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IMPROVING SANDAL POPULATION IN MARAYUR SANDAL RESERVES THROUGH ASSISTED NATURAL REGENERATION

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ABSTRACT OF PROJECT PROPOSAL

1. Title	: Improving Sandal Population in Marayur Sandal Reserves through Assisted Natural Regeneration and Planting Improved Seedlings
2. Investigators	: 1. M. Balasundaran 2. Divisional Forest Officer, Marayur Division
3. Research Fellows	: 1. Mr. Arun Sabastian 2. Ms. Ramya R 3. Mr. Sanal Thomas
3. Objectives	:

i. To provide optimum eco-physiological conditions for survival and growth of natural seedlings through shade and host plant manipulation in 10 ha area of fenced Nachivayal Reserve.

ii. To identify Candidate Plus Trees (CPTs) in Marayur reserves and planting superior seedlings in reserves.

iii. To estimate the extent of clonality and inbreeding caused by root suckers

iv. To provide technical expertise to the Forest Department for raising and planting seedlings.

4. Duration	: 3 years
5. Funding agency	: Plan Fund

ABSTRACT

A field experiment was carried out for enhancing regeneration of sandal in 10 ha experimental plot established in Nachivayal II Sandal Reserve (NSR II) under Marayur sandal division. Natural regeneration was monitored in 10 sample plots of 10 m x 10 m size selected randomly in the plot. The mean number of seedlings of size 5-15 cm which appeared during a period of 12 months was 2.9 per plot. But, most of them perished during the one year period of observation itself due to disease and pest attack, browsing by cattle and excessive shade caused by weeds such as lantana which smothered such natural seedlings. The average intensity of photosynthetically active radiation (PAR) at mid-day under lantana thickets was 16.6 µmol $m^{-2}s^{-1}$ while in open area it was 1061 µmol $m^{-2}s^{-1}$ and in diffused sunlight i.e. under miscellaneous trees it was 127 µmol $m^{-2}s^{-1}$. Apparently light under lantana is too low for plants to carry on photosynthesis and survive.

Improving regeneration was attempted by raising seedlings in the 10 ha plot; seeds were sawn on 45 cm x 45 cm mounds raised after 4 m wide strip-weeding of profuse lantana growth. About 100 numbers of GA_3-treated seeds were sown on each mound and watered regularly. The growing seedlings were protected by providing thorny bamboo fence around each mound. The mean per cent germination was 46. Two mud roads passing through the 10 ha plot divided it into three subplots. The subplots were protected by providing nylon-net fence all around them as a protection from gaur and other browsing animals.

Altogether about 4220 mounds were sown with GA_3-treated seeds in three sub plots of the 10 ha plot. In sub-plot I having 853 mounds sown with seeds during 2006, the mortality of seedlings was 32.36 per cent during the first month, 10.15 per cent (of the surviving seedlings) during the second month, 44.35 per cent during the third month and 26.45 per cent during the fourth month. The cumulative per cent mortality at the end of second year was 95.4 per cent. A major chunk of seedlings (68 per cent) died due to 'unknown reasons'. The mean number of seedlings per mound was 1.76 (6.86 % of the germinated seedlings) at the end of second year in sub plot I. Seedling mortality was higher in subplot II having large number of miscellaneous trees with near closed canopy. The higher mortality was due to excess shade, severe insect and fungal attack, and water drops dripping from trees which displaced the sandal seeds and the germinating seedlings.

The thorny bamboo fence erected around each mound could not deter deer, goats and gaur completely. While the former two jumped or crept into the plot, the gaur crashed through the nylon net fence. The former nibbled the sandal leaves squeezing their head through the gaps of the bamboo fence

while the latter trampled the smaller seedlings while roaming inside the plot and devoured the larger seedlings. Barbed wire fence fixed around 100 mounds using granite poles gave a better protection to the seedlings (3 seedlings/mound survived); but seedling growth above the height of such fence was also eaten by the large animal.

At the end of second year, about 4600 seedlings ranging in height 0.25 - 1.05 m survived in the 10 ha plot. Seedling survival was more in open areas. Sandal required 75 to 25 % shade upto one year starting from germination (75%) till one year (25%) growth. Thereafter it required good sunlight. Host plants were needed from 3-5 months onwards; seedlings grew fast once they got connected with good host plants and optimum shade combination.

