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Survey and Analysis of Shisham (*Dalbergia Sissoo Roxb*) Mortality in Doon Valley, Uttarakhand

Ranjana Dangwal, J.D.S. Negi and Manmohan J.R. Dobriyal*

*Forest Ecology and Environment Divison; Forest Research Institute (ICFRE), Dehradun, UK, India; *Author for correspondence:-email- manmohandobriyal@gmail.com; Current address: College of Horticulture & Forestry (MPUAT), Jhalawar, Rajasthan;*

ABSTRACT

Shisham (*Dalbergia sissoo Roxb*) is facing large-scale mortality, both in natural forest as well as in plantations. Survey was carried out in six sites in Pathri, Lalpani and Thano forests in Doon valley of Uttrakhand (India). Quadrat size of 50 x 50 mt. was randomly laid in triplicates at each site. In all the sites in the natural zone of shisham, mortality varies from 20-70%. In general, in site I, mortality ranges between 20-62% as compared to 14-25% in the site II of Pathri. In site III of Lalpani 25-63% mortality was observed as compared to the 9-25% in the site IV. Site V shows 28-63% mortality much higher than 11-25% site VI of Thano. Site II of Pathri, VI of Thano and IV in Lalpani suffer very less mortality as compared to the above said sites. Intensity of mortality in different diameter classes was observed to find out the most susceptible diameter class of tree mortality. In the site I, the dead tree category experience 61.1% mortality in total, individually being 16.66% in the diameter class of 20-25 cm, 13.88% mortality in the 25-30 cm followed by 11.11% mortality in the 30-35 cm diameter class. Most affected diameter class in the dead tree category was 20-25 cm and in the partially dead tree category was 25-30cm. similarly in site II of Pathri, most affected diameter class in the partially dead tree was 20-25cm. and in the dead tree was 20-35 cm. Young and mature trees are resistant to mortality as compared to the middle-aged trees. The study suggests that continuous water logging in Pathri site leads poor aeration (asphyxiation) of root and boulder areas long water stress in Thano site superficial root system of shisham leads mortality.

Keywords:

Afforestation, Dalbergia sissoo, Doon valley, mortality, natural forests, survey

INTRODUCTION

Mortality of trees and forests is characterized by episodes of premature, progressive loss of tree or stand vigour and health over a given period of time leading to eventual death of a forest or a tree species without obvious evidence of a single clearly definable causal factor. Generally, mortality is defined as the mass scale dying of population of a single species or group of species in a given area. Further, mortality is better known as forest 'decline' or 'dieback' in one way or the other in the ecological literature. Decline has a well-established meaning in ecology as the noticeable reduction in vigor of the trees growing together at the same site, whereas dieback refers to the unseasonable partial or complete loss of foliage or death of branches on many trees within a forest

(Mueller-Dombois 1987). A range of symptom expression may also occur within the tree category like dead or intermediate in condition or reduction in growth (Manion 1981). The dieback appears to be similar to decline as it involves several interactive causes that can be divided into predisposing, inciting and contributing factors (Sinclair 1965 and Mueller-Dombois 1983). Various combinations of the environmental stresses occurring in real time control the vigour of an individual tree and the health of a forest (Hakkarinen and Allan 1986).Tree mortality can be initiated by two processes either endogenic (senescence and intraspecific competition) or exogenic (natural, abiotic and biotic).

The factors that contribute to tree death are poorly understood (Franklin et al. 1987), particularly true for background tree mortality, which is prominent in the individual tree and occurs at relatively low rates in apparently healthy forest (Harcombe and Marks 1983).

