# SILVICULTURE ASPECT OF PASSUR (*XYLOCARPUS MEKONGENSIS*) TREE IN THE SUNDARBANS WITH SPECIAL REFERENCE TO HEART ROT DISEASE

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## ABSTRACT

The Sundarbans is the largest single tract mangrove forest of the world. The forest occupies the south-west corner of Bangladesh. It covers an area of 6017 $km^2$, of which 4143 $km^2$ are landmass and 1874 $km^2$ water bodies. The biodiversity of the Sundarbans is very rich. Among the floral species Passur (*Xylocarpus mekongensis*) is one of the important timber species in the Sundarbans. Passur belongs to the family Meliaceae. The canopy of Passur is dense, heavy and the stem is cleared bole. The tree attains a height of 15-20 m and the exploitable age 100 years. Now Passur is affected by heart rot problem. Actually heart rot is internal damaged condition locally known as "dhor." The fruit body, gall and cankers are developed on the different portion of the standing living trees. Thus it is characterized by the gradual death of the crown starting first with small twigs and then gradually larger branches die. To know the status of heart rot and its causal organism the research works were conducted from 2007 to 2009 at different locations in the Sundarbans. The locations are Baniakhali, Chunkuri, Kalabogi, Kashiabad, Bojboja and Supati. The result shows that heart rot affected percentages are 64%, 62% and 60%, 54% and 48%r 17% respectively. Very low amount of trees are affected at Supati located in the fresh water zone of the Sundarbans. The results also show that in the six locations diameter at breast height (dbh.) Class IV (>40cm) is highly affected 34%, then followed by dbh Class III (31-40cm) 31%,Class II (21-30cm) 25% and the lowest only 10% in the Class I (<20cm). So, it is clear that Passur trees having dbh class IV (>40cm) were highly associated with heart rot. This calls for pathological rotation of Passur trees arriving at dbh class IV (>40cm) for better salvage of useable trees. The International Mycological Institute, UK, identified and confirmed two fungal pathogens for causal organism namely *Phaenerochaete subglobosa and Schizophyllum commune* and locally identified *Ganoderma appalanatum*.

## INTRODUCTION

The Sundarbans is the largest single tract mangrove forest in the world. The forest occupies the south-west corner of Bangladesh between longitudes 89°00”E and 89°55”E and latitudes 21°30”N and 22°30”N. The forest cover an area of 6017 $km^2$, of which 4143 $km^2$ are landmass and remaining 1874 $km^2$ are under water bodies. It is tidally inundated twice a day. Prain (1903) reported 334 species belonging to 245 genera of spermatophytes and pteridophytes of the Sundarbans. Heining (1892) reported 70 species from 34 families from the entire

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Sundarbans. Chaffey *et al*., (1985) listed 66 species in the Sundarbans. Helal Siddiqui (1998, 2002) listed 130 species and he again listed 215 species in 2009 which are not all the mangroves (Appendix 1). Sundri (*Heritiera fomes*) and gewa (*Excoecaria agallocha*) are the major tree species in this forest. The other important species are Passur (*Xylocarpus mekongensis*), Goran (*Ceriops decandra*), Keora (*Sonneratia apetala*), Amur *(Amoora cucullata*), Baen (*Avicennia officinalis*), Kankra (*Bruguiera* spp.), Shingra (*Cynometra ramiflora*), Khalshi (*Aegiceras corniculatum*), Kirpa (*Lumnitzera racemosa*), Golpata (*Nypa fruticans*), Garjan (*Rhizophora mucronata*), Dhundul (*X. granatum*) etc. (Helal Siddiqui, 1999, 2002, Siddiqi, 2001, Canonizado and Hossain, 1998).

Passur is a valuable and highly useful timber species in the Sundarbans. It is a commercially important multipurpose tree species. The species are well represented all over the forests and very hard timber (Chaudhuri and Naithathani, 1985). The canopy of Passur is dense, heavy and spreading appears as lofty emergent tree in the class three type forest (Karim, 1995). The stem is cleared bole, some times buttressed at the base and bark is fissured with flakes, imbricate, compound leaved, 4 leaflets, leaves large and fleshy, fruits-globose, inner bark reddish brown and outer bark chocolate colour (Chaudhury and Naithani, 1985). The trees shed their leaves during March to April. It produces pneumatophores which are about 30 to 35 cm in length and dagger shaped. The species is light demander. It is tolerant to wide range of salinity and soil condition in the Sundarbans. It is a climax species of mangrove forest of Bangladesh. The trees are attaining a height of 15-20 m and diameter at breast height (dbh) of 10-50cm and annual growth rate ranges from 0.95-4.9 mm (Karim, 1995).Initial height growth and diameter increment of Passur at newly accreted char land is 0.26m to 0.34m and 0.30cm to 0.48 cm respectively (Siddiqi,2001). Choudhury (1968) reported that the exploitable diameter limits of Passur ranged between 8″ (20.32cm) to 10″ (25.4cm) and the exploitable age 100 years. The wood is heavy, fine textured, highly durable, good polish and reddish brown in color. It is also used in energy producing matter like fuel wood, charcoal, firewood etc. (Siddiqi, 2001).The wood is used for making good quality furniture. The wood is also used for making beams, tool handles, spokes of wheel, planking, house post, boat building, jetty making, bridge building and other purposes. Fleshy leaves are good fodder and highly palatable for the cattle and deer. Its bark tannin is used for medicinal purposes for dysentery, diarrhoea and febrifuge. Ash is used for toothache and for dish washing. Flowers are the source of honey (Helal Siddiqui, 1998; Helal Siddiqui, 2010, Helal Siddiqui and Khair, 2012).

