# New Approach to Select Top-dying Resistant Sundari *(Heritiera fomes)* Trees from the Sundarban of Bangladesh

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## Abstract

Selecting exceptionally *Heritiera fomes* seedlings from nursery is a promising and low-cost means of tree improvement, according to the study. From 2010 to 2016, 18,000 outstanding seedlings were chosen from nursery in the Sundarban and out planted. The final assessment as to efficiency of seedlings selection from selected trees of top-dying affected and non-affected (Healthy) areas awaits comparison of progeny from chosen selects with those from similarly chosen controls to see how much of the phenotypic gain is truly genetic. This investigation involved more selections and plantations than had not been tried for *H. fomes* in the past. The next step in evaluating nursery selection is to compare progeny from selects with those of controls to see how much of the phenotypic gain is truly genetic. The great promise of $L_3$, $L_4$, $L_{12}$, $L_{16}$, $L_{30}$, $L_{35}$ & $L_{36}$ *line* of *H. fomes* trees has been achieved with expected superior genetic material of unknown origin. This is reflected in the high variability observed in growth amongst individuals. Using advanced propagation techniques, these can be cloned and potentially provide the genetic base for a highly successful clonal forestry program for creation of top dying resistant H. fomes trees.

## সারসংক্ষেপ

গবেষণালব্ধ তথ্যানুসারে প্রকাশ, নার্সারিতে বাছাইকৃত সুন্দরী চারা উন্নত জনক্রম সৃজনে সাশ্রয়ী এবং ফলদায়ক। নার্সারিতে উত্তোলিত চারার মধ্য থেকে ১৮,০০০ বিশেষ গুণ সম্পন্ন সুন্দরী চারা বাছাই করে ২০১০ সাল থেকে ২০১৬ সাল পর্যন্ত সুন্দরবনে পরীক্ষামূলক বাগান সৃজন করা হয়। সুন্দরী আগামরা এবং সুস্থ্য-সবল গাছের সংগৃহীত বীজ থেকে উত্তোলিত চারার মধ্য হতে বাহ্যিকভাবে প্রকাশিত সুস্থ্য-সবল বাছাইকৃত চারার মধ্যেই রয়েছে প্রকৃত কৌলিতাত্ত্বিক গুণাগুণ। এ ধরণের নির্বাচন পদ্ধতিতে সুন্দরী গাছের বাগান সৃজন পূর্বে করা হয়নি। পরবর্তী ধাপে জনক্রমের মধ্য থেকে প্রকৃত কৌলিতাত্ত্বিক গুণ সম্পন্ন জনক্রম নির্ধারণ করা হয়। সুন্দরী গাছের $L_3$, $L_4$, $L_{12}$, $L_{16}$, $L_{30}$, $L_{35}$ এবং $L_{36}$ জনক্রম সারী সমূহের মধ্যে অজানা উৎসের চাহিদামাফিক উন্নত কৌলিতাত্ত্বিক গুনাবলী রয়েছে যা বিশেষভাবে আশাব্যঞ্জক। এর প্রভাব জনক্রমসমূহের ভিন্নতায় পরিলক্ষিত হয়। সফল ক্লোনাল ম্যানগ্রোভ বনায়ন কার্যক্রমে অত্যাধুনিক উদ্ভিদ প্রজনন কৌশল ব্যবহার করে আগামরা সহিষ্ণু ফলপ্রসু সুন্দরী গাছ সৃজন করা সম্ভব।

## Introduction

The Sundarban is the largest single tract natural mangrove forest in the world. It is located at the southern part of the Gengetic delta spanning over an area of 6,017 km2 (5,77,285 ha) in Bangladesh. Out of this approximately 70% are lands and 30% are water bodies. The floristic composition of this forest is very rich compared to other mangrove forests of the world. Sundari (Heritiera fomes) and gewa (Excoecaria agallocha) are the major mangrove species in the Sundarban. H. fomes is a most commercially valuable and dominant tree species of the Sundarban mangrove ecosystem which belongs to the family- Sterculiaceae. It is used for bridge and house construction, boat building, rafter, hardboard making, fire wood, brick burning, heavy furniture, paneling, electric poles, etc. This species commands its single dominance in 52.7% and co-dominance in 14.8 % of the forest area and representing about 64% of the total standing volume (Chaffey et al. 1985, Rahman 1995).