Shisham (*Dalbergia sissoo* Roxb*)* is facing large-scale mortality, growing naturally as well as in plantations. It grows gregariously and forms a forest, either pure or mixed with *Acacia catechu*, on the new alluvium formed of deposits of sand, boulders in the beds of rivers of the sub-Himalayan tract and outer Himalayan valleys. It is a multipurpose tree species, which is eco-friendly, and of socio-economic importance, widely used for afforestation in most parts of the country except the coldest, wettest and driest parts (Troup 1921). Under natural conditions, shisham grows healthy free from diseases. In recent years, the problem of shisham mortality has been reported from many parts of the country. Slowly this problem reached very dangerous dimensions and the problem spread over many states of India and even in other countries of Southeast Asia. It is estimated that more than 4 lakhs trees of shisham have been affected by wilting and drying, reported by the state forest departments (Shukla 2002). It is preferred species of afforestation by the foresters and farmers adopt it for plantations covering nearly all the states. In UP alone, the total land area under shisham plantation has been estimated as 55,997 ha (Shukla 2002). It is planted in dry regions for soil and water conservation as well as for production of fuel wood under agro-forestry. On account of its natural hardiness, fast rate of growth and high value of the resulting wood, shisham is an ideal species and has been widely used in afforestation and reforestation programs throughout the Indian sub-continent. Outside India it is planted in Nepal, Bhutan, Bangladesh, Myanmar, Malaysia, Pakistan, Afghanistan and in tropical to sub-tropical Africa. It has been introduced in Jawa, Nigeria, Mauritius, Sri Lanka, Kenya, Zimbabwe and the United States of America (Tewari 1994).

Deogun (1943) discussed relation between roots and method of irrigation in the dry tracts of Punjab. Shallow irrigation in an ordinary as well as in a hard soil produces shallow-rooted trees which are susceptible to changes in the atmosphere as drought, frost, storms etc. and the trees are solely dependent on irrigation water and take no advantage from the sub soil moisture and water. Trees died due to non availability of water, as the shallow root system was unable to draw water from the low water table. Baghcee (1945) presented a pathological note on the wilt and dieback of shisham trees in Punjab and concluded that wilt and dieback is common in water logged and marshy tracts of terai forests in open land. Bakshi and Singh (1954) reported mortality of *Dalbergia sissoo* observed both in the natural forests and artificially planted stands in taungya, of Lachhiwala range Dehradun East Forest Division and Saharanpur districts. *Fusarium solani*, a soil borne fungus was associated with wilted trees, particularly the roots and is responsible for the death of shisham. Khan (1956) found that no pathogen was responsible for the serious mortality in the irrigated plantation, studies were made on the roots of shisham and concluded that the dead and unhealthy trees were usually found where there was a kankar layer restricting root development aggravated by faulty irrigation practices. Bakshi et al. (1957) observed a significant correlation between the soil texture and the incidence of root diseases in shisham. In sand or sandy loam soils, shisham grows healthy but root diseases begin to manifest on shisham growing in sandy loam soils, increase to high proportion in clay loam or clay soils.

Gupta (2002) attempts to correlate some of the ecological factors to the incidence of mortality problem and on analyzing statistically concluded that the mature trees are less affected by mortality and also greater depth of water level leads to less mortality problem. Shukla (2002) outlined the reports of surveys conducted to assess the mortality of shisham in India and give environmental, hydrological, and pathological and site/soil factors responsible for its mortality. Negi et al. (2003) surveyed six northern states and suggests that various ecological factors such as physico-chemical properties of soil, water logging, water stress, nutrient deficiencies and environmental stress are held responsible for the large-scale mortality in shisham. Various studies have been carried out in the past to identify the cause of large scale mortality in shisham plantations but no substantiative result has been obtained so far therefore, the study have been undertaken to work out ecological indices (indicative values) to ascertain the cause of mortality in *Dalbergia sissoo* growing naturally or in plantations.