The method of raising sandal seedlings on mounds and providing shade and host at appropriate time in localities free of browsing animals is a better option for enhancing sandal regeneration. In places with thick lantana and other weed growth along with sandal trees, strip weeding and sowing seedlings on mounds, regulating shade and providing complete protection from animals through chain link fence will only promote regeneration.

Profuse flowering occurred in the seed stand; however, the seed set was poor. Lack of genetic diversity in seed stand was suspected as the probable reason for poor seed set. Therefore, ISSR marker profiling of sandal genotypes was carried out in two randomly selected plots of 20 m x 20 m size in a seed stand at Anackalpatty in NSR II. DNA finger printing using ISSR markers showed identity of genotypes of closely located trees indicating that the trees were actually clones. Seventy per cent of trees were clones in one plot and 47 per cent in the other plot. The mean genetic diversity was a poor (0.15 and 0.17 respectively) in the two plots. The clones might have arisen through root suckers induced by the Forest Department for enhancing regeneration. The practice of root sucker induction reduced genetic diversity and enhanced clonality in the plot. As sandal is a cross pollinated tree, clonality caused inbreeding and reduced seed setting. Lower genetic diversity observed in the sandal reserve has long- term adverse effect on adaptability of sandal in the changing environment. Hence, this practice of root sucker induction in reserve forests has to be discontinued.

1. Introduction

Sandal trees of Marayur had been the subject of a few scientific studies done by KFRI. Earlier studies focused on etiology and epidemiology of spike disease, and methods of control (Ghosh *et al.,* 1985; Balasundaran, 2004). Spike disease, reported for the first time in Marayur in 1980, has almost completely killed the trees from the former Reserves 51 and 54 and part of the Chinnar Reserve of the Chinnar Wildlife Sanctuary (Balasundaran, 2004). The disease, caused by phytoplasma and spread by insect vector such as *Redarator bimaculatus,* kills infected trees within 2-3 years (Ghosh *et al*., 1985; Balasundaran and Muralidharan, 2001).

Among eight potential sandal provenances of India, Marayur sandal population has got the highest genetic diversity as revealed through RAPD and isozyme studies and it is the most adapted provenance for Kerala (Balasundaran, 2004). Marayur population has been considered as genetically superior with highest oil content (Venkatesan *et al*., 1995).

In the forests of Marayur, sandal population has come down drastically during the last few years. The total number of sandal trees above 30 cm GBH in the sandal reserves was 1,86,594 during 1976 (Varghese, 1976). The number has come down to less than 60,000 in 2004. Besides large-scale smuggling of superior trees and drying up of trees infected by spike disease, decrease in sandal population is caused by low seed setting, lack of natural regeneration and browsing by cattle and wild animals.

The survival and growth of natural seedlings is also hampered by the hemi-parasitic nature of the plant and its shade requirement at varying intensity during different maturity periods of the seedlings. Poor seed setting and lack of seedling vigour observed in some pockets of seed stands also are reasons for poor regeneration. The seedling population can be improved by sowing genetically superior seeds, providing optimum shade at various stages of seedling maturity and planting suitable host plants at appropriate growth period of sandal. The objective of the present study is to increase seedling population in 10 ha area of Nachivayal Reserve of Marayur Sandal Division through assisted natural regeneration and sowing seeds. The project was implemented as a collaborative project between KFRI and Kerala Forest Department.

2. Materials and Methods

The sandal regeneration experiment was done in 10.5 ha area of Nachivayal II Reserve (NSR II) of Marayur Forest Range under Marayur Sandal Division, located in the eastern side of the Western Ghats in Idukki District. After obtaining permission from the Forest Department to carry out the studies, an area opposite to Nachivayal Forest Station was surveyed and boundary of the plot marked (PLATE I a). The altitude of the area was about 1050 m above msl. The soil was mostly sandy loam to alluvial and slightly acidic. Most of the 10.5 ha area was covered by lantana (PLATE I b); hence free movement inside the plot was difficult. The experimental plot was part of the western segment of NSR II which was chain link-fenced on three sides. The fourth side bordering the black-topped road to Anackalpatty was not fenced (PLATE I c). Hence, cattle and wild animals such as deer and gaur could freely enter the plot. Two mud roads, which passed through the plot divided it into three subplots. During 2008, nylon fish net fence of 1.5 m height was erected surrounding the three subplots in order to prevent the entry of animals.