This important species has been subjected to a serious disease syndrome called top dying. This disorder causes death from top to downwards. Top dying appears as a decline and dieback of the foliage and twigs of the upper part of the crown. Ultimately upper portion of the main stem becomes die, dries and can be broken off by strong wind. In case of older trees, one or more of the major branches may be broken off, then gradually other branches die and the crown is subsequently reduced. The symptoms of top dying was observed as early as in 1926 and recorded as such in 1960 by the Forestal during their inventory of the Sundarban (Chowdhury 1968). The history of top dying of H. fomes in the Sundarban is not a new thing. It has reported as an epidemic in the last few decades. Now, it has become a threat for the species and to the world's largest mangrove forest, the Sundarban. There is substantial dieback of Sundari trees in the forest. Sundari trees in the Sundarban are being destroyed following outbreak of the top-dying disease, locally known as 'agamora'. Top dying of sundari in the Sundarban was first reported by Troup (1921). He mentioned that sundari trees growing in the depressions tend to deteriorate rapidly and die off. Afterwards Curtis (1933), Ahmed (1957), Forestal (1960) recorded top dying of H. fomes trees in the Sundarban. Later on, it was reported by Chowdhury (1968), Sobhan (1973), Gibson (1975), Sattar (1977), Rahman et al. (1983), Rahman et al.(2003a), Rahman et al. (2003b), Chowdhury (1984), Chaffey et al. (1985), Karim (1995) and Rahman (1990, 1995, 1996, 1998, 2001 and 2004).

There are 9 blocks and 55 Compartments in the Sundarban. Top dying of H. fomes has been found to prevail in all 9 blocks in the forest. The incidence and distribution of top dying trees was first investigated by Chaffey et al. (1985). He reported 14 Compartments viz. 6, 14, 21, 23, 25, 26, 28, 32, 33, 38, 39, 45, 46 and 47 top dying of H. fomes were found to be severe. He also reported that 17% of the main forest types of the Sundarban are affected by top dying, of which 10% are moderately affected (crown less than 50% affected) and 7% are severely affected (crown 50% or more affected).

Rahman (1990) studied the extent and intensity of occurrence of top dying of H. fomes. He found that over 45.2 million H. fomes trees were affected by top dying in 22 Compartments viz. 6, 14, 17, 18, 21, 23, 25, 26, 28, 31, 32, 35, 36, 37, 38, 39, 40, 42, 45 and 47 out of 55 Compartments in the Sundarban. Out of this, 25.02 million trees covering 25,446 ha were found moderate top dying and 20.18 million trees covering 19,848 ha were severely affected.

Rahman et al. (2003a) also studied the extent of top dying by the analysis of data of top dying sundari in 1190 Temporary Sample Plots (TSP) falling in 55 compartments in the Sundarban. The data were generated through Forest Resources Management Project, Forest Inventory of the Sundarban during 1996 and 1997. They prepared a Relative Ranking Index considering the percent of top dying. Based on the value of the relative ranking index the compartment were arranged in decreasing order of occurrence of top dying of sundari trees in the Sundarban and are as follows: 37, 33, 40, 19, 36, 18, 45, 34, 22, 8, 20, 5, 31, 38, 25, 29, 32, 13, 26, 43, 28, 27, 17, 44, 10, 30, 24, 4, 9, 16, 35, 2, 3, 14, 39, 1, 11, 21, 6, 7, 12 and 15 (Rahman 2004). Top dying of H. fomes was seemed to be due to a single or a combination of several factors (Hossain 2015).

Disease is an abnormal unhealthy condition produced in an individual due to defective nutrition, defective heredity, unfavorable environment or infec¬tion. Disease causing organism is called pathogen. The individual in which a disease is caused by a patho¬gen is called host. The development of disease in a plant depends on three factors: (i) host genotype, (ii) patho¬gen genotype and (iii) the environ¬ment. Some host genotypes possess the ability to prevent a pathogen strain from producing disease. Such host lines are called resistant, and this ability is called resistance or disease resistance. The term strain has a similar meaning for the pathogen as line has for the host. Those lines of a host that are not resistant to the pathogen are called susceptible. A successful breeding for disease resistance depends mainly on the following two factors: (i) a good source of resistance, and (ii) a dependable disease test. In disease test, all the plants are grown under conditions in which a susceptible plant is expected to develop disease. Therefore, disease resistant plants should be produced to avoid infec¬tion.