MATERIAL AND METHODS

Geographically, Doon valley is situated in Uttrakhand (India) between longitude 77°38' to 78° 20' E and latitude 29°35' to 30°30' N stretching NW-NE direction following the main Himalayan ranges. More precisely this is a longitudinal synclinal valley with the river Ganga on the east and Yamuna on the west. The study sites I and II of Pathri were approximately 70 km from Dehra Dun, whereas Site III and IV of Lalpani were located on the way to Dehradun-Rishikesh road. Site V and VI of Thano lie in the Ranipokhri Bhogpur beat, Nahi block 1-3 and 5-7 in the eastern part of Doon valley (Table 1).

Six sites in Pathri, Lalpani and Thano were selected as study sites considering the condition effecting the mortality viz. wet and water logged sites, dry areas, canal plantations and drainage systems. Site II is a valley as compared to Site I of Pathri and remains waterlogged round the year while in site V and VI of Thano the terrain is gently undulating.

Selection and gradation of the study sites was done keeping in mind varying degree of mortality percentage of *Dalbergia sissoo* trees, however the sites where mortality percentage is rare are also treated as the stressed sites. The present study was undertaken with the objective to survey and analyze shisham mortality in relation to the various ecological parameters. Work begins with the survey of the six study sites, to assess the extent of mortality percentage. Quadrat size of 50 x 50 mt. was randomly laid in triplicates in each site under study. Shisham trees were enumerated for DBH in each quadrate and categorized into healthy, partially dead and dead trees, according to the various symptoms observed in the study site. Tree possessing the loose spreading crown characterizes the healthy tree, while the tree which show-reduced canopy in the same diameter class comes under the partially dead tree. In case of the dead trees no such character regarding tree canopy was observed. Leaves of the healthy tree were found to be lush green in color while there were brown dried leaves in the dead tree category. The tree growing under stress i.e. partially dead tree exhibits the symptom of reduction in leaf size as the leaves become smaller, change in color from dark to light green and injury appears in the form of scorching of leaves. The top and side branches start dying, eventually dry and exhibited moribundicity. Ultimately half-dried tree remains standing and dead branches become more prevalent. Typical dieback of shoots, cracking of stems is also prevalent in the partially dead tree. In the later stages the tree dries from the top subsequently proceeds downwards and finally the whole tree dries up within a short span time. Trees were marked as per following criteria

a. Healthy tree- Unaffected, no dieback symptom visible with lush green leaves.

b. Partially dead tree- 50 % of mature crown show some signs of hill health, or very thin crown carrying considerable quantities of light green leaves.

c. Dead tree- More than 50 % of mature trees dead, or having dead portions with brown dried leaves.

Preliminary field survey was carried out in all the sites under study, which were severely affected by shisham mortality. Mortality was also calculated between healthy, partially dead and dead trees on the basis of the incidence of mortality percentage. DBH of all the trees in six sites from where samples were collected for studying mortality was measured (Table 2). The DBH of these trees in the six sites ranges from lowest to highest and trees were categorized into different diameter classes and analyzed statistically in order to obtain the percent mortality by applying the following formula

Percent mortality = Number of individual trees (healthy / partially dead / dead)/ Total Number of trees sampled x 100

RESULTS AND DISCUSSION

Average mortality percentage in site I of Pathri is found to be highest (61.1%) in the dead tree category (Table 2). Site II of Pathri witness very less mortality (13.3%) in the dead trees as compared to site I. while comparing the two sites on the basis of mortality it was found that mortality percent: Site I > Site II. In site III highest mortality was found in the dead trees (61.7%) followed by the partially dead trees (26.7%). Site IV Lalpani mortality was very low in the dead trees (9.30%) as compared to (24.0%) in the partially dead trees. While comparing the two sites on the basis of mortality it was found that % Mortality: Site III > Site IV. In site V, Thano has the highest mortality in the dead trees (62.5%), followed by the partially dead trees as (27.5%) while in Site VI, Thano the mortality was very low in the dead trees (11.0%) followed by (25.0%) in the partially dead trees. While comparing the two sites on the basis of mortality it was found that % Mortality: Site V > Site VI. In the all the sites, which have been examined for mortality in the natural zone of shisham, reflect that the mortality varies from 20-70%. In general, in site I, mortality ranges between 20-62% as compared to 14-25% in the site II of Pathri. In site III of Lalpani 25-63% mortality was observed as compared to the 9-25% in the site IV. Site V shows 28-63% mortality much higher than 11-25% site VI of Thano. Highest shisham mortality was observed in the site V of Thano followed by nearly equal mortality of trees in the site III of Lalpani and site I of Pathri. Site II of Pathri, VI of Thano and IV in Lalpani suffer very less mortality as compared to the above said sites where the mortality percentage was very high.

