ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 07, pp.12804-12808, July, 2020

DOI: https://doi.org/10.24941/ijcr.39282.07.2020

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

CARBON STOCK IN THE LEAVES OF SOME INDIAN TREE SPECIES

***Uma Shanker Singh IFS**

3/184, Vibhav Khand Gomti Nagar, Lucknow, Uttar Pradesh

ARTICLE INFO

Article History:
Received 07th April, 2020
Received in revised form
25th May, 2020
Accepted 27th June, 2020
Published online 30th July, 2020

Key Words:

Apical Meristem, Leaf primodium, Ontogenesis of Leaf, Chloroplast, Photosynthetic activity, Sink tissues, Carbon Sequestration, Carbon Stock, Growth hormones, Carbon factor.

ABSTRACT

The state of Uttar Pradesh has been divided into four economic regions namely, western, eastern central and Bundelkhand region. The entire state has nine agro climate zones and the present study area (Kanpur Dehat) falls under central plain agro climatic zone. The district receives 683 mm of average rain fall with the maximum temperature running in between 45^0 C and 48^0C during peak of summer. The Kanpur Dehat district occupies the central part of Uttar Pradesh on eastern bank of Yamuna river and encompasses a total geographical area of 3021 sq.km., lying in between 26N to 25 55'N latitude and 79"30'E to 80"E Longitude. The study area was chosen very carefully in Kanpur Dehat district of Uttar Pradesh. This was a plantation of early 1990s (to be very precise 1983 and 1984) on both sides of Kolkata-Delhi National Highway number-2 with multi layering. The total length of the plantation carried out along both sides of the Kolkata-Delhi NH-2 was to the tune of 113.17 km. with the total number of plants to the level of 8266. The left and right side of the plantation along the national highway were 56.8km and 56.32 km respectively. Leaf samples are required for the total carbon estimation of foliage. However, obtaining these materials from the branches of trees was extremely difficult in the study area despite of the fact that all the trees (8266 in number) of the study area were felled. It was not humanly possible to collect all the leaves present in the crown of 8266 trees therefore; twenty-seven species with varying diameter classes were selected for the complete defoliation. Once the trees were felled, all the leaves were collected and it was taken care that while collecting leaves, safety equipment and requisite dresses were put on. Results were quite interesting. The carbon content of all the leaves present in crown in each of the twenty-seven species was found through Walkley-Black method. Some of the fast growing species like C. siamea, D. sissoo, F. bengalensis, F. rumphii, A. indica, Eucalyptus spp., S. cumini, A.lebbeck are containing maximum carbon stock in the leaf cells, whereas there are some species namely, Shahtut, Ber, Mango, Imali, Mahua, Desi babul, Brachystegia eurycoma and Prosopis which contain minimum level of carbon storage in the leaves. Only two species namely, Ficus religiosa and Cordia dichotoma have been found to contain a little more than 4 kg of carbon in the crown. This was also seen that increase in carbon stock has no relationship with the increment of girth class of the trees in the study area. Therefore, some other factors are responsible for the carbon stock in the leaves.

Citation: ***Uma Shanker Singh IFS.* 2020.** "Carbon stock in the leaves of some Indian tree species", *International Journal of Current Research*, 12, (07), 12804-12808.

INTRODUCTION

Leaves are lateral expansions of the axis and are instrumental in photosynthesis, a process well known to sequester carbon dioxide. Leaves are also called as the plant's powerhouses, providing energy for all organs through sugar production. Ontogenesis of leaf is very complex and process varies from one species to another. The leaves arise as protrusion from the pro-meristem of shoot apex. This protrusion is called as leaf primordium which originates by anticlinal and periclinal divisions of outer layer of apical meristem. The meristematic cells found at the tip of a leaf form the apical meristem of leaf. The apical growth in leaves continues only at younger stage but stops later and further expansion of the leaves is carried out by the intercalary growth and rapid enlargement of the cells. There have been many studies on the export of fixed carbon from the source to, leaves, to the different parts of the trees and this has been observed that around 80% of the fixed carbon is exported by mature leaves through phloem. The amount of sucrose available in the leaves for export depends on many variables namely, photosynthetic activity (carbon fixation), partitioning between starch synthesis in the chloroplast, triose-phosphates exported from the chloroplast for sucrose synthesis, and transient storage of sucrose in the vacuole. One imbalance in the above stated factors lead to the altered level of carbon storage in the leaves and its export into the different parts of the trees[1]. In the source leaves, sucrose can be converted into its hexose products through a metabolic process and it can be stored in the vacuole or can be transported to the sink tissues[2]. The export of the carbohydrates from the leaves for the growth and maintenance of non-photosynthetic plant tissues (sinks) is a very complex process and not yet fully understood. High concentration of carbohydrates in the sieve cells raise the turgor pressure which results in the mass flow of sugar through the sieve tube to the sink however, there are many complexities in sugar uploading in the phloem which largely depend upon the tree species and