Breeding is carried out either by conventional breeding techniques or by mutation breeding. The conventional method of breeding for disease resistance is hybrid¬ization and selection. The various sequential steps are: screening germplasm for resistance sources, hybridization of selected parents, selection and evaluation of hybrids and testing.

It is feared H. fomes may be soon driven to extinction due to the rapid spread of the disease that lead to slow forest growth and reduced productivity of forest sites. Although a number of works on pathological, ecological (soils), entomological and silvicultural aspects to address the problem of top dying of H. fomes have been conducted but no conclusive result yet achieved till to date. The purpose of this research is to discuss tree improvement methods as an evolving technology, considering the increasing levels of knowledge of the underlying mechanisms and the control of the process of generating and selecting superior plant types. Therefore, this study has been undertaken to develop a top dying resistant H. fomes population in the Sundarban.

**Materials and Methods**
The research was carried out in the Sundarban. It lies between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 89°55'E. The Mangrove Silviculture Division of Bangladesh Forest Research Institute has been studying selection of top-dying resistant sundari trees since 2010 by establishing healthy sundari stands. Four locations were selected from severely top dying affected (>50% trees affected), moderately affected (25-50% trees affected), less affected (<25% trees affected) and non-affected (healthy) sundari areas of the Sundarban. Ten top dying free healthy H.

fomes trees were selected randomly from each location and thus a total of 40 healthy trees were selected. Seeds of these trees were collected separately and seedlings were raised. From 2010 to 2016, 18,000 outstanding seedlings were selected from the mangrove nursery. Experimental plantations were raised with sundari seedlings from selected 40 trees (each tree considered as one pure line) in a completely randomized design at 1.5m x 1.5m spacing with five replications at four locations (one in top-dying free area and three in top-dying affected areas) of the Sundarbans. Plantations were initially protected by fencing against browsing up to the period it reached beyond the browsing height. The analysis of variance (ANOVA) was done to note whether there any difference existed in the treatments. All tests were at the 0.05 probability level.