Intensity of mortality in different diameter classes was observed to find out the most susceptible diameter class of tree mortality. In the site I, the dead tree category experience 61.1% mortality in total, individually being 16.66% in the diameter class of 20-25cm, 13.88% mortality in the 25-30cm followed by 11.11% mortality in the 30-35cm diameter class. Most affected diameter class in the partially dead tree category was 25-30 cm. Similarly in site II of Pathri, most effected diameter class in the partially dead tree was 20-25 cm. and in the dead tree was 20-35 cm. (Fig. 1)

Several theories suggest that tree mortality is the combined result of different factors that collectively stress the tree that may vary from time to time and place to place but have similar effects. The Indo-Gangetic plains of India are predominantly agricultural based catchments e.g Punjab, Haryana, Rajasthan, Gujarat, Uttrakhand, Uttar Pradesh, Bihar and West Bengal. The characteristic riverain forests of shisham in northern India appear to owe their existence not so much to the presence of water in the soil as to the favorable conditions for the germination of the seed and the development of the young plants which are met within these open riverain tracts. These conditions are loose porous soil, complete exposure to light and absence of heavy weed growth (Troup 1921). Shisham is a characteristic species of khair-sissoo primary serial type of dry deciduous forests (Champion and Seth 1968). In present study with varying degree of mortality percentage and different site conditions as site II of Pathri remains waterlogged round the year while sites V and VI of Thano faces severe water stress round the year. The variation in the intensity of mortality could be attributed to many biotic as well as abiotic factors.

The incidence of mortality exhibited great variation with respect to the diameter class. Shisham mortality was found to be prominent in trees of all age gradations (diameter class), though the extent of mortality was very severe in the middle

Table 1: Description of survey site for *Dalbergia sissoo*forests /plantations

Site	Name	Forest Range	Forest Division	Compartment Number	Age of plantation (Year)
I	Pathri	Pathri	Hardwar	10 A	70
II	Pathri	Pathri	Hardwar	12 A	36
III	Lalpani	Rishikesh	Dehradun	7 A	35
IV	Lalpani	Rishikesh	Dehradun	13 A	35
V	Thano	Thano	Dehradun	3 A	28
VI	Thano	Thano	Dehradun	5 A	26

aged trees 25-35 cm than in very young or very old trees as discussed above. Results of the tree mortality in the site I of Pathri, depict varying mortality in the different diameter classes of the dead and partially dead tree category. However the most affected diameter class in both the tree category was 20-25 cm and 25-30 cm respectively thereby showing that maximum mortality occurred in the diameter class of 20-30 cm (Fig 2.). On contrary to that, healthy trees were found above 30-35 cm diameter class thus concluding that the middle-aged tree are most affected by mortality as compared to the mature trees because no healthy tree was found in between the diameter class of 15-30 cm. In site II of Pathri, only 13.3% mortality was observed in the dead tree category and that too in the diameter classes of 20-35 cm. Healthy trees were found to be absent in the above said diameter classes and present 18.33% in the 35-40 cm diameter class. In the higher diameter classes no mortality was observed however there was marked variation in the intensity of mortality in the various sites studied. This lead to the result that the young and mature trees are resistant to mortality as compared to the middle-aged trees, which are more prone to mortality.