Sundarbans is rich in its biodiversity. The major mangrove tree species are being affected by different disorders and diseases. Passur, a commercially valuable deciduous multipurpose tree species is affected by heart rot problem. As a result the condition is characterized by a gradual loss of tree vigor which

can lead to tree death and dieback or decline. The species is affected by heart rot diseases. Heart rot is generally regarded as a condition locally known as "dhor" (Helal Siddiqui, 2009, Helal Siddiqui, 2010). It is characterized by the gradual death of the crown starting first with small twigs and then gradually larger branches die and lignin portion of the stem becomes useless. The fruit body, gall and cankers are developed on the different portion of the standing trees. Some environmental factors i.e. water salinity; soil contents, water turbidity, sedimentation and successional changes are also responsible for the heart rot problem" (Helal Siddiqui, 2009, Helal Siddiqui, 2010). This is a great loss to the forest ecosystem and the country. Useful tree species in the Sundarbans can play a considerable role both in successional changes and forest community development thereby changing restoration of forest structure Helal Siddiqui (2002). It is necessary to estimate the cover of mature and mortality affected tree species by visual field survey method for tree status identification and selection felling. Thus the major understory vegetation and residual species will get entirely exposed to environmental changes to maintain the species composition and abundance of Successional understorey vegetation (Helal Siddiqui, 2002). Considering the disorders of the economic important species it needs integrated research to overcome and to detect infestations of the problems heart rot disease of Passur in the Sundarbans. The different causes are responsible for loss to the standing crops in the forest. Due to heart rot disease the decaying is immense important. Heart rot is probably the greatest single cause of damage to the forest crop (Bakshi *et al*., 1970). It is necessary to observe the occurrences of heart rot and top dying affected passur trees in the Sundabans. The study have been undertaken to identify causal organisms, infestation status and associate factors relating to the heart rot disease as well as remedial measures to minimize the loss of trees.

## MATERIALS AND METHODS

For the purpose of site selection and study pre-visits were conducted on the basis of the dominance of passur tree areas of the Sundarbans as reported earlier by Karim (1995), Rahman (1994), Siddiqi (2001), Chaffey *et al.,* (1985). Several field visits were made for selection of study sites. In the process consultation were made with stakeholders like experienced professional wood cutters, locally known as Bawalies, Foresters, Range Officers, Forest Officials, Mangrove Research Officers attached to the Bangladesh Forest Research Institute (BFRI) and academies of Khulna University who have gathered professional experience on the Sundarbans over the years. Then on the basis of passur trees several compartments belonging to different Ranges distributed over in Fresh water zone, Moderate saline water zone and Strong saline water zones were selected as working site for the study. Finally six locations were selected at three salinity zones of the Sundarbans according to dominance of passur trees. The locations (Map-1) are Supati (22°03′00"N and 89°50′00"E) in

compartment no.4 in the fresh water zone (FWZ), Kalabogi (22°24′16"N and 89°27′58"E) in compartment no. 32, Baniakhali (22°32′37"N and 89°27′02"E) in compartment No.35, Bojboja (22°21′59"N and 89°22′35"E) in compartment No.37 and Kashiabad (22°21′00"N and 89°19′00"E) in compartment no.36 in the Moderate saline water zone (MSWZ) and Chunkuri (22°15′02"N and 89°09'01"E) in compartment no.47 in the Strong saline water zone (SSWZ). Infestation and other relevant data were collected properly from November 2007 to December 2009.

## Symptoms of Heart Rot Disease

In each location, a total of 100 Passur trees were randomly selected for observing symptoms of heart rot disease. The symptoms of heart rot disease have been observed, recorded and fruit bodies collected from time to time in the Sundarbans. Photographs were taken. Disease affected and healthy trees were also recorded.

## Categorization of Heart Rot infested Passur Trees

The data of percent heart rot of Passur in four canopy classes following modified method of Karim (1995, Leech and Ali, 1997). The dbh classes were CI (<20cm), C2 (21-30cm), C3 (31-40cm) and C4 (>40cm).

## Canopy Class Description of Passur in the Study Site

1. G1 canopy tree class - G1 class was characterized with healthy foliage and intact shoot. It was considered as unaffected (Healthy) Passur trees.
2. G2 canopy tree class- G2 canopy tree class was unhealthy foliage and the top was 25 % leafless with presence of fruit bodies anywhere of the stem.
3. G3 canopy tree class- G3 canopy tree class was characterized for having unhealthy foliage (top broken), less than 50% crown were leafless along with presence of fruit bodies and
4. G4 canopy tree class- G4 canopy tree class was characterized for having unhealthy foliage (top broken), more than 50% crown leafless and appearances of fruit bodies on the stem or branches.

## Collection of Data in the TSPs

One hundred individuals of Passur stems were investigated randomly to detect heart rot status in each location and the data on diameter at breast height (dbh 1.3m) were recorded in all the study sites from the selected Passur trees. In this study, in each of the six locations three quadrants Temporary Sample Plots

(TSP) were established to count regeneration (seedling, sapling and tree) of the major mangrove species. Each TSP plot covered an area of (2.5m x 4m =10m$^2$x3=) 30m$^2$.


## Identification of Fungal Disease

This section includes detailed methodology of collection of samples from the field and their transportation to the laboratory and further processing for isolation. Wood samples of decay materials have been tested for pure culture in the Pathological Laboratory of Forestry and Wood Technology (FWT) Discipline,

and Agro-technology Discipline, Khulna University for isolation of causal organisms. Wood decay and heart rot fungi and their isolation were done in the laboratory systematically.

### Confirmation of Fungal Identification

The pure culture of isolates (four samples) was sent to The International Mycological Institute (IMI), UK for confirmation and identification of fungus.