Corresponding author:* **Uma Shanker Singh IFS
3/184, Vibhav Khand Gomti Nagar, Lucknow, Uttar Pradesh

varies accordingly[3]. Plant growth is yet another a very complex phenomenon and carbon sequestration largely depends on sixteen elements in different proportion. Carbon, Nitrogen and Phosphorous are the most important limiting nutrient for carbon sequestration. The concentrations of N ([N]) and P ([P]) in plant tissues are also critical in controlling other ecological processes, such as grazing, parasitism, and decomposition[4].

MATERIALS AND METHODS

The study area was chosen very carefully in Kanpur Dehat district of Uttar Pradesh. This was a plantation of early 1990s (to be very precise 1983 and 1984) on both sides of Kolkata-Delhi National Highway number-2 with multi layering. Plantation and management are done on the basis of the management plan. The total length of the plantation carried out along both sides of the Kolkata-Delhi NH-2 was to the tune of 113. 17km.with the total number of plants to the level of 8266. The left and right side of the plantation along the national highway were 56.8km and 56.32 km respectively. Kanpur Dehat's climate is characterized by hot summer and dryness except in the south west monsoon season. The climate in Kanpur can be divided broadly into four seasons. The period from March to the mid of June is the summer season which is followed by the south-west monsoon, which lasts till the end of September, October and first half of November from the post-monsoon or transition period. The cold season spreads from about the middle of November to February. The climate is of a tropical nature and shade temperature varies from 20C to 480 C. Rainy season extends from June to September, with the period of maximum rainfall normally occurring during the months of July and August. About 89 percent of the annual rainfall is received during the monsoon months (June to September). The total rainfall in the district varies from between 450 mm to 750mm.

LEAF COLLECTION: Leaf samples are required for the total carbon estimation of foliage. However, obtaining these materials from the branches of trees was extremely difficult in the study area despite of the fact that all the trees (8266 in number) of the study area were felled. It was not humanly possible to collect all the leaves present in the crown of 8266 trees therefore; twenty-seven species with varying diameter classes were selected for the complete defoliation. Once the trees were felled, all the leaves were collected and it was taken care that while collecting leaves safety equipment and requisite dresses were put on. It was also ensured that the area is clear of other people or objects that could be hurt by falling trees. The important details were immediately written on a predesignated format with the details namely, scientific name: genus, species, detailed location, general mapping of the region, and date of collection. Once all the leaves are plucked off from a tree of a particular species, it is immediately weighed accurately on a digital weighing machine and data recorded properly on a format. The total biomass of all the leaves in all the twenty-seven species was found out from the default values being worked out by Forest Survey of India.

Dry weight of the leaf: A small fraction of leaf is taken out of the total leaf collected and it's the green weight was taken in the laboratory once again. The leaf sample fractions were cut into smaller parts for drying in an oven at 70^0C to constant mass. The oven dry weight was also recorded in the cold after drying.

We calculated the % dry matter for each fraction, from which the total dry matter can be calculated. The leaf sample was grinded for the further titration process (Walkley-Black, 1934).