Most of the trees, which had developed heartwood, exhibited dying phenomenon, therefore, young trees which do not develop prominent heartwood are resistant to mortality. The saplings and coppice plants without heartwood did not exhibit any sign of top dying (Prasad et al. 1989). Similar results were also found in the sal forest where mortality was prominent in the middle-aged trees only (Shah 1998; Kukreti 2002 and Gupta 2002). The trees growing under stress exhibits the symptom of reduction in leaf size, changes in dark to light green colour and appears to be scorched. In the later stage, the top and side branches start drying and the leaves of the affected tree turn yellow and eventually dry, At advanced stages the top and the side branches exhibited moribundicity, as a result half dried tree remain standing. Finally, the whole tree dries from the top subsequently proceed downwards and ultimately complete tree dries up within a span of 2-3 years. Reduction in *rhizobium* population and decay of roots was also observed when the roots of the stressed trees (dead or partially dead) were exposed, as the feeding roots were black in color and partially decomposed. While studying shisham mortality, we observed compacted soil structure combined with a high percentage of dead roots. With a reduced root system, the tree loses potential reactions to other adverse site factors. Therefore tree recovery after natural damaging events is reduced. The impacts of biotic factors, weather conditions as well as soil factors such as water availability, nutrient supply and physico-chemical properties need to be kept in mind while investigating the cause of shisham mortality. No

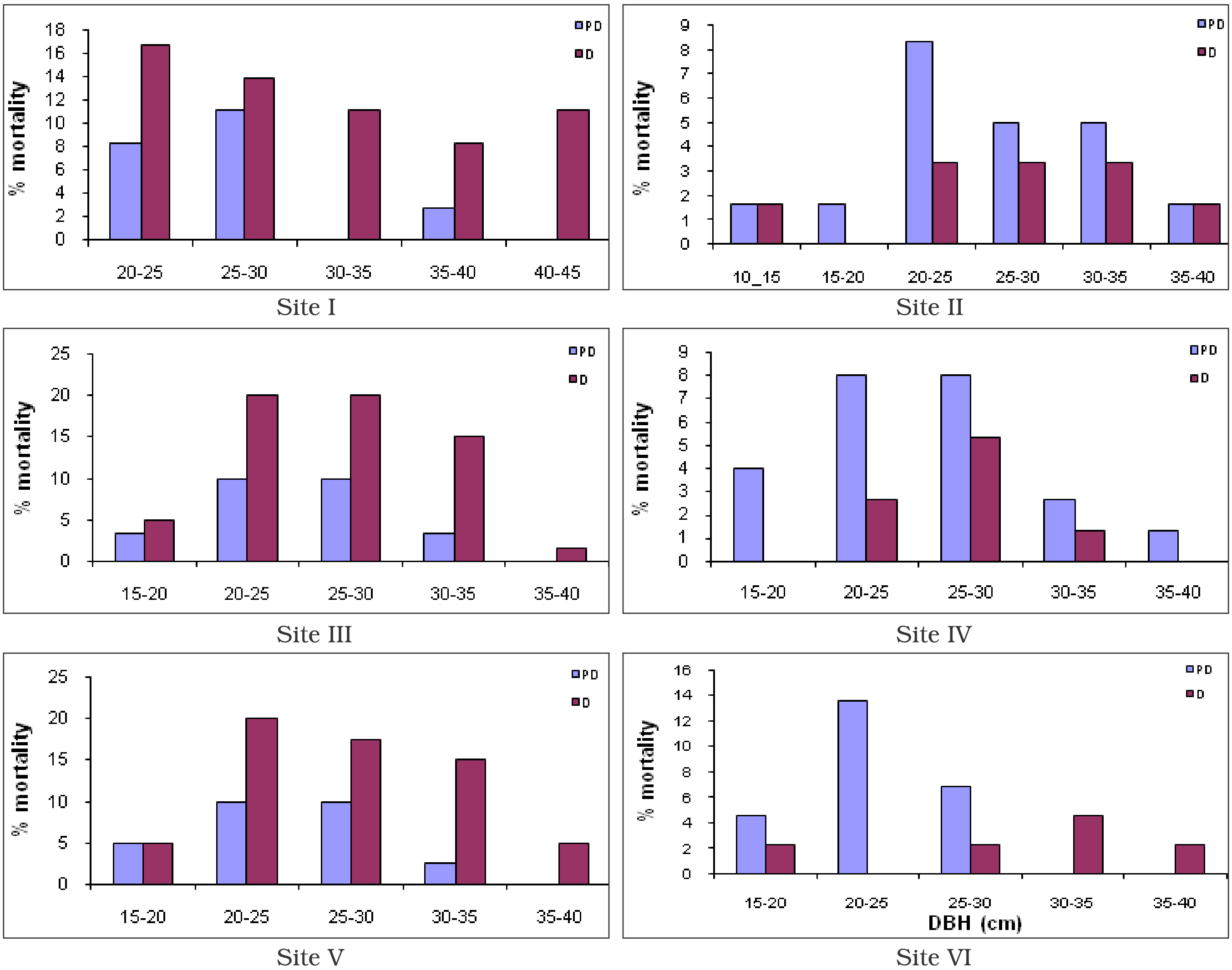
Table 2: Stand Characteristics and intensity of mortality of *Dalbergia* in the Six Sites