## Results and Discussion

The traditional method of tree improvement based on an elementary knowledge of the laws of inheritance has been the selection of plants within landraces, based on the assumption that the progenies of the best individuals are expected to be superior to the progeny of a random sample of the population. This method was formally proposed by Louis de Vilmorin in 1856, although there are mentions of the use of its principles by some farmers earlier in the 19th century (Allard, 1999). Although a more general type of cross-resistance should not be expected to be a typical feature of most resistance mechanisms (Panda and Khush, 1995; Riipi et al.,2005), it may now be important to seek to understand the degree of variation present in currently selected elite parent trees making up the seed production and breeding populations. A reduction in the number of genotypes that researchers should and can afford to work with needs to be tempered with the difficulty of accommodating more traits (Verryn, 2008), particularly if negative genetic correlations are present between traits of interest. Moreover, resistance does not always incur a physiological cost (King et al.,1997), so mechanisms of resistance that are positively correlated with growth would also be desirable ones to pursue.
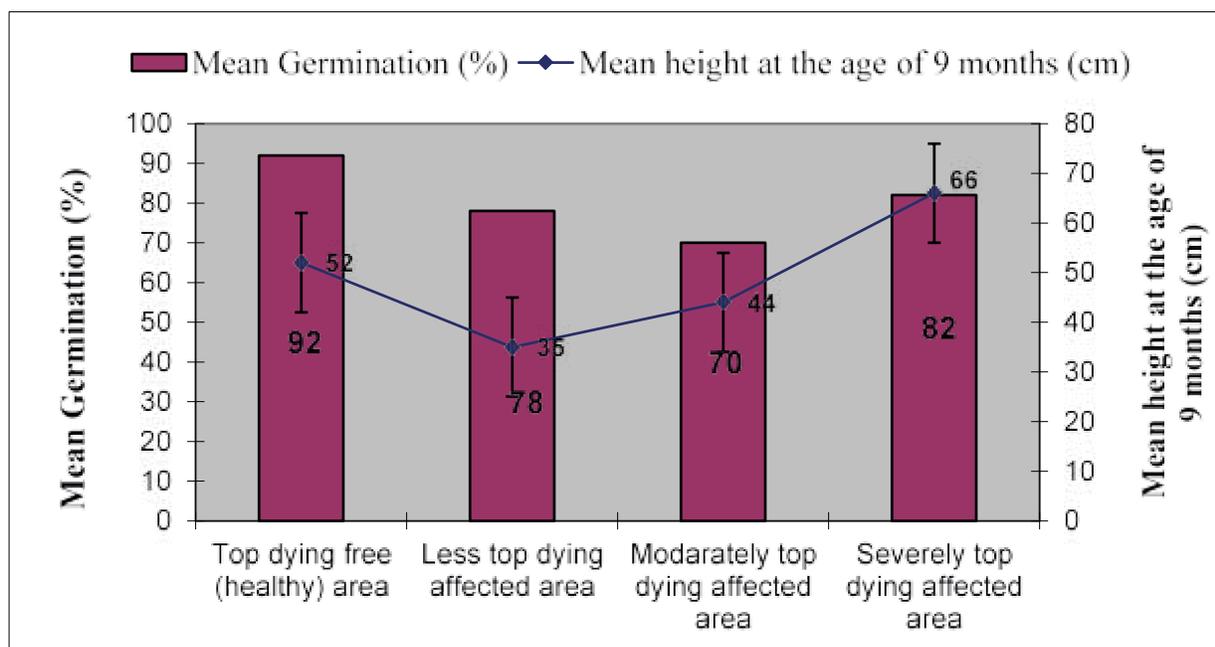


Figure 1: Germination and mean height of offspring of Heritiera fomes selected from top dying affected and non-affected areas of the Sundarban

The Mean height (cm) of 9 months old offspring selected from four top dying severity categories such as healthy area, less affected area, moderately affected area and severely top dying affected area were 52.0±3.16, 35.0±2.12, 44.0±4.05 and 66.0±5.10 as well as mean germination percentage were 92, 78, 70 and 82 respectively shown in Figure 1 & Figure 11,12,13,14.
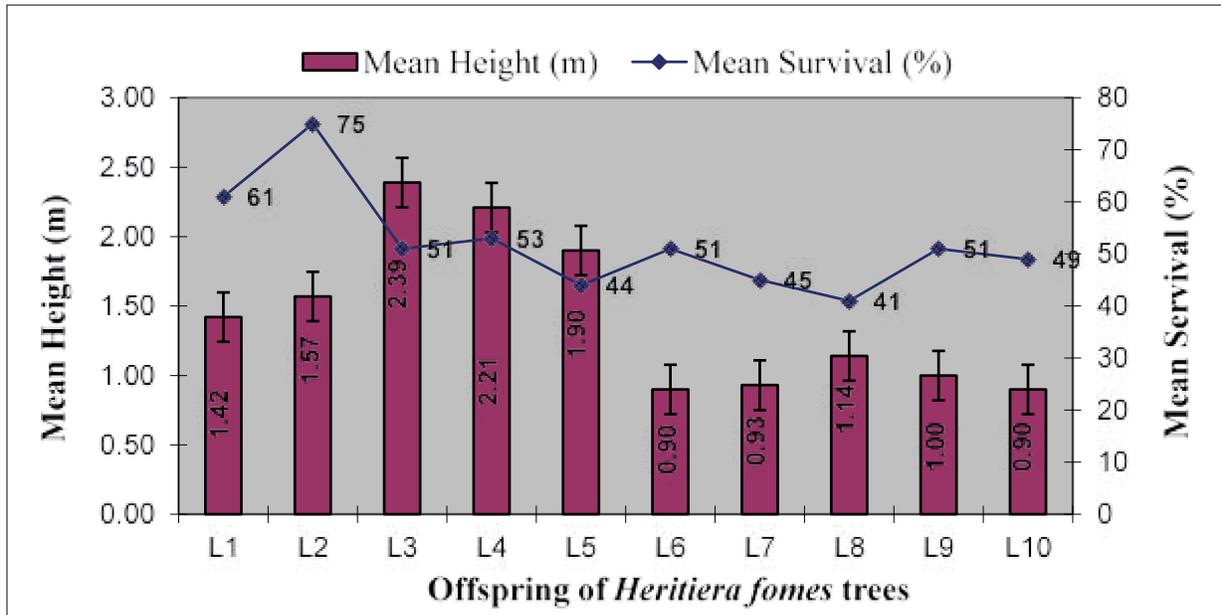