## RESULTS AND DISCUSSIONS

### Heart Rot Symptoms Observed during field visit in the Sundarbans

The decay of heart wood by fungi in living trees is heart rot. A basic separation of wood decay can be made on the basis of whether the fungus survives primarily in living trees or in dead trees and wood products. However decay fungi may attack heartwood through openings in the barks and sapwood. Observations on heart rot of Passur trees in the Sundarbans were made during closer observation and diameter at breast height (dbh) measurement of 100 hundred trees in each of six sites. The following symptoms observed in heart rot affected Passur trees (Helal Siddiqui, 2009; Helal Siddiqui, 2010; Helal Siddiqui and Khair, 2012):

- Presence of dead branch, stub and top dying.
- Presence of dead branches in the top portion.
- Early stage of development fungal fruit bodies on dead branch stub.
- Presence of fruit bodies is generally one of the diagnostic characters of heart rot of Passur (Figure-10).
- The number of fruit bodies, their sizes, age, colour, and the general condition of the tree give some indication of the amount of wood decay Helal Siddiqui (2009a).
- Quite often heart wood of heart rot affected tree show distinct rot in side the tree trunk (Figure-11).
- There are decayed dusts like material inside the root of fruit bodies.
- Sometimes presence of gall or cancer formation on the stem and branches may also be found.
- Dieback may or may not be found on heart rot affected trees. But the dieback condition is not related to heart rot. Dieback is an altogether different disease problem.
- Cyclone damage may result in broken tops or major or minor branches. When these get old can act as an entry point of heart rot fungi.

Fig.1. Top dead passur trees in Sundarbans

Fig.2. Fruit body on the Passur stem

Fig.3. Fresh and Heart rot affected sawn plank

In this study to assess the vegetation and regeneration composition of the major species with a view to evaluating the stand density the recorded field data were tabulated and summarized. The status of vegetation survey at the six sites have been summarized in Table 1 and 2.

Table 1. Status of regeneration per hectare at six sites in the Sundarbans

| Name of Species | Name of locations | | | | | |
|---|---|---|---|---|---|---|
| | Kashia bad | Chun kuri | Kalabogi | Bania khali | Bojboja | Supati |
| | Regeneration per hectare | | | | | |
| Passur (*Xylocarpus mekongensis*) | 11000 | 2333 | 8667 | 48000 | 7000 | 333 |
| Gewa (*Excoecaria agallocha*) | 23000 | 6000 | 1000 | 2333 | 21000 | 9333 |
| Sundri (*Heritiera fomes*) | 4000 | 4333 | 5667 | 2000 | 3667 | 26333 |
| Amur *(Amoora cucullata*) | 12000 | - | 333 | - | 666 | 333 |
| Jhana(*Rhizophora mucronata*) | 2000 | - | - | - | - | - |
| Lata sundry(*Brownlowia tersa)* | 666 | - | - | - | - | - |
| Bain (*Avicennia officinalis*) | - | 333 | 1000 | 666 | - | 333 |
| Goran (*Ceriops decandra*) | - | 13000 | - | | 12000 | - |
| Khalshi (*Aegiceras corniculatum*) | - | 7666 | - | 11333 | - | - |
| Hantal (*Phoenix paludosa*) | - | 1000 | - | 5666 | - | - |
| Kankra (*Bruguiera* spp.) | - | - | 50667 | - | 1667 | - |
| Hargoja (*Acanthus illicifolias*) | - | - | - | 6000 | 666 | - |
| Keora (*Sonneratia apetala*) | - | - | - | - | 666 | 666 |
| Golpata (*Nypa fruticans*) | - | - | - | - | | 666 |
| Total | 52666 | 34666 | 67334 | 75998 | 47332 | 37333 |

At Kashiabad (Table 1 and 2) in MSWZ mainly six species were found. It is gewa dominated area of the Sundarbans. In this location Gewa dominated in the list of six species, 23000/ha (43.67%). This followed by Amur (22.79%) and Passur 11000 per/ha (20.88%).Sundri constituted 4000 per/ha (7.59%), Jhana (3.80%) and Lata Sundri (1.26%). At Chunkuri (Table 1 and 2) in SSWZ Goran dominated in the list of seven species being 13,000 per/ha (37.50%). This is followed by Khalshi 7666/ha (22.11%) Gewa constituted 6000/ha (17.31%), Sundri (12.50%), Passur (6.73%) Hantal (02.88%) and Baen (0.96%), Goran (37.5%) and Khalshi (22.11%).

Table 2. Status of regeneration at six sites in the Sundarbans

| Name of Species | Nane of locations | | | | | |
|---|---|---|---|---|---|---|
| | Kashiabad | Chun kuri | Kala bogi | Bania khali | Bojboja | Supati |
| | Percentage (%) Total vegetation | | | | | |
| Passur (*Xylocarpus mekongensis*) | 20.88 | 06.73 | 12.87 | 63.16 | 14.79 | 14.79 |
| Gewa (*Excoecaria agallocha*) | 43.67 | 17.31 | 01.48 | 03.05 | 44.37 | 44.37 |
| Sundri (*Heritiera fomes*) | 07.59 | 12.50 | 8.42 | 02.63 | 07.75 | 07.75 |
| Amur *(Amoora cucullata*) | 22.79 | - | 00.49 | - | - | 00.89 |
| Jhana(*Rhizophora mucronata*) | 03.80 | - | - | - | - | - |
| Lata sundry(*Brownlowia tersa)* | 01.26 | - | - | - | - | - |
| Bain (*Avicennia officinalis*) | - | 00.96 | 01.48 | 00.87 | 01.41 | 00.89 |
| Goran (*Ceriops decandra*) | - | 37.50 | - | - | 25.35 | - |
| Khalshi (*Aegiceras corniculatum*) | - | 22.11 | | 14.91 | - | - |
| Hantal (*Phoenix paludosa*) | - | 02.88 | | - | - | - |
| Kankra (*Bruguiera* spp.) | - | - | 75.25 | 7.45 | 03.52 | - |
| Hargoja (*Acanthus illicifolias*) | - | - | - | 7.89 | 01.41 | - |
| Keora (*Sonneratia apetala*) | - | - | - | - | 01.41 | 01.78 |
| Golpata (*Nypa fruticans*) | - | - | - | - | - | 01.78 |
| Total | 100% | 100% | 100% | 100% | 100% | 100% |

