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# CARBON ASSIMILATION POTENTIAL OF NAGPUR MANDARIN (*CITRUS RETICULATA* BLANCO.)

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**Abstract:** The results of this study highlight the assimilation potential of Nagpur mandarin orchards in fixing atmospheric $CO_2$.The field studies on Nagpur mandarin plants based on different diameter classes were investigated during 2012-13 at Fruit Instructional Farm of College of Horticulture and Forestry, Jhalawar to estimate their biomass allocation pool of this crop in Jhalawar district. Experimental findings revealed that among different treatments $T_7$ (10-11 cm, diameter class) was found significantly superior over other treatments with respect to fresh fruit weight, leaves weight, stem weight, bark weight, branches weight, twigs weight and root weight. The results exhibited that treatments with more diameters had more increase in growth parameters and also the carbon sequestration potential. Of the total biomass produced, dominance of fruits followed by roots formed the potent sink in the plants. Of all the component parts i. e. fruits, stem, bark, branches, twigs and roots, the carbon storage was maximum in fruits followed by roots. The present studies indicate the innate potential of Nagpur mandarin as $CO_2$ sequester being dependent on stem, leaf and root biomass under different diameter classes. We conclude that choice of appropriate plant density with the use of good agricultural practices with a sound irrigation scheduling can augment the capacity of an orchard system to transform significant amounts of $CO_2$ into biomass and humus.

**Keywords:** Nagpur mandarin; potential; carbon sequestration; biomass.

## Introduction

There is investment by the plants for competing activities for carbon like growth, development and reproduction. It is closely related to plant survival, perpetuation and fitness caliber in nature. The importance of orchards contribution has been widely reported for carbon cycling to carbon storage under studies conducted by Procter *et al.* (1976) in apple; Sekikawa *et al.* (2003) in grape ecosystem and Sofo *et al.* (2005) in olive and peach orchards. Jhalawar district of Rajasthan state in India synonymously popularized as ‘Chhota Nagpur’ is well known for its Nagpur mandarin fruits of best quality comparable to the main Nagpur

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mandarin growing 'Vidharba' region in India. In Rajasthan state, Nagpur mandarin is grown over 22,500 hectares area; out of it 13000 hectare area is under bearing phase with an annual production of 2 lac tonnes (Anon.2002).

There is tremendous innate potential of biomass production in Nagpur mandarin plants and mandarin is also a potential carbon sequester. However, in case of it, the innate potential of Nagpur mandarin has been not studied so far in India. Perennial crops such as Nagpur mandarin have the potential to absorb and sequester $CO_2$ from the atmosphere. Citrus production is primarily an agricultural activity that is used to generate income for producers through the production and sale of fruits. However, given the amount of carbon dioxide that the trees fix through the plant dry matter, it can play a role as a means of removing carbon from atmosphere commonly referred to as carbon sequestration. The amount of carbon dioxide removed from the atmosphere through the sequestration is proportionate to the amount of biomass the plant accumulates over its life time.

In Jhalawar, Nagpur mandarin is grown as medium sized upright trees. They are cultivated under calcareous vertisols under humid subtropical conditions. The water requirement range is about 800 to 1300 mm per annum and they are more commonly grown under irrigation with optimum rainfall. Nagpur mandarin grows well between a temperature of $12^{o}C$ and $40^{o}C$ under clay loam soils.

Carbon sequestration is an inbuilt mechanism in plants in which they trap $CO_2$ available in the environment to transform it into a range of products varying from flowers, fruits, seeds etc. In doing so, they lessen the atmospheric carbon level which has been issue of much concern in our growing world today. A study on carbon sequestration by fruit plants is very meager in our country. The orchard can also be treated as one of the sources of carbon pool. With an intent to adjudge the efficacy of Nagpur mandarin plant in mitigating the impact of environment pollution especially due to $CO_2$, present studies were undertaken to estimate the carbon storage potential of different parts of the plant during 2012-13 at College of Horticulture and Forestry, Jhalawar.