Figure 2: Field evaluation of six years old offspring of *Heritiera fomes* trees selected from natural conditions of top dying free (healthy) areas of the sundarba
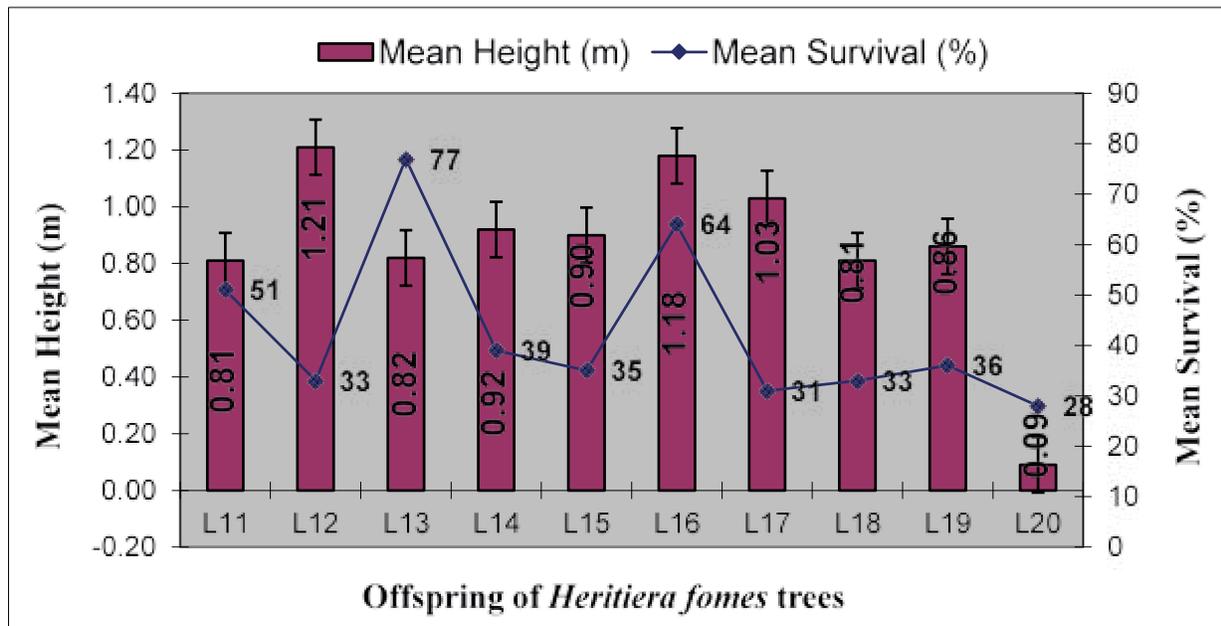


