# STRESS EFFECTS ON CANOPY GROWTH AND ARCHITECTURE: A CASE STUDY ON SAL MORTALITY

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***Abstract*:** Disturbances and fragmentation of the study area- Barkot Range (Moist Deciduous Sal Forest, Dehradun Forest Division) resulted in changes in the physical environment due to microclimatic variations, altered species composition and soil properties and had severe implications on the physiological functioning of the Sal trees. Two *Shorea robusta* (Sal) stands one containing many Sal trees with canopy dieback, mortality site (MS) and the other with healthy green, full crowns, non-mortality site (NMS) were selected. The paper investigates the soil moisture status of the two sites and evaluates effect of nutrient and water stress on the canopy growth and architecture of the Sal trees. In the present study, the difference in the average soil moisture percentage in the NMS (14.30%) and MS (12.74%) was statistically significant, indicating lower moisture availability in the mortality site in comparison to the non-mortality site. Tree growth increment was affected especially leaf production and lateral branching, which was greatly reduced. Sal stressed trees of the mortality site had highly reduced canopy growth. The crown height increased invariably however the crown width had greatly reduced. In general, canopy height was positively correlated to the bole height of the healthy Sal trees in the non- mortality site. No such relationship was obtained for stressed Sal trees in the mortality site.

***Keywords:*** **Canopy height, microclimate, Sal mortality, soil moisture, water stress.**

## INTRODUCTION

Forest Disturbances influence the ecological functions of the forest community (Sagar et al. 2003). Initially once disturbance sets in; it increases the predisposition of a forest to further disturbances. Although the stressful event is merely temporary, the vitality of the plant becomes weaker the longer the stress is maintained. It is known that one of the principal effects of disturbances is to alter the availability of the resources. While one resource may be adequate or abundant another resource may be lacking.

*Shorea robusta* Gaertn. F. (Sal) is a commercially valuable widely distributed tree of the Indian subcontinent. It is a dominant tree species in the tropical moist as well as dry deciduous forests in India (Champion and Seth 1968). There is almost a continuous belt of Sal stretching along the Sub-Himalayan tract from Punjab to Assam in the northern Indian region. Sal forests are among the most disturbed forests due to anthropogenic disturbances and various chronic stress factors have been the cause of mortality of this important tree species and subsequent reduction in the forest area over the past decades. Sal forest area is 17.86% of the forest cover of the state (ISFR 2019).

Investigations on mortality of Sal in the Barkot Range (Moist Deciduous Forest in Dehradun Forest Division) were initiated. The predisposing stress factor in the Barkot forest had been removal of forest cover or corridor (Negi and Chauhan 2002). Typical dieback of the crown of the trees with drying from apical branches spreading progressively downwards was observed in the mortality site. The dying of Sal was sporadic and random in occurrence, sometimes in patches also. This paper evaluates the effects of water and nutrient stress on the canopy growth and architecture of the Sal trees.

## MATERIALS AND MEHODS

### *Study Site*

Barkot Forest Range (Dehradun Forest Division) lies between $30^0$ 02' to $30^0$ 12' N Latitude and $78^0$ 07' to $78^0$ 20' E Longitude. It has an altitude of 340-560 m. The study sites- Non-mortality and Mortality lie in the Ghamandpur block of the range. Major forest types in the study area are Moist Bhabar Dun Sal and West Gangetic Moist Deciduous Forests (Champion and Seth 1968). Soil is brown in colour, acidic to neutral in reaction and fine loamy in texture (Kumar 1990).

The mean annual temperature recorded in the Barkot Range during the study period was $22.6^0$C and the total annual rainfall was 1718.3 mm with bulk of the rainfall during the monsoon season from mid June to September. Maximum temperature recorded was $37.3^0$C in April.

Two *S.robusta* stands one containing many Sal trees with canopy dieback, mortality site (**MS**) and the other with healthy green, full crowns, non-mortality site (**NMS**) were selected for the studies.