**Materials and Methods**: A field experiment entitled "Carbon sequestration potential of Nagpur mandarin (*Citrus reticulata* Blanco.) was conducted during 2012-13 at Fruit Instructional Farm of College of Horticulture and Forestry, Jhalawar. Geographically Jhalawar district is located at $23^{o}4'$ to $24^{o}52'$ N-latitude and $75^{o}29'$ to $76^{o}56'$ E- longitude in South Eastern part of Rajasthan state in India. Agro climatically, the district falls in Zone V known as Humid South Eastern Plain. Average rainfall in the region is 954.7mm. Maximum temperature range in the summer is 43-48°C and minimum 1-2.6°C during winter. Agriculture and forest lands occupy predominantly 73.5 per cent area, respectively in the district. The district has attained premier position in the cultivation of Nagpur mandarin. Nagpur mandarin plants of 5 years age budded on rough lemon rootstock spaced at 6x6m were taken for experimental study. There were seven treatments based on diameter classes to differentiate the plants into different diameter classes of trees. The total number of plants falling under different diameter was counted in the orchard. The specific diameter of each plant was measured. Based on the lowest and highest diameter, the plants were grouped under seven categories denoted by $T_1$ to $T_7$. Under specific diameter class, total number of plants was further counted. Based on total diameter and total number of plant belonging to a particular diameter, mean value was calculated as detailed below:

| S.No. | Treatment | Diameter class(cm) | Mean (cm) |
|---|---|---|---|
| 1. | $T_1$ | 4-5 | 4.25 |
| 2. | $T_2$ | 5-6 | 5.54 |
| 3. | $T_3$ | 6-7 | 6.56 |
| 4. | $T_4$ | 7-8 | 7.46 |
| 5. | $T_5$ | 8-9 | 8.38 |
| 6. | $T_6$ | 9-10 | 9.49 |
| 7. | $T_7$ | 10-11 | 10.25 |

A total of 105 plants were undertaken for study with 5 plants per unit replication and three replications for seven treatments. The calculation of carbon storage was done by calculating a. Above ground biomass (wood, bark, branches, twigs, leaves and fruits of Nagpur mandarin plants.

b. Below ground biomass (roots) of plants.

Stratified sampling method was used to determine biomass. From all the diameter classes, the mean tree was used for destructive harvesting. All the components viz. fruits, leaves, twig; branch, bark, wood and roots were harvested and dried at 68°C up to the constant weight. The biomass was calculated using the following formula:

Biomass = Total dry weight per unit area.

Total biomass per unit tree component wise summed and mean value of biomass was multiplied by number of trees/hectare. Based on biomass carbon storage was calculated using the formula:

Carbon storage (Mt) = Biomass x Carbon% (Negi *et al.*, 2003). As per factor standardized by Carvallo et al., (1998); Lal and Singh (2000), 0.45 was taken as carbon per cent in plants.

The data obtained after experimentation were statistically analyzed following RBD as per method suggested by Fischer (1950). The significance of various treatment effects were judged with the help of "F" value test at 5 per cent level of significance. The critical difference was calculated to assess the significant difference between treatment means, so as to draw inferences as regard to affectivity of a particular treatment. Statistical analysis of multiple regression was done using online wessa.stat software.

## RESULTS AND DISCUSSION:

The data presented in table 1 indicated that fruit weight got increased significantly with more diameter classes. The magnitude of fresh weight was found maximum (40.00kg) under treatment $T_7$ which was significantly superior over all other treatments. However, it was at par with treatment $T_5$ and $T_6$. The minimum value of fresh wt. (30kg) was recorded in $T_1$ treatment.

The higher fruit weight in this treatment may be explained in light of photosynthate distribution ability of different diameter plants. The higher fruit weight could be attributed to innate potential of plants of different classes due to differential photosynthetic capacity and diversion of assimilates from roots to different parts of the plant. The fruit growth may be augmented by root strength.

The data also elucidated that with respect to fresh weight of leaves, maximum value (2.80 kg) was recorded under $T_7$ and the minimum (0.90 kg) in $T_1$ treatment. Plants having maximum diameter attained the maximum weight of leaves. The fresh weights of leaves were observed in ascending trend with increase in diameter classes. This may be attributed in light of the fact that higher source-sink ratio is the driving force to supply the photosynthates in view of higher demand of nutrition by leaves catalyzed by rhizosphere activities. Leaves are the most important organ for photosynthesis, a process well described by Kozlowski and Pallardy (1997), the capacity of leaves determines the capture of light energy by green plants (mainly by chlorophyll in leaves) and used to synthesize reduced carbon compounds from carbon dioxide and water. Fischer *et al.* (2012) reported that a high leaf fruit ratio assures a sufficient storage supply for better crop and photosynthesizing organs known as sources mainly leaves produce photosynthates mainly carbohydrates, translocated by the sieve tubes of the phloem to non photosynthetic organs (fruits, roots and immature leaves) known as sinks and this capacity to generate photosynthates is governed by a reliable canopy, number of leaves, certain leaf area per fruit or fresh weight unit.