Figure 3: Field evaluation of six years old offspring of *Heritiera fomes* trees selected from natural conditions of less top dying affected areas of the sundarban
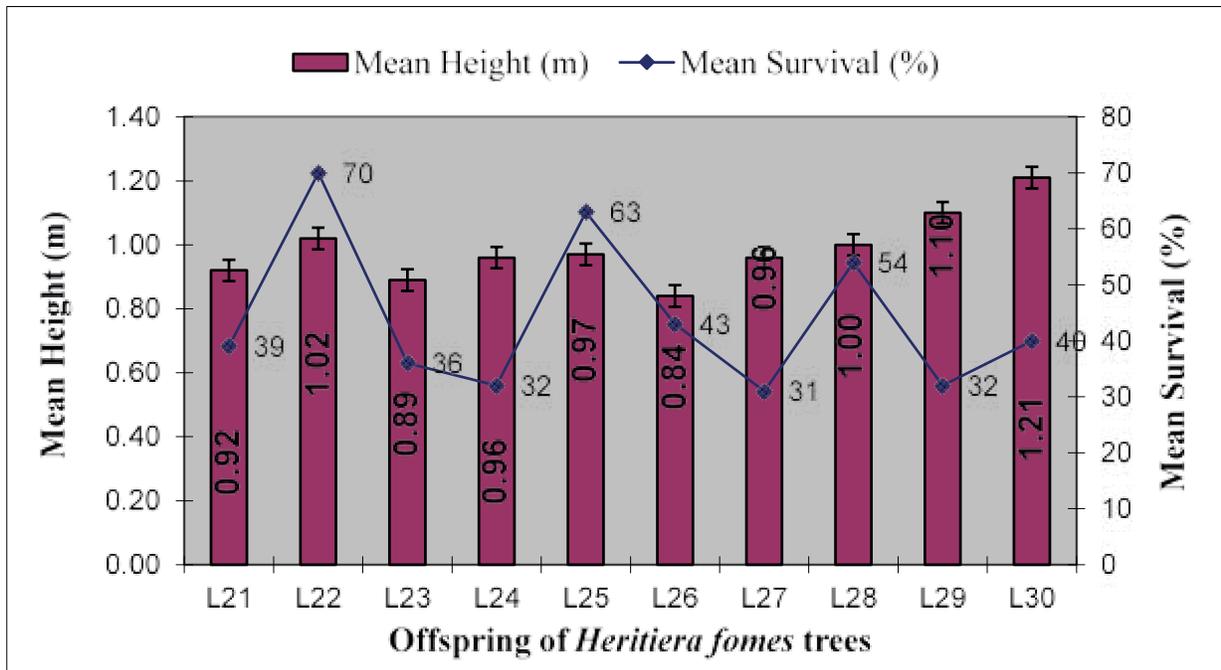
Figure 4: Field evaluation of six years old offspring of *Heritiera fomes* trees selected from natural conditions of moderately top dying affected areas of the sundarban
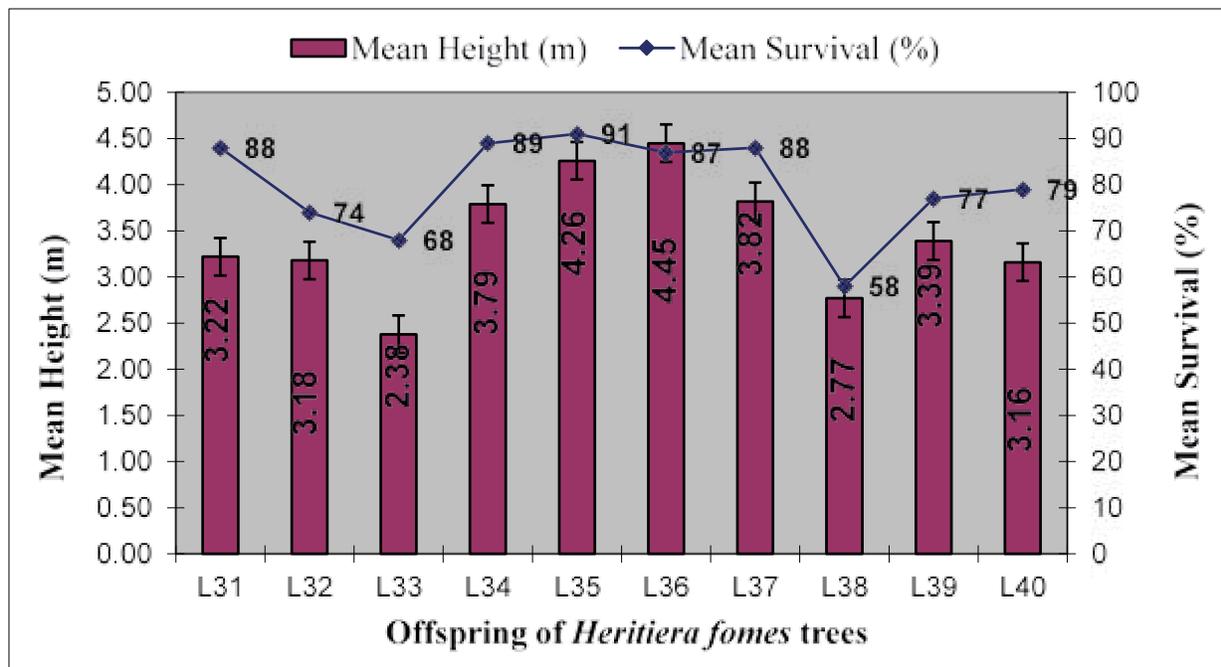