**Table: 1** Detail of the Stands

| Stand character | Non-mortality site | Mortality site |
|---|---|---|
| Total no. of trees/hectare | 926 | 759 |
| Total no. of Sal trees/hectare | 270 | 148 |
| Total no. of Sal healthy trees/hectare | 270 | 19 |
| Total no. of Sal partially dead trees/hectare | - | 48 |
| Total no. of Sal dead trees/hectare | - | 81 |
| Average diameter of Sal (cm) | 40.2 | 30.3 |

### *Methodology*

Three 30m x 30m plots were randomly established in each of the two stands. Trees were enumerated for their diameter at breast height (DBH), canopy width, canopy height and bole height. Data was obtained from 73 sample trees in NMS and 40 sample trees in MS and the linear regression equations worked out for allometric relationship between crown height and bole height.

### *Soil Moisture*

Surface soil was sampled in replicates of three from two soil depths 0-15 cm and 15-30 cm. Soil collected in replicates from near Sal tree roots and in canopy gaps from each site – non-mortality and mortality with the help of soil auger. Samples were roughly homogenised and brought to the laboratory in sealed polythene bags. Moisture percentage was determined immediately after being brought to the laboratory as per procedure mentioned underneath.

Soil was oven dried at 105°C for 48 hours or more till a constant weight was recorded. The moisture content was expressed as percentage of the oven dry weight.

$$\% \text{ Moisture Content (MC)} = \frac{\text{Fresh weight - Oven dry weight}}{\text{Oven dry weight}} \times 100$$

***Statistical Analysis* of** the data ANOVA (Analysis of Variance) was done using SPSS.

## RESULTS AND DISCUSSION

Barkot and its peripheral areas on experiencing predisposing stress from reduction in forest cover exhibited alteration in the species composition especially in the Sal mortality site thus evidencing for the microenvironment variability induced by stress In the interiors of the forest the disturbed habitat lead to secondary succession by the plant species with better competitive ability for acquisition and utilization of resources as well as stress-tolerant strategies predisposing the Sal trees to further stress for nutrient and water resources (Kukreti and Negi 2004).

### *Soil Moisture*

The average soil moisture percentage (on oven dry weight basis) at soil depth of 0-30 cm in the non-mortality site (**14.30%**) was statistically higher than the mortality site (**12.74%**).

In both the sites, moisture variations with soil depth were also significant with lower soil moisture at lower depth of 15-30 cm than in 0-15 cm **(Table 2)**.

**Table 2**: Effect of Soil depth on Soil moisture (%)

| Soil depth | Site | |
|---|---|---|
| | **NMS** | **MS** |
| 0-15 cm | 15.56 | 13.00 |
| 15-30 cm | 13.04 | 12.49 |

Ample soil moisture is so essential to tree growth and stand development that site quality is largely determined by those soil physical properties that influence soil moisture relations. Sal prefers soils which have a better capacity for storing larger amounts of water for a longer period to exercise a better regulated and higher supply of moisture, especially in the critical period of moisture deficiency which coincides with the growth period for Sal and also at the other periods of active growth when water is required in larger quantities (Bhatnagar 1958, 1960, 1961).

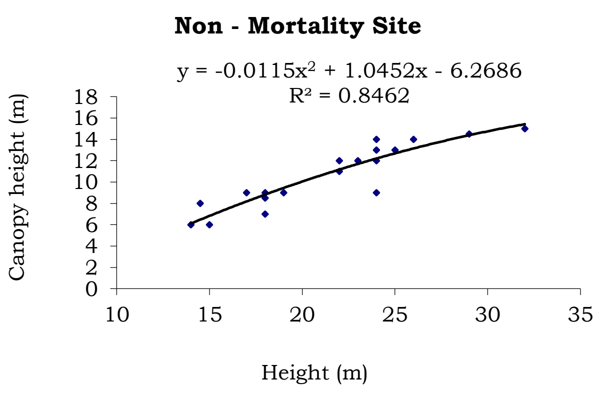
Compared to short trees, the path and height of internal water transportation are longer and higher in tall trees so the effect of gravity and path related resistance is also greater, resulting in their substantial sensitivity to changes in water (Zhang et al.2009). Soil moisture percentage in the canopy gaps of healthy moist Sal varies from 7.2–14.2% (Bisht 1989). In the present study, the difference in the average soil moisture percentage in the NMS (14.30%) and MS (12.74%) was statistically significant, indicating lower moisture availability in the mortality site in comparison to the non-mortality site. The situation worsens during the leaf initiation period of the tree species, which coincides with the peak litter fall period of March and April. Moisture percentage during this seasonally dry period, **6.05%** in NMS and **5.22%** in MS, is probably the water stress period for Sal trees especially in the mortality site. The condition deteriorates with increasing soil depth. Elevation of the mortality site by 30-50 m from the non-mortality site accentuates soil moisture stress.