S.N.	Name of the site	Av. tree density (trees/ha)	Average dia. (cm)	Average no. of Trees sampled	Healthy trees (%)	Dead trees (mortality %)	Partially Dead trees (mortality %)	Total mortality (% PD +D)*
I	Pathri	144	34.30	36	16.67	61.10	22.20	83.30
II	Pathri	240	30.27	60	63.33	13.30	23.40	36.70
III	Lalpani	240	27.28	60	11.67	61.70	26.70	88.40
IV	Lalpani	300	28.48	75	66.67	9.30	24.00	33.30
V	Thano	160	28.48	40	10.00	62.50	27.50	90.00
VI	Thano	176	26.08	44	63.36	11.40	25.00	36.40

*P= Partially dead, D= Dead; Average value is mean of three sample plots in each site

single reason can be held responsible for the large-scale mortality in shisham plantations. Excessive water can create as much stress on the tree as deficit water. Symptoms of flooding are similar to those of drought, which includes stomatal closure, pattern of yellowing leaves from base to top of tree, drooping of the petioles while the tree is still turgid, leaf epinasty, hypertrophy, new root formation from the stems and wilting under severe condition of flooding (Nilsen and Orcutt 1996). Unusual climatic conditions such as erratic rainfall, extreme foggy days during winter December-March hot summer season, water logging, non-judicious irrigation schedules and imbalances in soil physical properties and monoculture plantations creates stress conditions for the growth of shisham. During February and March followed by the initiation of new buds especially juvenile leaves, which requires bright sunshine hours for efficient photosynthesis, diffused sunlight slows down the photosynthetic efficiency causing tree under stress. This repeated phenomenon for a period of 2-3 years looses the resistance of the tree ultimately causing death of shisham tree. However the reason for the large-scale mortality in shisham plantation may vary from place to place with one or the other reason.