Figure 5: Field evaluation of six years old offspring of *Heritiera fomes* trees selected from natural conditions of severely top dying affected areas of the sundarban

Table 1: Growth performance of six years old offspring of Heritiera fomes trees selected from top dying affected and non-affected areas of the Sundarban

| Indicators | Top dying free (healthy) area | Less top dying affected area | Moderately top dying affected area | Severely top dying affected area |
|---|---|---|---|---|
| Mean total height (m±SE) | 1.44 ± 0.18 | 0.95 ± 0.05 | 0.99 ± 0.03 | 3.44 ± 0.20 |
| Survival % | 51 | 35 | 37 | 87 |
| SD | 0.56 | 0.15 | 0.11 | 0.64 |
| $F_{.05}$ (3) | 73.16** | | | |

The Mean total height (m) of Heritiera fomes at six years old offspring selected from four top dying severity categories of top dying free (healthy) area, less top dying affected area, moderately top dying affected area and severely top dying affected area were 1.44±0.18, 0.95±0.05, 0.99±0.09 and 3.44±0.20 as well as mean survival percentage were 51, 35, 37 and 87 respectively shown in Table 1. The highest mean total height (m) recorded as 3.44±0.20 of the experimental plantations, raised from selected mother trees of the severely top dying affected area of Sundarban. Here, $F_{.05}$ (3) = 73.16** with 3 d.f., there is highly significant differences in the mean total height (m) of the sundari trees among five years old offspring of H. fomes trees selected from top dying affected and non-affected areas of the Sundarban. Experimental plantations were raised with sundari seedlings from selected 40 trees (offspring of each tree considered as a line). Field evaluation of six years old offspring of H. fomes trees selected from natural stress conditions of top dying affected and non-affected (healthy) areas of the Sundarban are shown in figure 2, 3, 4 & 5. Rahman M M (2003) learned that certain genotypes of H. fomes are more adapted to their environment than others as evidenced by their ability to survive and reproduce in that environment. He also suggested that selection and improvement of top dying resistant H. fomes can therefore be attempted from its natural population in the Sundarban.

Natural selection is the process of naturally 'screening' characteristics within individuals within a species for or against a certain outcome. Natural selection can affect morphological, physiological, biochemical and anatomical characters, however natural selection can only act on traits which can be genetically inherited and which are expressed. In summary, natural selection acts on the phenotype of an organism. The theory states that if an organism has a trait that is of benefit, then it will have a greater chance of reproducing and passing on that gene. However if an organism has a gene which is causing it disadvantage, then the organism will die and not pass on that gene.

Natural selection does not have to be gradual – in fact if there are sudden and major environmental changes then evolution (through natural selection) can occur relatively quickly. So, natural selection is a complex process in which the total environment determines which members of a species survive to reproduce and so carry on their genes to the next generation. Natural selection occurs when individuals with certain genotypes are more likely than individuals with other genotypes to survive and reproduce, and thus to pass on their alleles to the next generation. As Charles Darwin (1859) argued in On the Origin of Species, if the following conditions are met, natural selection must occur: i. There is variation among individuals within a population in some trait. ii. This variation is heritable (i.e., there is a genetic basis to the variation, such that offspring tend to resemble their parents in this trait). iii. Variation in this trait is associated with variation in fitness (the average net reproduction of individuals with a given genotype relative to that of individuals with other genotypes). In natural populations, the mechanisms of evolution do not act in isolation. This is crucially important to conservation geneticists, who grapple with the implications of these evolutionary processes as they design reserves and model the population dynamics of threatened species in fragmented habitats. Natural populations of trees have large variations among species, races and individuals as regards stress tolerances and this provides vast possibilities for the selection and breeding of superior types (Schreiner, 1966).