At Kalabogi (Table 1 and 2) in MSWZ the result shows that Kankra dominated in the list of six species being 50,667/ha (75.25%). This is followed by Passur 8667/ha (12.87%). Sundri constituted 5667/ha (8.42%), Gewa (1.48%), Baen (1.48%) and Amur (0.49%). At Baniakhali (Table 2) in MSWZ Passur trees dominated in the list of seven species, 48,000/ha (63.16%). This is followed by Khalshi 11,333/ha (14.91%,). Sundri constituted 2000/ha (2.63%), Gewa (3.05%), Kankra *(*7.45%), Baen (0.87%) and Hargoja (7.59%).

At Bojboja (same table) in MSWZ eight major species were found. It is also Gewa dominated area of the Sundarbans. In this location Gewa dominated in the list of eight species and Gewa 21000/ha (44.37%). This is followed by Goran 25.35% and Passur 7000/ha (14.79%). Sundri represented 3667/ha (7.75%). Kankra (3.52%), Baen (1.41%), Keora, (1.41%) and Hargoja (1.41%) are the dominant ones in descending order.

At Supati in (Table 1 and 2) FWZ seven major species were found. It is also Sundri dominated area of the Sundarbans. In this location Sundri dominated in the list of seven species and Sundri occupies 26333/ha (70.53%). This is followed by Gewa (24.89%) and Golpata (1.78%). Keora represented (1.78%), Kankra (3.52%), Baen (0.89%), and Amur (0.89%) are the dominant ones in descending order.

The highest regeneration were recorded at Baniakhali (Moderate saline water zone) 76,997/ha, 37,333/ha at Supati (Fresh water zone) and lowest at Chunkuri (Strong saline water zone) 34,666/ha (Table 3). The status of only Passur (Trees, saplings (<5 cm dia) and saplings (>5 cm dia) at the six sites are presented in Table 3.

Table 3. Status of only Passur (Trees, saplings (<5 cm dia) and saplings (>5 cm dia) at the six sites in the Sundarbans

| Name of Location | Salinity zones | Compartment No. | No. of Total regeneration per/ ha | Total Passur /ha. | Passur as % of total vegetation of all species |
|---|---|---|---|---|---|
| Supati | FWZ | 04 | 37333 5th | 333 | 00.89 |
| Kashiabad | MSWZ | 36 | 52666 3rd | 11000 | 20.88 |
| Kalabogi | MSWZ | 32 | 67334 2nd | 8667 | 12.87 |
| Baniakhali | MSWZ | 35 | 76997 1st | 48000 | 63.16 |
| Bojboja | MSWZ | 37 | 47332 4th | 7000 | 14.79 |
| Chunkuri | SSWZ | 47 | 34666 6th | 2333 | 06.73 |

It is thus evident from Table-3 (above) that Passur trees, saplings up to 3 years (dbh <5 cm), and saplings above 3 years (dbh >5 cm)were most dominant in the moderately saline water zone 63.16% at Baniakhali followed by 20.88% at Kashiabad; its occurrence in saline water zone and was the least in fresh water zone in the Sundarbans.

**Comparison of vegetation in three salinity zones in the Sundarbans**

The regeneration status of the different locations are also more or less similar on number of trees and saplings of the major species in the Fresh Water Zone (FWZ), Moderately Saline Water Zone (MSWZ) and Strong Saline Water Zone (SSWZ) as earlier published by Helal Siddiqui (1999). Table 4 shows the occurrence of only Passur in three salinity zones in the Sundarbans (Table modified after Helal Siddiqui, 1999).

Table 4. Status and composition of Passur trees and saplings in three salinity zones in the Sundarbans (Helal Siddiqui, 1999).

| Species | Salinity Zones | Trees/ha | % of trees of all species | Saplings/ha | % of saplings of all species |
|---|---|---|---|---|---|
| Passur | FWZ | 48 | 1.21 | 53 | 0.10 |
| Passur | MSWZ | 240 | 4.67 | 48 | 0.05 |
| Passur | SSWZ | 181 | 3.21 | 1488 | 8.38 |

Table 4 shows that highest no. of Passur trees/ha were present in moderately saline water zone (MSWZ) followed by that in Strong saline water zone (SSWZ), and the lowest occurrence of Passur trees were in fresh water zone (FWZ). But the occurrence of Passur saplings/ha were the highest in SSWZ followed by that in FWZ and the lowest in MSWZ in the Sundarbans.

**Occurrence of heart rot Passur trees at six sites in the Sundarbans**

In each of the six sites at Supati, Kashiabad, Chunkuri, Kalabogi, Baniakhali, and Bojboja 100 Passur trees were randomly selected and status of the health of each of the tree was classified into four categories such as G1,G2,G3 and G4 canopy tree classes. Diameter at breast height (dbh) and status of the health of each of the tree (Which was classified into four categories of each of the 600 trees) from six sites was also recorded.

The status of healthy and heart rot categories are summarized in Table-5 and shown in the Figure 4.