As regard to fresh weight of stem, maximum value (1.60 kg) was observed in $T_7$ treatment while the minimum stem weight (0.60kg) was observed under T1 treatment. There were significant differences among the treatments $T_1$, $T_2$, $T_5$ and $T_6$. In context to fresh weight of bark, it was recorded maximum (0.08kg) in $T_7$ treatment and the minimum value (0.04kg) in T1 treatment. Other treatments $T_1$, $T_2$ and $T_5$, $T_6$ were found significant over one another. These findings are in consonance to the investigations reported by Hartmann and Kester (2012) who pointed that plant trunk cross section area has been found positively correlated with transport of nutrients from roots to different parts of the plant and the distribution of photosynthates from site of production to site of utilization.

The results pertaining to fresh weight of branches, maximum value (6.20 kg) of it was noted under $T_7$ treatment whereas the minimum fresh weight (4.10kg) was recorded in $T_1$ treatment. Treatments $T_1$, $T_2$ and $T_3$, $T_4$ were found significant over one another. This is supported by the fact that branches are a set of compartments connected to source (leafy shoots) and sink (fruits) compartments connected to source (leafy shoots) and sink (fruits) compartments. Carbon translocation between two compartments depends on the gradient of assimilate concentration using the simplified form of Munch hypothesis (Thornley and Johnson, 1990). The physiological processes involved in the way are photosynthesis, respiration of fruits and leaves, translocation of assimilates and fruit growth. The higher increase in fresh weight of branches in $T_7$ could be attributed to higher assimilate production regulated by sink strength and light availability.

Fresh weight of twigs (3.00kg) was found maximum under $T_7$ and it was minimum (1.20kg) in $T_1$ treatment. It also shared the trend of having higher value under higher diameter classes. Rest all treatments were found significant over one another. The higher fresh weight in $T_7$ may be attributed to better root-shoot-fruit interactions as the photosynthesis rate was the highest for trees with better fruit load. This is evident from the present results that sink organs grew more and accumulated more reserves when the leaf fruit ratio was higher.

Statistical interpretation of fruit weight versus leaf and root biomass revealed a highly significant and positive correlation (r = 0.9841**) at 5% level of significance along with ascending trend of actual fruit weight with increasing diameter classes (interpolations) being slightly lower in T2, T3, T4 and T5 and comparatively better in $T_6$ and $T_7$ classes as evident in Fig.1.

**Carbon Storage Potential**: The maximum carbon storage potential of fruits, leaves, stem, bark, branches, twigs, and roots was recorded in treatment $T_7$ while it was minimum in $T_1$ treatment (Table 2). The more the diameter, the more was the value of carbon storage by different parts of plant such as fruits, leaves, stem, bark, branches, twigs, and roots. Such findings may be due to differential of production/utilization of energy reserve of the plant. As the age of the tree advances, owing to the phasic change of juvenility to maturity, diversion of nutrients sets in towards reproductive phase i.e. towards flowers and fruits, leaves, stem, bark, branches, twigs etc. Being supportive to fruits they also utilizes considerable amount of nutrients reserve of the plant. Nadir (1973) and Dasberg (1987) reported that the largest proportion of total tree biomass was constituted by fruits which represented 30% of the total biomass of sweet orange. Carbon storage of leaves constituted 9.7% and the roots 27.7%. In the overall estimation of carbon balance of an orchard, it is very difficult to measure carbon fluxes due to natural flower and fruit droppings, microbial respiration and rhizodeposition.

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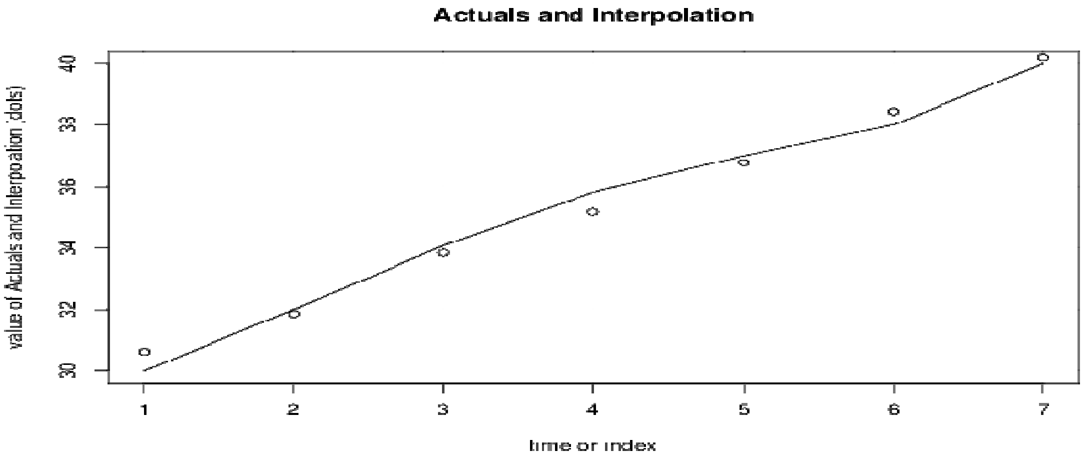
**Table1: Fresh weight (kg) of different components in different diameter classes (Pooled data of 2012-13)**