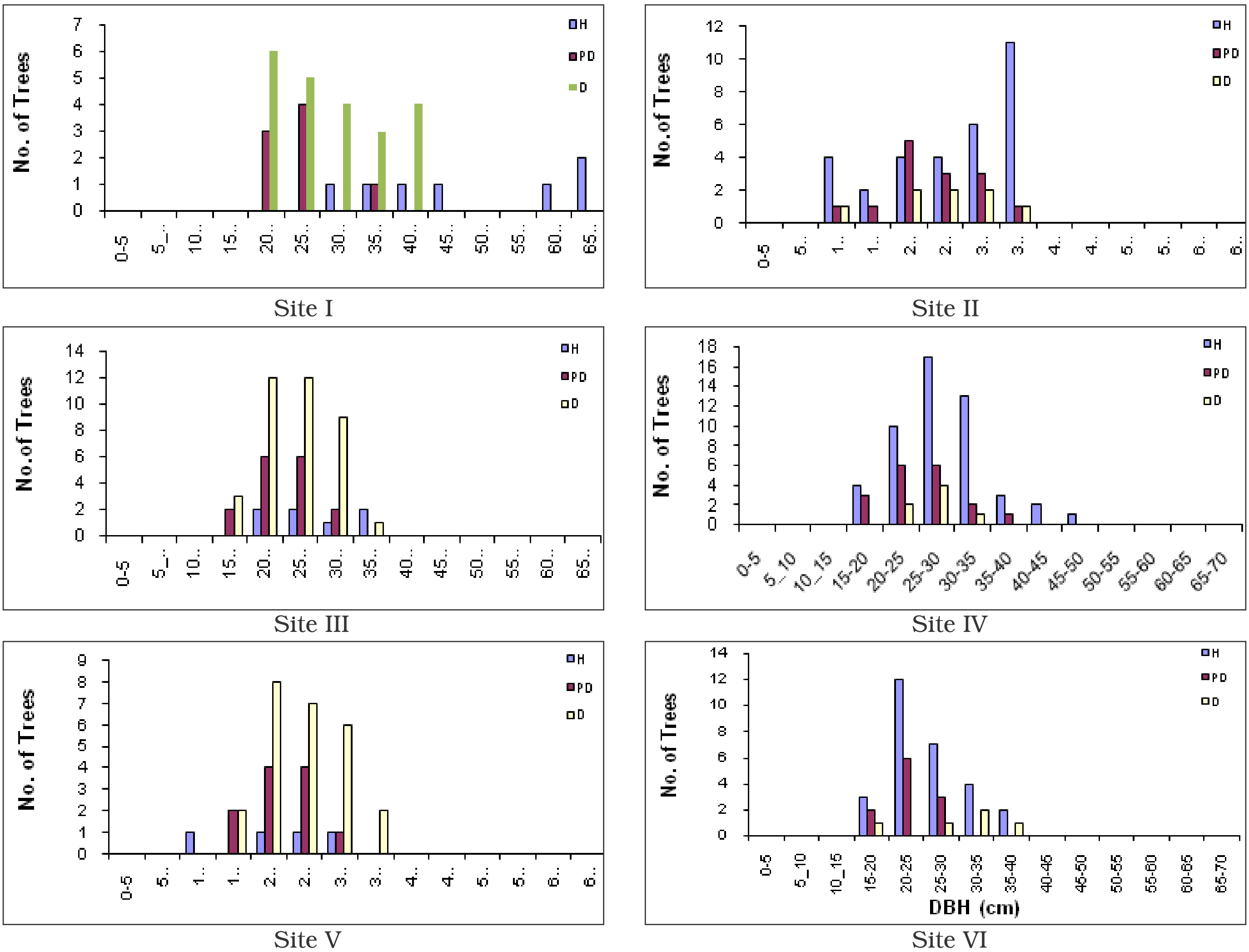
Trees of almost all the age classes are affected in the six sites of Pathri, Lalpani and Thano under study. Apart from the dead trees, partially dead trees are also increasing at an alarming rate thus predicting that a higher rate of mortality is expected in the near future in all the shisham trees growing under plantations. Trees under 20-40cm diameter class are most effected by mortality in all the six sites, i.e. very young and mature trees are resistant to mortality as compared to the middle-aged trees. This is probably because the younger trees below 20 cm (DBH) have lower requirement and hence counter any stress due to resource limitations (nutrient and/water). Shisham has feeding roots in the upper zone of the soil layer and therefore, is more vulnerable to any change in the soil physico chemical properties. As a result of these young trees are more affected as compared to the mature trees as the mature trees have deep penetrating roots for resource acquisition from deeper soil, and are therefore resistant to mortality. However, the middle-aged trees because of their higher requirement of nutrition for growth purpose have to face greater competition for resource from other tree species and are vulnerable to stress. Changes in the microclimatic conditions in different sites. In sites (I, III and V) of Pathri, Lalpani and Thano where the rate of mortality is high, rate of solar radiation penetrating the forest floor is higher due to canopy opening thus increasing the evapo-transpiration rate and causing trees under stress. In Pathri site I, age of plantation is very old 70 years as compared to site