Table 5. Determination of healthy (G1) and heart rot affected (G2, G3, G4) Passur trees at six locations in the Sundarbans

| Location | Healthy trees | Heart Rot Affected trees categories | | | Number of heart rot affected | Total nos. of trees observed |
|---|---|---|---|---|---|---|
| | G1 | G2 | G3 | G4 | | |
| Kalabogi | 36 | 23 | 28 | 13 | 64 | 100 |
| Bojboja | 38 | 19 | 29 | 14 | 62 | 100 |
| Baniakhali | 40 | 17 | 31 | 12 | 60 | 100 |
| Kashiabad | 46 | 14 | 19 | 21 | 54 | 100 |
| Chunkuri | 36 | 15 | 25 | 24 | 64 | 100 |
| Supati | 83 | 11 | 4 | 2 | 17 | 100 |
| Mean | 46.50 | 16.50 | 22.67 | 7.71 | | |

Since heart rot affected Passur trees at Supati area were very low as compared to five other sites and at the same time healthy trees were also very high, this contributed to very large pooled Standard deviation of 11.31 and that is why one cannot find any significant difference among the three categories of Passur heart rot as is evident from over lapping of the confidence intervals of G2 (represented by C2), G3 (represented by C3) and G4 (represented by C4). Therefore, by excluding data from Supati a comparison of the Passur heart rot data from remaining five sites were made and presented in the Table 6.One can find a significant F=6.72 with 2 and 12 df and P=0.011. A further comparison of the individual 95% Confidence Intervals (CIs) for mean based on pooled standard deviation (StDev) shows that CI of G3 (represented by C3) do not

overlap with any of the remaining two CIs (i.e. that of G2 (represented by C2) and G4 (represented by C4)), but these last two CIs overlaps revealing that the mean values of 17.50 and 16.80 respectively for G2 and G4 do not differ significantly (Table 6). This is also shown in Fig.4.

Table 6. Analysis of variance of per cent heart rot of Passur trees of three categories G2 (represented by C2), G3 (represented by C3) and G4(represented by C4) at five sites in the Sundarbans

Analysis of Variance:

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Factor | 2 | 283.7 | 141.9 | 6.72 | 0.011 |
| Error | 12 | 253.2 | 21.1 | | |
| Total | 14 | 536.9 | | | |

Individual 95% CIs For Mean
Based on Pooled St Dev

| Level | N | Mean | St Dev | ----------+---------+---------+------ |
|---|---|---|---|---|
| C2 | 5 | 17.600 | 3.578 | (------*-------) |
| C3 | 5 | 26.400 | 4.669 | (------*------) |
| C4 | 5 | 16.800 | 5.357 | (------*------) |
| | | | | ----------+---------+---------+------ |
| Pooled St Dev = | | 4.593 | | 18.0 24.0 30.0 |

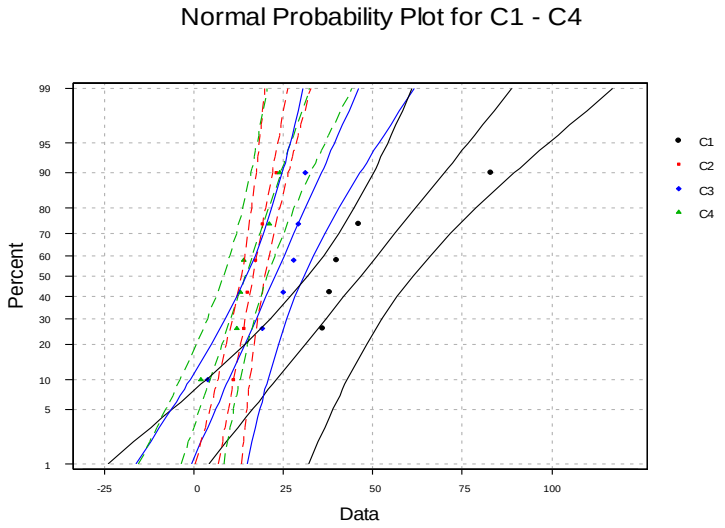


Figure 4. Normal probability plot of the data of G1 (represented by C1), G2(represented by C2), G3(represented by C3) and G4 (represented by C4) of six sites (vide Table 6)

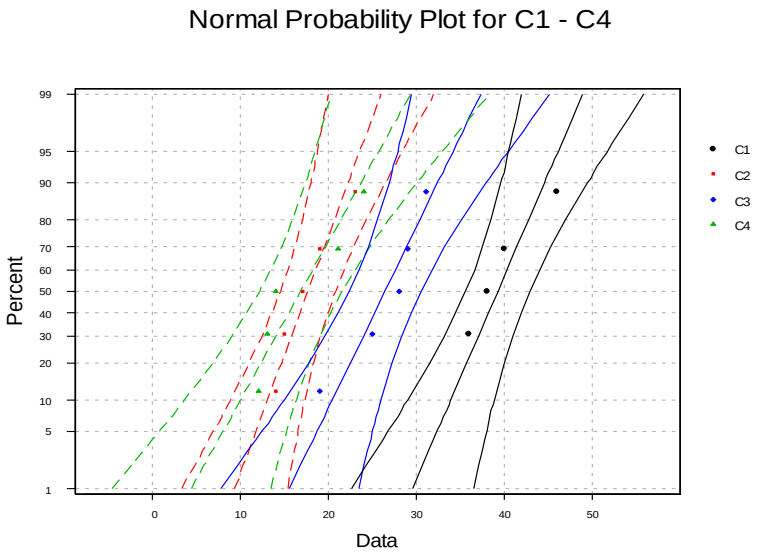


Fig.5. Normal probability plot of the data of G1 (represented by C1), G2(represented by C2), G3(represented by C3) and G4 (represented by C4) of five sites excluding Supati data (vide Table 6).