RESULT AND DISCUSSION

The leaf is the most important plant component in production and plays a major role in the flow of energy, matter and convert them, between the land and atmosphere. Each day, the trees have leaves to perform photosynthesis to increase their biomass. Annual production of leaf alone makes up a large amount of biomass. This study aimed to estimate carbon storage in the leaves of twenty-seven tropical species of northern India. Dry weight and carbon content of the leaves was measured in the laboratory. The results showed that the carbon storage in the leaves of twenty-seven species chosen for study varies in accordance with the species (Table-1). There are seventeen tree species which are found to contain maximum carbon stock as shown in the following table-1. This is quite interesting to find out that some of the fast growing species like C. siamea, D. sissoo, F. bengalensis, F. rumphii, A. indica, Eucalyptus spp., S. cumini, A.lebbeck are containing maximum carbon stock in the leaf cells, whereas there are some species namely, Shahtut, Ber, Mango, Imali, Mahua, Desi babul, Brachystegia eurycoma and Prosopis which contain minimum level of carbon storage in the leaves. Only two species namely, Ficus religiosa and Cordia dichotoma have been found to contain a little more than 4 kg of carbon in the crown. This was also seen that increase in carbon stock has no relationship with the increment of girth class of the trees in the study area. Therefore, this can be safely concluded that some other factors are responsible for the carbon stock in the leaves. Not much of the studies have been done in this area but on the basis of a study which was carried out to find Carbon content of 54 plant species in different component of the trees namely, bark, wood and leaves a relationship was established in amount of Ca present in the trees and carbon stock in the leaves. The carbon content was estimated by two methods, first by ash content method and secondly by regression equation derived between carbon and Ca content (% age). Nutrient concentration in various tree components varies in accordance to their utilization for regulating different physiological processes. These nutrients are also translocated to various components as and when required. Most of the macronutrients (N, P, K, Mg, S and Na) are highly mobile and leachable except for Ca. Ca being an immobile element can be used as indicator of carbon content in different tree components. In order to find out carbon in leaf a total of 289 observations were made for developing a prediction equation between Ca and carbon content. Most of the observed values were scattered and this was found that minimum level of Ca presence in the leaf retains maximum amount of carbon stock[6].

In another experiment in agro-forestry research farm in Punjab Agriculture university Ludhiana carbon was assessed in different components of 13 tropical species of India namely, Accacia catechu, A.nilotica, Acrocarpus flaxinifolis, Anthocephalus cadamba, Bombax ceiba, D.sisoo, Eucalyptus treticornis, Gmelina arborea, Melia azedarch, Populus deltoids, Syzygium cumini, Terminalia arjuna and Toona ciliate. Thirty-six plants of each species were planted at a distance of 6m by 3m. The carbon stock was found to be varying in different components of the trees and maximum amount of carbon was found to be in stem whereas

Table 1- Carbon Stock in The Foliage of Selected Twenty-Seven Tree Species

Sr.No	Name of Species	Diameter (In Cm)	Green Weight of The Total Leaves of Crown (In Kg)	Dry weight Factor	Dry Weight of The Total Leaves of Crown (In Kg)	Carbon Percentage of The Leaf	Carbon Factor	Total Carbon of The Leaves in Crown (In Kg)
1	CASSIA (Cassia siamea)	17.19	96.4	0.887	85.5	51.66	0.5166	44.169
2	BARGAD	26.75	77.8	0.7948	61.83	53.68	0.5368	33.19
3	SHISHAM (Dalbergia sissoo)	24.52	91	0.894	81.35	31.3	0.313	25.46
4	NEEM (Azadirachta indica)	30.57	40	0.9109	36.43	68.24	0.6824	24.859
5	EUCALYPTUS Spp.	26.43	47.7	0.8945	42.66	5.8	0.58	24.742
6	PAKAD (Ficus virens)	33.12	76	0.9158	69.6	31.78	0.3178	22.118
7	KANJI (Pongamia pinnata)	11.14	58	0.9415	54.6	29.87	0.2987	16.309
8	BALAMKHIRA (Kigelia pinnata)	27.07	38	0.8548	32.48	50.19	0.5019	16.3
9	SIRAS (Albizia lebbeck)	25.47	56	0.8974	50.25	32.24	0.3224	16.2
10	JAMUN (Syzygium cumini)	20.38	35	0.8627	30.19	37.98	0.3798	11.446
11	BAHEDA (Terminalia bellirica)	16.56	44.6	0.9333	41.62	24.59	0.2459	10.234
12	KACHNAR (Bauhinia variegate)	21.33	66.7	0.9144	60.99	16.39	0.1639	9.996
13	ARJUN (Treminalia arjuna)	24.2	70	0.8529	59.7	16.57	0.1657	9.892
14	AWALA (Emblica Officinalis)	9.55	27.4	0.8544	23.41	35.71	0.3571	8.359
15	CHILBIL (Holoptelea integrifolia)	14.33	25	0.8726	21.81	36.41	0.3641	7.941
16	ARRU (Ailanthus excels)	46.17	52	0.9363	48.68	16.1	0.161	7.8374
17	GULAR(Ficus racemosa)	25.47	48	0.8585	40.93	16.14	0.1614	6.606
18	PIPAL(Ficus religiosa)	13.69	10	0.935	9.35	49.88	0.4988	4.663
19	LASORA (Cordia dichotoma)	34.71	20	0.9056	18.31	24.17	0.2417	4.425
20	ACHI (Brachystegia eurycoma)	16.24	12.2	0.9132	11.14	34.02	0.3402	3.789
21	SHAHTUT (Morus alba)	8.91	12.3	0.8776	10.79	31.91	0.3191	3.443
22	BER (Ziziphus mauritiana)	17.51	10	0.8463	8.46	29.8	0.298	2.52
23	MANGO (Mangifera indica)	14.33	15	0.8781	13.17	16.1	0.161	2.12
24	IMALI (Tamarindus indica)	9.23	8	0.8973	7.17	26.91	0.2691	1.929
25	MAHUA (Madhuca longifolia)	9.55	12.7	0.8973	11.39	14.73	0.1473	1.677
26	DESI BABUL (Acacia nilotica)	10.5	4.6	0.8369	3.84	42.39	0.4239	1.627
27	PROSOPIS (Prosopis Juliflora)	13.37	4.3	0.8307	3.57	44.85	0.4485	1.601