PD- Partially Dead trees, D- Dead trees

Fig. 1. Mortality in the different diameter classes of *Dalbergia sissoo*

II of Pathri under study which is 36 years old. In site I previously the conditions were used to be similar as the condition is today in site II. Site II remains under high soil moisture over a prolonged period and therefore causes significant damage to the tree roots. When excess moisture blocks or reduces soil porosity for an extended period it creates anaerobic conditions because of poor aeration (asphyxiation) and accumulation of toxic metabolites in tree roots. As a result reduction in root growth occurs, and high ground water table tends to lead to a layer of roots at the ground-water interface. Streets (1962) also confirmed that the shisham could withstand high soil moisture only for a short duration under conditions of good drainage. In the Tarai the water table is high and may come up to the surface during rains creating water logged conditions. As a result roots die of asphyxiation affecting the health of tree, which become stag headed and finally die. Singh (1983) also reported 60% mortality in 1962-70 in shisham plantations in Hasanpur and Baghalkhand blocks of Janakpur range north Gonda forest divisions. High water table in Hasanpur and clayey to clayey loam soil in Baghalkhand were resposible for shisham mortality. Nema and Khare (1992) also reported that sissoo can not withstand waterlogging even



H- Healthy trees, PD- Partially Dead trees, D- Dead trees

Fig. 2. Enumeration of Healthy, Partially Dead and Dead trees of Dalbergia sissoo in six sites

for a short duration as the root die of by asphyxiation suggesting that the species should be grown under well-drained areas for good growth. Bulk density is increasing in the sites III and IV of Lalpani where the trees are under stress. Lalpani is under excess biotic pressure such as grazing and lopping along with the debarking by elephant increases the bulk density of the area. Higher bulk density makes the soil more compacts resulting in less penetration of the roots in the soil thus restricting the uptake of nutrients from the soil to the tree. Insufficient soil moisture in site V and VI of Thano arises due to low water table, and when the water requirement of the tree falls below the level necessary to carry out its physiological functions, drought conditions occur. The trees had dried up due to non-availability of water, as the superficial root system is unable to draw water as a result, plantations fail.

The analysis of survey results recommends that while establishing plantations select species, varieties and provenance that are adapted to the sites being planted. Plantation of shisham should be done on the suitable sites preferably on sandy, low water table areas with good drainage. Soil with light texture should only be selected. Avoid clay and clayey loam soil as shisham gets infected and stunted by the wilt diseases in stiff soil. On sites with high water table, shisham tree starts drying and dying when taproot reaches free water zone in the soil, therefore this condition should be avoided. The mixed stands are ecologically far superior than pure stands as they keep nutrient status to a high degree, cover the soil better, are more resistant to pests and diseases. Pure stands deteriorate as they age as they are less efficient in trapping released nutrients from decomposing litter due to less use of available rooting space. Extensive survey and generation of complete database is required to provide classified information about all the aspects of the problem. In order to save the remaining trees of these species on the field, complete maintenance is required. Removing the dead trees, improving the drainage conditions and treating the sites with plant protection methods if feasible, could achieve this. Broad based genetic improvement through selection of trees tolerant of adverse climatic and edaphic factors and resistant to pathogen and pests should be done. Further, maintaining biodiversity by protecting the associate's species in the canopy gaps as per the forest carrying capacity will also increase the survival of seral community of Shisham.

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