**Heart Rot of Passur in relation to its diameter at breast height (DBH)**

The data of heart rot of Passur trees and the diameter at breast height (dbh) of 100 randomly selected Passur trees at each of Kalabogi (in compartment No.32), Bojboja (in compartment No.47), Baniakhali (in compartment No.36), Kashiabad (in compartment No.35), Chunkuri (in compartment No.37) and Supati (in compartment No.4) in the Sundarbans Reserved Forest in Bangladesh have been summarized in Tables 7. The Tables are self explanatory. Average percentage of heart rot affected Passur trees according to diameter at breast height (dbh) classes are provided in Table 7 and presented in Figure-4. The results also show that in the six locations of the Sundarbans diameter at breast height (dbh) Class IV (>40cm) is highly affected 34%, then followed by dbh Class III (31-40cm) 31%,Class II (21-30cm) 25% and the lowest only 10% in the Class I (<20cm) as is evident from pie chart in Fig.6.

Average heart rot affected percentage (%) results were also calculated from the collected field data sheet. The result shows that the infection status of heart rot disease of Passur differs place to place and at different locations of the Sundarbans. The analyzed result shows that it is heavily infected at Kalabogi. Then followed at Baniakhali. It was observed and enumerated heart rot infection status at six different locations in the Sundarbans. The result shows that the

Table 7. Percentage of heart rot affected Passur trees according to Diameter at Breast height (DBH) classes at six locations in the Sundarbans

| Compt. Nos. | Location | No. of heart rot affected Passur trees according to DBH classes | | | | |
|---|---|---|---|---|---|---|
| | | Class I (<20cm) | Class II (21-30cm) | Class III (31-40cm) | Class IV (>40cm) | Average heart rot % |
| 3 | Supati | 01 | 01 | 06 | 09 | 17 |
| 36 | Baniakhali | 04 | 16 | 34 | 06 | 60 |
| 35 | Kashiabad | 06 | 10 | 34 | 04 | 54 |
| 47 | Bojboja | 06 | 10 | 20 | 26 | 62 |
| 32 | Kalabogi | 04 | 18 | 36 | 06 | 64 |
| 37 | Chunkuri | 02 | 16 | 24 | 06 | 48 |
| | Total: | 23 | 71 | 154 | 57 | 50.83 |

percentages are 64%, 62% and 60% respectively. These are followed by Kashiabad 54% and Chunkuri 48% (in Table 7).Very low amount of trees are affected at Supati located in the fresh water zone of the Sundarbans. The results also show that in the six locations of the Sundarbans diameter at breast height (dbh.) Class IV (>40cm) is highly affected 34%, then followed by dbh Class III (31-40cm) 31%,Class II (21-30cm) 25% and the lowest only 10% in the Class I (<20cm) as is evident from pie chart in Fig.6. The average per cent of heart rot from the four dbh classes in each of the six locations are provided in pie chart in Fig.6. Percent of Passur trees affected by heart rot according to four diameter at breast height (DBH) classes at each of six sites at Kalabogi, Bojboja, Baniakhali, Kashiabad, Chunkuri and Supati in the Sundarbans provided in Fig. 7.

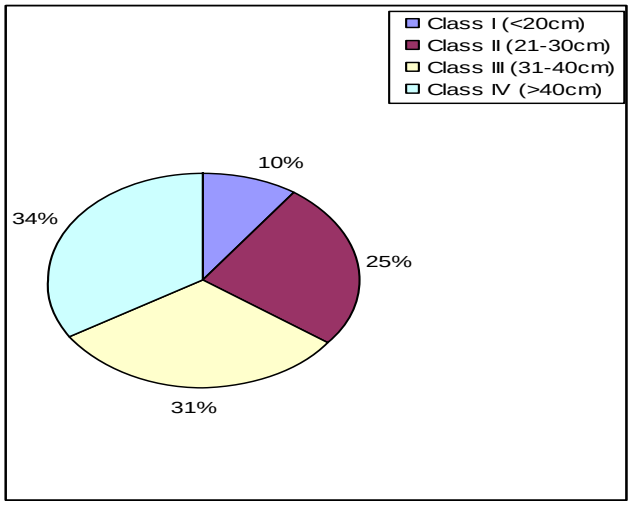


Fig.6. Percentage of heart rot affected trees according to DBH class on an average of six locations of in the Sundarbans

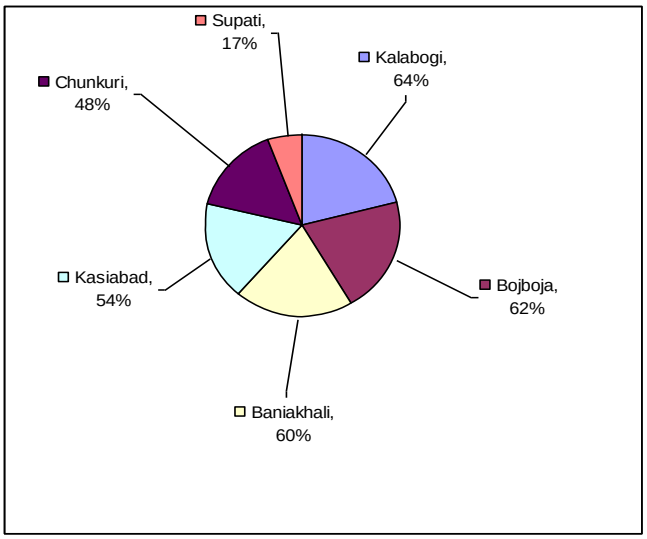


Fig.7. Percent (%) of heart rot affected Passur trees at six sites in the Sundarbans