the minimum was recorded in leaves (Sanjeev Kumar Chouhan *et al*., 2007). Another study assessed the carbon stocks in the soil and various tree fractions in a 10-year-old plantation of Eucalyptus urophylla S.T. Blake × Eucalyptus globulus Labill in Southern Brazil. Four experimental plots were established, and an inventory of Eucalyptus trees was conducted by considering five diametric classes and it was found that the concentration in the different biomass fractions of the eucalyptus trees were 55.7% (±0.6), 50.4% (±0.4), 49.5% (±0.6) and 45.4 % (±0.9) for leaves branches, wood and bark, respectively[8]. In yet another study altogether, 23 sample trees were selected for aboveground biomass assessment. The roots of9 of the 23 sampled trees were partially excavated to assess the belowground biomass at a single tree level. The average relative share of carbon content in the stem, branch, leaf and root compartments was 44.6%, 43.0%, 46.1% and 37.8%, respectively, which is smaller than the generic value commonly used (50%)[9]. Sugar translocation is a very complex phenomenon and not yet fully understood. Translocation depends on many factors namely many environmental factors that alter source/sink relationships. There are reported parameters which affect translocation adversely such as the effects of several a-biotic (water and salt stress, mineral deficiency, CO_2, light, temperature, air, and soil pollutants) and biotic (mutualistic and pathogenic microbes, viruses, aphids, and parasitic plants) factors. Concerning abiotic constraints, alteration of the distribution of sugar among sinks is often reported, with some sinks as roots favored in case of mineral deficiency. There are many studies which suggest that up to 80% of photosynthetic fixed carbon can be exported by mature leaves. The amount of sucrose available for export from source leaves depends on several parameters: photosynthetic activity (carbon fixation), partitioning between starch synthesis in the chloroplast and triose-phosphates exported from the chloroplast for sucrose synthesis, and transient storage of sucrose in the vacuole. If one of these factors is altered, the amount of sucrose available for export is affected and therefore source/sink relationships can be altered. Therefore, this is understandable that why the concentration of sugar varies in the leaves[10]. This has been found in many studies that droughts have adverse impact on photosynthetic processes and unfortunately the forestry plantations suffer most in it as there is no provision of irrigation. The study area which falls in Kanpur Dehat is rain deficient district and monsoon fluctuations have a reflective influence on photosynthetic productivity in trees. In one of the studies on the impact of El Niño on spatial variability of summer monsoon rainfall was analyzed for the period 1974–2009. It was clear from the analysis that the delayed onset of monsoon along with El Niño has varied influences over different states as well as over India. Out of eight El Niño years, 6 years received deficit rainfall during monsoon season. But, the quantity of deficit varies from −20.3% in 2002 to −5.5% in 1991. The monthly distribution of monsoon rainfall shows higher frequency of deficit occurred during July and September. Interestingly, all El Niño years, except in 1997, September received deficit in rainfall which indicate the early withdrawal of monsoon. During 8 moderate and strong El Niño years, 5 years the productivity falls below the technological trend ranging by between −4.3% in 1986 and −13.8% in 2002 over India. Uttar Pradesh is no exception and faced many drought years in the past. The district of Kanpur Dehat remained driest on many occasions[11]. Sustained drought and concomitant high temperature reduce photosynthesis and cause tree mortality. Possible causes of reduced photosynthesis include stomatal closure and biochemical inhibition, but their relative roles are unknown in Amazon trees during strong drought events. A study was carried out to assess the effect of strong El Niño drought on leaf-level photosynthesis of Central Amazon trees via two mechanisms and this was found that

