of results obtained from the field experiment entitled “**Effect of different rootstocks on success of budding in Nagpur Mandarin (*Citrus reticulata* Blanco)**” it may be concluded that the different rootstocks namely Rough lemon, Rangpur lime, Sour orange and Carrizo influenced success of budding in Nagpur Mandarin. Budding performance of scion, growth attributes of scion and rootstocks performance affected significantly over different rootstocks. In terms of vigour especially budding success (68.313%), length of scion shoot (17.978 cm), plant height (34.584 cm), number of nodes (1.546), number of branchlets/plants (0.054), perimeter of leaves (15.06 cm), water potential of leaves (-0.14), chlorophyll contents (0.194 mg/g), leaf area (15.958 cm²), RWC in leaves (51.74) were observed on Rough lemon. By and large, Rough lemon had significantly higher edge over other rootstocks under study on budding performance in Nagpur Mandarin.

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