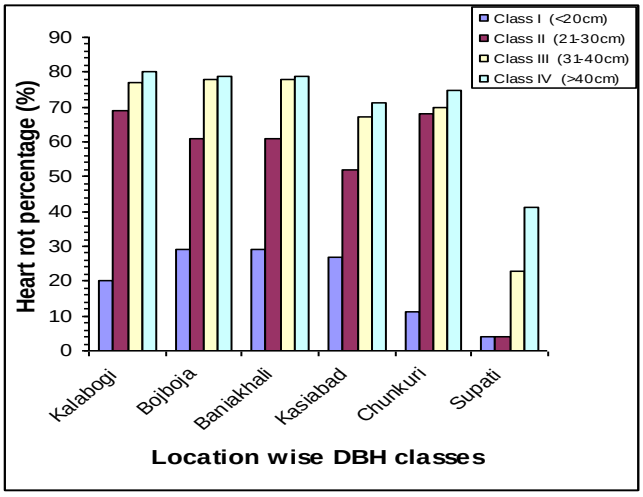


Fig.8. Percent (%) of Passur heart rot affected trees according to four DBH classes at each of six locations in the Sundarbans.

Summary of analysis of variance of heart rot affected per cent of Passur trees in four dbh classes at six locations in the Sundarbans is presented in Table 8.

Table 8. Analysis of variance of heart rot affected per cent of Passur trees in four dbh classes (dbh Class I (<20cm); dbh Class II (21-30cm); dbh Class III (31-40cm) and dbh Class IV (>40cm) at six locations in the Sundarbans.

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Factor | 3 | 1546.5 | 515.5 | 8.42 | 0.001 |
| Error | 20 | 1224.5 | 61.2 | | |
| Total | 23 | 2771.0 | | | |

Individual 95% CIs for Mean
Based on Pooled St Dev

| Level | N | Mean | St Dev | ---+---------+---------+---------+--- |
|---|---|---|---|---|
| C1 | 6 | 3.833 | 2.041 | (------*-----) |
| C2 | 6 | 11.833 | 6.274 | (------*-----) |
| C3 | 6 | 25.667 | 11.553 | (------*-----) |
| C4 | 6 | 9.500 | 8.240 | (------*-----) |
| | | | | ---+---------+---------+---------+--- |
| Pooled St Dev | = | 7.825 | | 0 10 20 30 |

Analysis of variance of the data of per cent heart rot of Passur at six sites (i.e. Supati, Baniakhali, Kashiabad, Bojboja, Kalabogi and Chunkuri) are provided below (Table 9 ) which shows a very highly significant F value of 8.42 having a P = 0.001. This suggests that data of per cent heart rot of Passur are different from the four dbh (diameter at breast height) classes (C1(<20cm), C2 (21-30cm), C3 (31-40cm) and C4 (>40cm) showed very highly significant variations. A comparison of the Individual 95% CI (Confidence Intervals) for Mean based on pooled Standard deviation (StDev) reveals that there is no significant difference between the 95% CI from per cent heart rot of Passur from dbh class C1, C2 and C4 as these CIs overlap, whereas the CI for dbh class C3 (dbh31-40cm) has the highest value and do not overlap with any of the remaining three CIs. So it is clear that Passur trees having dbh class C3 (31-40cm) were most highly associated with per cent heart rot. This calls for pathological rotation of Passur trees arriving at dbh class C4 (>40cm) for better salvage of useable timbers. Pathological rotation (the point in the life of trees when both volume of wood increment and deterioration are same) should be practiced which will ensure maximum timber yield and which would be different for different hosts as well as causal fungi (Khan and Rahman, 2013).

## Preparation of Culture Media

For the preparation of MA media 20 gm of malt, 20 gm agar powder and 1 liter water were used and laboratory works that is Isolation were done very sincerely and systematically with the help of Forestry and Wood Technology Discipline, Laboratory, Khulna University. The pure culture of isolates (four samples) were sent to The International Mycological Institute (IMI), UK for confirmation and identification of fungus. The IMI finally identified two pathogens from three samples and one sample was contaminated. The identified two pathogens are *Schizophyllum commune, Phanerochaete subglobosa* and the other one is *Ganoderma appalanatum* locally identified.