Photosynthesis decreased 28% in the upper canopy and 17% in understory trees during the extreme dry season of 2015, relative to other 2015 seasons and was also lower than the climatically normal dry season of the following non-El Niño year[12]. When a plant's leaves are removed, its roots are also affected. Excessive defoliation makes the root system smaller. Removal of too many leaves has a profound effect on the root system. Study on grasses has demonstrated that when 80 percent of the leaf is removed, the roots stop growing for 12 days. When 90 percent of the leaf is removed, the roots stop growing for 18 days. Root growth drops by half when 60 percent of leaf is removed. As root growth is reduced or stopped, root volume decreases. Plants with smaller roots have less access to water and other nutrients in the soil needed to manufacture food. A smaller root system also makes plants less drought resistant. Studies also demonstrated that roots lose stored foods after defoliation. These observations led to the conclusion that the roots and crown were major sources of food for the initiation of growth after defoliation. Girdling is very common in the road side plantation in Uttar Pradesh and this is done with a view to kill the trees in long run and finally take them away for the fuel wood or timber by the villagers. This has been seen that girdling impacts photosynthetic process very adversely. Girdling resulted in a sharp decrease in whole plant transpiration and root hydraulic conductance. The reduction of leaf area after girdling was strengthened by the high levels of abscisic acid found in buds which pointed to stronger bud dormancy, preventing a new needle flush. Accumulation of sugars in leaves led to a coordinated reduction in net photosynthesis and stomatal conductance in the short term, but later net photosynthesis decreases faster. Stem girdling does affect xylem embolism [13]. Soil, water and mineral nutrients play important role in photosynthetic process as soil moisture and nitrogen (N) are considered to be the main environmental factors limiting plant growth and photosynthetic capacity. However, less is known about the interactive effects of soil water and N on tree growth and photosynthetic response in the temperate ecosystem[14]. A study was carried out in order to find out the impact of soil nitrogen deficiency and its impact on the photosynthetic process the plants. In the study, seedlings of two N-fixing (Dalbergia odorifera and Erythrophleum fordii) and two non-N-fixing trees (Castanopsis hystrix and Betula alnoides) were chosen as study objects, and a pot experiment with three levels of soil N treatments (high nitrogen, set as Control; medium nitrogen, MN; and low nitrogen, LN) was conducted. The results showed that soil N deficiency significantly decreased the leaf N concentration and photosynthesis ability of the two non-N-fixing trees, but it had less influence on two N-fixing trees[15].

Conclusion

Carbon stock in the leaves of Indian trees has not been worked upon extensively in India and overseas. Leaves have always been considered as the manufacturing site of the food for the entire plant. Leaves also stock some sugar for its metabolic activities and its storage within the leaves depend on many factors. In this study, twenty-seven species have been taken to understand the carbon storage potential of different tree species in India. This has been found that 17 species contain maximum carbon stock ranging from 44.160 kg to 7.83 kg where as two species namely Ficus religiosa and cordia dichotoma contain carbon to the extent of 4.66 kg and 4.425 kg respectively. The carbon storage between 3.78 kg and 1.60 kg has been considered as the lower range for this study and 8 species have been found to be lower in carbon stock values out of twenty-seven species. The lowest carbon stock has been seen in Prosopis juliflora. No relationship has been seen in the diameter classes of the trees and the carbon stock of the leaves. Therefore, this can be safely concluded that there are many factors (external and internal) which are responsible for the carbon sequestration and its storage potential of the species. The land for the plantation in the state of Uttar Pradesh is mineral nutrient deficient and under different degree of degradation therefore, the quality of plantation is normally not good. The plantations are not looked after well after the formation year and its survival is always a suspect. The kind of input a plantation requires in the form of manure, mineral nutrients and irrigation is always inadequate or completely lacking at together. The plantation raised by Uttar Pradesh forest department way back in 1983-84 on NH-2 was undertaken for the carbon assessment in this study and this was found that the plantation site was typically a Usar area in the beginning and the plantations were under varying degree of grazing and lopping by villagers. Usar land is defined as that land where the vast patches of white efflorescence salt called 'Reh'. Such type of lands needs special attention because they are quite different in nature from other type of lands in the beginning if taken for plantation. Usar lands requires different approaches for their better management and reclamation. Gypsum application followed by leaching and improved cultural practices are the main technological tools for the reclamation of sodic usar lands before actual plantation is done. Besides gypsum, several other materials have been used for the reclamation. These are gypsum containing material (phosphor-gypsum), organic waste material (press mud, molasses, green manure and rice husk), and water with low PH values. This is presumed that all the measures as discussed above would have been taken well in time and before the plantation because the plantation journals which contain all these details were not available for perusal and reaching a conclusion. In my view the carbon stock in different components must be much higher than the values obtained, if all the parameters like soil improvement measures, irrigation, adequate protection to plantation and nutrients would have been added in the soil in proper doses. The worst part of any plantation raised by the Uttar Pradesh forest department is its inadequacy in providing protection to it. The plants are left open for grazing and lopping, or de-branched for fuel wood & fodder by villagers living in and around the plantation site. Despite all the constraints the carbon stock in the leaves are comparable to other reported cases in India and overseas.