| S.No. | Treatment | Diameter classes (cm) | Fruits | Leaves | Stem | Bark | Branches | Twigs | Roots |
|---|---|---|---|---|---|---|---|---|---|
| 1. | $T_1$ | 4-5 | 30.00 | 0.90 | 0.60 | 0.04 | 4.10 | 1.20 | 5.20 |
| 2. | $T_2$ | 5-6 | 32.00 | 1.10 | 0.80 | 0.05 | 4.60 | 1.60 | 5.70 |
| 3. | $T_3$ | 6-7 | 34.08 | 1.50 | 1.00 | 0.06 | 5.00 | 1.90 | 6.00 |
| 4. | $T_4$ | 7-8 | 35.82 | 1.80 | 1.08 | 0.06 | 5.37 | 2.08 | 6.32 |
| 5. | $T_5$ | 8-9 | 37.00 | 2.10 | 1.28 | 0.06 | 5.37 | 2.28 | 6.55 |
| 6. | $T_6$ | 9-10 | 38.00 | 2.40 | 1.50 | 0.07 | 5.60 | 2.50 | 6.80 |
| 7. | $T_7$ | 10-11 | 40.00 | 2.80 | 1.60 | 0.08 | 6.20 | 3.00 | 7.30 |
| SE(m)± | | | 1.071 | 0.040 | 0.027 | 0.002 | 0.109 | 0.040 | 0.177 |
| C. D. at 5% | | | 3.298 | 0.123 | 0.084 | 0.005 | 0.337 | 0.123 | 0.546 |

**Table 2. Carbon storage potential (kg) of different parts of plants indifferent diameter classes (Pooled data of 2012-13)**

| SN | Treatment | Diameter classes (cm) | Fruits | Leaves | Stem | Bark | Branches | Twigs | Roots | Total carbon storage |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | T1 | 4-5 | 1.66 | 0.21 | 0.27 | 0.01 | 0.67 | 0.28 | 0.99 | 4.09 |
| 2. | T2 | 5-6 | 1.84 | 0.31 | 0.36 | 0.01 | 0.81 | 0.39 | 1.17 | 4.89 |
| 3. | T3 | 6-7 | 2.02 | 0.37 | 0.45 | 0.01 | 1.03 | 0.46 | 1.35 | 5.69 |
| 4. | T4 | 7-8 | 2.16 | 0.44 | 0.48 | 0.01 | 1.21 | 0.59 | 1.54 | 6.43 |
| 5. | T5 | 8-9 | 2.20 | 0.40 | 0.57 | 0.01 | 1.26 | 0.63 | 1.53 | 6.60 |
| 6. | T6 | 9-10 | 2.34 | 0.54 | 0.67 | 0.02 | 1.35 | 0.67 | 1.62 | 7.21 |
| 7. | T7 | 10-11 | 2.47 | 0.63 | 0.72 | 0.02 | 1.44 | 0.76 | 1.76 | 7.79 |
| SE(m)± | | | 0.057 | 0.011 | 0.016 | 0.0003 | 0.022 | 0.014 | 0.030 | 0.170 |
| C. D. at 5% | | | 0.175 | 0.033 | 0.049 | 0.0008 | 0.67 | 0.042 | 0.091 | 0.525 |

**Fig.1** Comparison of Actuals (Fruit wt).and Interpolations (Expected Outcomes as dots)



## Multiple Regression dynamics of Nagpur mandarin fruit wt. (a) vis a vis leaf wt. (b) and root wt. (c)

Multiple Regression Equation (a[t] = + 25.7914 + 3.7888b[t] + 2.36915c[t] + e[t].