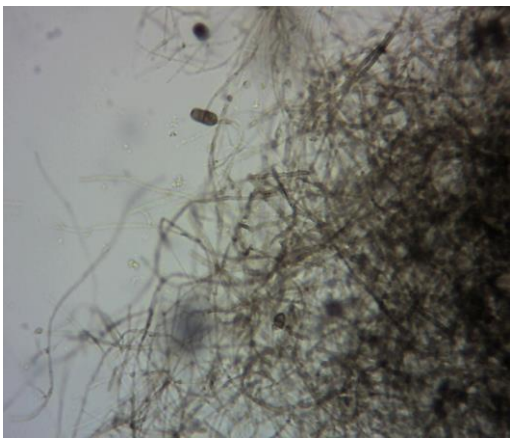

Fig.9. Microscopic photo of Fungal pathogen grown in the media at the laboratory

Fig.10: Heart rot affected Passur stem with hole

Fig.11: Heart rot damaged Passur log

Vegetation status differs from place to place in the different locations in the Sundarbans (Helal Siddiqui, 1999, 2002; Siddqi, 2001). Different ecological causes are responsible for this. The highest regeneration were recorded at Baniakhali 76997 per/ha, 37333per/ ha at Supati and lowest at Chunkuri 34666per/ha. Pasur (*Xylocarpus mekongensis*) is one of the most important timber yielding species like other important mangrove species in the Sundarbans mangrove forest of Bangladesh. Indeed heart rot is the inconspicuous disease of Pasur, resulting gradual increase with age and loss of merchantable heart wood of lignin portion. So, proper treatment methodology is must to increase the durability of various things. The disorders and diseases caused by different fungal pathogen. More than 50% pasur trees in the respective areas are affected by heart rot problem. The observation reveals that young trees are merely affected and old, useable and mature trees are affected severely associated with gewa (*Excoecaria agallocha*), sundri (*Heritiera fomes*) and goran (*Ceriops decandra*) vegetation in the moderate saline water zone of the Sundarbans. In the fresh water zone pasur trees are poorly affected by heart rot disease. On the other hand in strong saline water zone it is moderately affected by heart rot disease, associated with gewa and goran vegetation. The factors which causing these diseases are identified. It is already been isolated fungal pathogen through pure culture medium in collaboration with the pathological laboratory of Forestry and Wood Technology Discipline, Khulna University. The International Mycological Institute, UK, confirmed two fungal pathogens within three samples. They identified two fungal pathogens for causal organism namely *Phaenerochaete subglobosa and Schizophyllum commune* and locally identidied *Ganoderma appalanatum*.

The average per cent of heart rot from the four dbh classes in each of the six locations are provided in pie chart in Figure 72. Analysis of variance of the data of per cent heart rot of Passur at six sites (i.e. Supati, Baniakhali, Kashiabad, Bojboja, Kalabogi and Chunkuri) show a very highly significant F value of 8.42 having a P = 0.001. This is primarily due to higher occurrence of heart rotted passur trees in dbh class C4 (dbh>40cm) (vide Table 8). A comparison of the Individual 95% CI (Confidence Intervals) for Mean based on pooled Standard deviation (StDev) reveals that there is no significant difference between the 95% CI from per cent heart rot of Passur from dbh class C1, C2 and C3 as these Classes overlap, whereas the dbh class C4 (dbh>40cm) has the highest value and does not overlap with any of the remaining three Classes. So it is clear that Passur trees having dbh class IV (>40cm) were most highly associated with per cent heart rot. This calls for pathological rotation of Passur trees arriving at dbh class IV (>40cm) for better salvage of useable trees. Khan and Rahman (2013) noted that pathological rotation is the point in the life of trees when both volume of wood increment and deterioration are same, hence it should be practiced which will ensure maximum timber yield and which would be different for different hosts as well as causal fungi.

In the present study in each of six sites (Supati in Compartment 4 in FWZ; Kashiabad in compartment 36; Kalabogi in compartment 32, Baniakhali in compartment 35 and Bojboja in compartment 37 in the MSWZ; and Chunkuri in compartment 47 in SWZ in the SRF) one hundred Passur trees were carefully observed for the presence of heart rot. In all 305 Passur trees out of 600 were found have developed heart rot, while 295 trees did not show an presence of heart rot. For each of the observed 600 trees, the diameter at breast height (dbh) were also measured. The results also show that in the six locations of the Sundarbans diameter at breast height (dbh.) Class IV (>40cm) 34% is affected, then followed by dbh Class III (31-40cm) 31%, II (21-30cm) 25% and the lowest only 10% in the Class I (<20cm) as is evident from pie chart in Figure-71. The average per cent of heart rot from the four dbh classes in each of the six locations are provided in pie chart in Figure 72. Incidence of heart rot is known to be correlated with age of trees (Benizry *et al.*, 1988, Graber, 1994; Baranchugov, 1995; Ito, 1999). Baranchugov (1995) opioned that heart rot infection increased in aspen clones grown in microdepressions in Tatarstam and Ulymnovsk region of Russia. Kimmey and Bynum (1961) reported that thrifty, uninjured young fir trees are generally free from heart rots, but old over-mature trees are frequently so badly decayed they are worthless for lumber manufacture.

## CONCLUSION

The problem of heart rot of Passur has been put forward. Detailed general information on many aspects of Passur has been provided. Through a reconnaissance survey six Passur dominant areas were selected from three

salinity zones in the Sundarbans. These included Supati in compartment 4, Baniakhali in compartment 35, Kashiabad in compartment 36, Chunkuri in compartment 47, Bojboja in compartment 37 and Kalabogi in compartment 32 in the Sundarbans Reserved Forest. Supati represented Fresh Water Zone (FWZ), Cunkuri represented Saline Water Zone and the remaining four sites were in Moderately Fresh Water Zone (MFWZ). Vegetation in each of these six sites was surveyed. On that basis the population of major tree species was calculated. The level of Passur trees/ha were found to be the highest of 240 trees (4.67% of all species) in MSWZ and saplings/ha were 1488 (8.38% of all species) in SSWZ.. Occurrence of heart rot of Passur were surveyed by studying 100 randomly selected trees at each of six sites Supati, Baniakhali, Kashiabad, Bojboja, Kalabogi and Chunkuri. Per cent occurrence of heart rot of Passur were classified according to dbh class I (<20cm), dbh Class II (21-30cm), dbh class III (31-40cm). dbh Class IV (>40cm). It was found that Passur trees having dbh class C4 (>40cm) was most highly associated with per cent heart rot. This calls for pathological rotation of Passur trees arriving at dbh class C4 (>40cm) for better salvage of useable trees. Pathological rotation is the point in the life of trees when both volume of wood increment and deterioration are same, hence it should be practiced which will ensure maximum timber yield and which would be different for different hosts as well as causal fungi. But some biotic and abiotic factors are responsible for the causes. It is suggested that this should be taken into consideration for future decision about management strategy of Passur in the Sundarbans. The wood loss becomes a very high rate which shall impact the total loss of economy and the Sundarbans ecosystem. So, to overcome the disorder and disease special monitoring, care, multi disciplinary research with field study, introduction of proper management system are to be required to formulate and eradicate the problem in the Sundarbans.

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