REFERENCES

Remi Lemoine, Sylvain La Camera, Rossitza Atanassova, Fabienne Dédaldéchamp, Thierry Allario, Nathalie Pourtau, Jean-Louis Bonnemain, Maryse Laloi, Pierre Coutos-Thévenot, Laurence Maurousset, Mireille Faucher, Christine Girousse, Pauline Lemonnier, Jonathan Parrilla, and Mickael Durand; Source-to-sink transport of sugar and regulation by environmental factors; Frontiers in Plant Science; Vol.4: 272 pp. 1-36, 2013

Judith Van Dingenen, Liesbeth De Milde, Mattias Vermeersch, Katrien Maleux, Riet De Rycke, Michiel De Bruyne, Véronique Storme, Nathalie Gonzalez, Stijn Dhondt, and Dirk Inzé; Chloroplasts are Central Players in Sugar-Induced Leaf Growth; Plant Physiology; Vol. 171(1); pp.-590–605, 2016

Elizabeth A. Ainsworth and Daniel R. Bush; Carbohydrate Export from the Leaf: A Highly Regulated Process and Target to Enhance Photosynthesis and Productivity; Plant Physiology; pp. 1-8; 2011

Zhiyao Tang etal. Patterns of plant carbon, nitrogen, and phosphorus concentration in relation to productivity in China's terrestrial ecosystems; PNAS; Vol. 115 (16); pp.4033-4038; 2018

Walkley and Black; An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method; Soil Science; Vol.37; pp-29-38,1934

Rajesh K Manhas and Permeshwar Singh Chauhan; Carbon allocation in different components of some tree species of India: A new approach for carbon estimation; Current science; Vol. 85; No. 11; Pp.-1528-1531,2003

Sanjeev Kumar Chouhan etal.; Biomass and carbon allocation in different parts of agroforestry tree species; Indian Forester; pp.-981-993, July 2009

Márcio Viera and Roque Rodríguez-Soalleiro ; A Complete Assessment of Carbon Stocks in Above and Belowground Biomass Components of a Hybrid Eucalyptus Plantation in Southern Brazil; Forests; Vol.10 (536); pp.-1-12 2019

Sabina Cerruto Ribeiro, Carlos Pedro Boechat Soares' Lutz Fehrmann' Laércio Antônio Gonçalves Jacovine and Klaus von Gadow' Aboveground and belowground biomass and carbon estimates for clonal eucalyptus trees in southeast brazil; Revista Árvore; vol.39(2), 2015

Remi Lemoine etal.; Source-to-sink transport of sugar and regulation by environmental factors;Front Plant science, Vol.4(272),2013

N.Subhah and B.Gangwar; Statistical analysis of Indian rainfall and rice productivity anomalies over the last decades; International journal of climatology; Volume 34; Issue7; pp.-2378-2392,2014

Santos etal.; Causes of reduced leaf-level photosynthesis during strong El Niño drought in a Central Amazon forest; Global Change Biology; Vol. 24(9); pp.-4266-4279, 2018

Rosana Lopez etal.; Stem girdling evidences a trade-off between cambial activity and sprouting and dramatically reduces plant transpiration due to feedback inhibition of photosynthesis and hormone signaling; Frontiers in plant science; Vol. 6(285),2015

Miao Wang, Shuai Shi, Fei Lin, Zhanqing Hao, Ping Jiang and Guanhua Dai;(2012) Effects of Soil Water and Nitrogen on Growth and Photosynthetic Response of Manchurian Ash (Fraxinus mandshurica) Seedlings in Northeastern China; PLoS ONE; Vol.7(2),2012

Jingchao Tang etal.; Effects of soil nitrogen (N) deficiency on photosynthetic N-use efficiency in N-fixing and non-N-fixing tree seedlings in subtropical China; Scientific Reports; volume 9; Article number: 4604, 2019

****