*Figure 6: Germinated seeds of Heritiera fomes in poly-bags at mangrove nursery in the Sundarban*

*Figure 7: Nine months old offspring of Heritiera fomes at mangrove nursery, raised from selected mother trees of non-affected (healthy) sundari areas of the Sundarban*



*Figure 8: Nine months old offspring of Heritiera fomes at mangrove nursery, raised from selected mother trees of natural stress conditions of top dying less affected (<25% trees affected) areas of the Sundarban*

*Figure 9: Nine months old offspring of Heritiera fomes at mangrove nursery, raised from selected mother trees of natural stress conditions of top dying moderately affected (25-50% trees affected) areas of the Sundarban*



*Figure 10: Nine months old offspring of Heritiera fomes at mangrove nursery, raised from selected mother trees of natural stress conditions of top dying severely affected (>50% trees affected) areas of the Sundarban*

*Figure 11: Six years old experimental plantations of offspring of Heritiera fomes raised from selected mother trees of non-affected (healthy) sundari areas of the Sundarban*



*Figure 12: Six years old experimental plantations of offspring of Heritiera fomes raised from selected mother trees of natural stress conditions of top dying less affected (<25% trees affected) areas of the Sundarban*

*Figure 13: Six years old experimental plantations of offspring of Heritiera fomes raised from selected mother trees of natural stress conditions of top dying moderately affected (25-50% trees affected) areas of the Sundarban*



*Figure 14: Six years old experimental plantations of offspring of Heritiera fomes raised from selected mother trees of natural stress conditions of top dying severely affected (>50% trees affected) areas of the Sundarban*

Figure 6-14 show the offspring of Heritiera fomes at mangrove nursery and experimental plantations, raised from selected mother trees of natural stress conditions of top dying affected and non-affected areas of the Sundarban.

The great promise of $L_3$, $L_4$, $L_{12}$ $L_{16}$ $L_{30}$ $L_{35}$ & $L_{36}$ line of Heritiera fomes trees has been achieved with expected superior genetic material of unknown origin. This is reflected in the high variability observed in growth amongst individuals. It is anticipated that some of these faults can be improved quite quickly through traditional tree improvement techniques. It is recommended that the genetic improvement of this species is a high priority for plantation development. The more promising lines are then selected for further propagation, and they are further improved by promoting as much variation as possible through advanced tree improvement techniques. Finally, selection of the plants showing greatest promise takes place. Among new generation plantation candidates, the individuals appear to have the most potential for plantation development in the Sundarban. While these results are still relatively recent (<6 years), they demonstrate great promise for the establishment of selected sundari trees. Through greater development of the genetic base of these individuals and through long-term and rigorous screening of the saplings in the plantation, it is likely that a number of exceptional individuals will be identified. Using advanced propagation techniques, these can be cloned and potentially provide the genetic base for a highly successful clonal forestry program for creation of top dying resistant H. fomes trees.

**Conclusion**

Top-dying disease of Heritiera fomes has already been an important factor restricting the sustainable mangrove forest development in Bangladesh. Disease decreases the quality of wood and reduces productivity of economic forest, leading to serious damages and economic loss. The common conception of evolution focuses on change due to natural selection. Natural selection is certainly an important mechanism of allele-frequency change, and it is the only mechanism that generates adaptation of organisms to their environments. Before a selection and breeding program for H. fomes trees can go into effect, a multidisciplinary approach is needed that involves geneticists, plant pathologists and silviculturists working closely together on a long-range research project. Research should be focused on genotypes and genotype-phenotype interactions that could form the basis of a program. Better alignment of forest genetics and forest health research program will help mitigate the predictable negative impacts of climate change on forest productivity and health. Future needs for maximum progress in genetic improvement of disease resistance in H. fomes trees. The research project needs to be adequately funded for 40 to 50 years or more to bring forth lasting and useful results.

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