### *Sal Canopy Growth and Architecture*

Growth rates represents a tree's integrated response to current and past stresses (Kozlowski et al. 1991) and are indicator of tree's vigour (Pederson 1992). Slow growing plants from infertile habitats respond to nutrient stress by maintaining higher tissue nutrient concentrations through luxury consumption and/or reduced growth rate and show no visible macro element deficiency symptoms (Beadle 1966, Nassery 1970, Grundon 1972). The nutrients that support continued growth on meristems and young leaves come from older leaves (Williams 1948, 1995).

The Sal trees of the mortality site respond to stress (nutrient and water) by resorting to reduced growth rate and this further affects the biomass, which is also reduced along with the productivity. The total biomass of the Sal trees in the mortality site 96544.30 (kg $ha^{-1}$) is greatly reduced as a result of mortality and most of the biomass is in the form of dead and partially dead standing trees. The apparently healthy Sal trees of the area have lost tree vigour and have much reduced tree growth. The non-mortality site has a total biomass of 324691.87 kg $ha^{-1.}$

The canopy volume of the stressed Sal trees is greatly reduced however the canopy height has increased. In general, canopy height is positively correlated to the bole height of the healthy Sal trees in the non- mortality site **(Figure 1)**. No such relationship was obtained for stressed Sal trees in the mortality site **(Figure 2)**. Canopy height appears to be influenced by the increasing solar radiation penetrating the forest. Leaves emerged on the trunk of the tree at lower heights of the tree where sunlight and water translocation could be attained. Water and nutrient stress had resulted in the much-reduced canopy of the Sal trees in the mortality site. The canopy development through leaf production and lateral branching was greatly influenced. The small quantity of leaves produced was seen adhering to the trunk of the tree in absence of lateral branches. Hence canopy width could not be measured. Reduced nutrient status has much less effect upon leaf number and size in the apical shoot than upon the size and number of lateral shoots produced (Watson 1963, Langer 1966, McIntyre 1977).



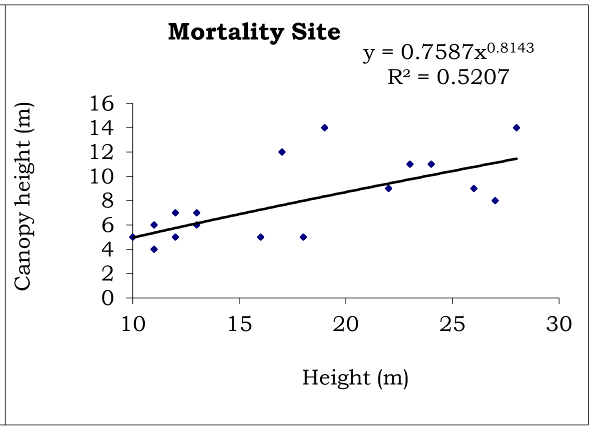




**Figure 1** **Figure 2**

There are several reports of water stress causing reduced leaf area, leaf size, number of leaves (leaf production) as well as lateral branching (Souch and Stephens 1988, Jose Leiva and Fernandez-Alies 1998). At whole plant level, decreasing water availability substantially reduced the relative growth rate (Kalapos et al. 1996).

Rate of leaf production and leaf biomass accumulation almost halved in the stressed plants (Metcalfe et al.1990). Similarly, lesser total number of leaves was reported in the stressed plants by Pandey (1999). Although rate of leaf production may vary, the number of physiologically active leaves remains nearly constant over a broad nutritional range (Milthorpe and Moorby 1974).

Plants in stress suspend leaf production reducing the canopy area to cut on the maintenance cost. Similarly, the production of twigs and branches are also affected. The Sal mortality site under study typically exhibits these features.

## CONCLUSION

Disturbances in the forest corridor and microenvironment variability in the interiors of the forest led alterations in the species composition; nutrient and water stress in the study area especially the mortality site. The Sal trees of the mortality site respond to stress (nutrient and water) by resorting to reduced growth rate and suspend leaf production reducing the canopy area to cut on the maintenance cost. Similarly, the production of twigs and branches are also affected. Thus the canopy growth is reduced and architecture different from healthy Sal trees.

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