2.1. Survey for natural sandal seedlings

For estimating the number of sandal seedlings coming up naturally (wildlings), we marked randomly 10 sample plots of 10 m x 10 m size within 10 ha area under sandal trees and counted the number of seedlings during the month of October 2007. The size of the seedlings was measured and their number monitored once in a month (PLATE I d).

2.2. Sowing sandal seeds in the plot for artificial regeneration

In order to find out the survival of sandal seedlings when artificially sown in the forests and to find out a useful method for artificial regeneration, sandal seeds were sown in the 10 ha plot after partial weeding. Lantana thickets were cut close to the ground level and removed in strips of 4 m width, and length extending from one end to the other end of the plot. Within the 4 m wide strip, 45 cm x 45 cm size pits/mounds (according to the nature of the terrain) were made at a distance of 2.5 m x 2.5 m spacing on opposite sides of weeded strips (PLATE II a). Sandal seeds collected during previous seeding season were soaked overnight in 0.05% Gibberellic acid; about 100 seeds were sown on each mound/pit. Each mound was overlaid with dried grass for keeping the seeds moist (PLATE II c). The mounds were watered everyday (PLATE II g,h).

The seeds were sown during the following period.

i. September - October 2006 -- In sub plot I
ii. February- March 2007-- In sub plot I and II
iii. September – October 2007-- In sub plot II
iv. February – April 2008 -- In sub plot III

The per cent of germination was calculated after one month of sowing the seeds. Lantana and other weed growth was regulated to provide sufficient shade up to one year. The intensity of shade was reduced from 75% up to 3 months and to 25% up to one year and thereafter the shade was removed as far as possible. *Cajanus cajan* seeds were sown on each mound and four plants were allowed to grow on each mound as host for the sandal seedlings. The *Cajanus* seedlings were pruned to regulate the shade over the growing sandal seedlings. The sandal seedlings were protected from deer by erecting thorny bamboo fence after three months.

2.3. Observation on loss of seeds and seedling mortality

The seeds sown during 2006 were monitored every alternate day for about five months and observations recorded. Rats and rabbits feed on the seeds before and after germination. Hence, the following protective measures were given against rodents and rabbits during the time of seed sowing itself except those planted in 2006 (PLATE II c,d,e,f).

i. Covering the mound with plastic net till seed germination
ii. Protecting the seedlings by fixing plastic sack around the mound
iii. Protecting the seedlings by fixing shade net upto 60 cm height around the boundary of the pit

Cause of seedling mortality such as excessive shade, fungal infection, insect attack and animal browsing were also recorded every month for five months. Subsequently, height of seedlings and survival percentage were recorded once in a year.

2.4. Protection of seedlings by providing fencing

Though the experimental plot was close to the human habitat and opposite to the Nachivayal Forest Station, browsing animals were a serious problem to the sandal seedlings. Besides deer and goats, gaur and cattle browsed the growing seedlings. They not only fed on the leaves and tender twigs but also trampled the groups of seedlings growing on each mound. Protection of the growing sandal seedlings from gaur and cattle was attempted by providing fencing around the three sub-plots covering the entire 10 ha area using fish net (PLATE IV c).

Protection of mature seedlings upto 1.5m height was also attempted by providing individual barbed wire fence supported by granite poles. 100 such fences were erected in sub-plot 1, at the end of second year.

2.5. Shade measurement

The Photosynthetically Active Radiation (PAR) in the three plots under lantana thickets, under host trees (diffused light) and open space was measured using a quantum sensor (LI-COR, Nebraska, USA) during mid-day in order to get information on the availability of light for the growing sandal seedlings.

2.6. Comparison of genotype of trees in seed production area

Sandal trees growing in two seed production areas in Nachivayal were not yielding sufficient seeds. Being a cross pollinated plant, pollination and fertilization between genetically similar trees may cause inbreeding resulting in failure to produce viable seeds and poor performance of inbred seeds. Hence, these trees were subjected to DNA profiling in order to investigate genetic similarity of all the trees in two sample plots, each of size 20 m x 20 m, randomly selected in one of the seed stands established at Anackalpatty in Nachivayal II Reserve. Seventeen trees each were present in plot I and in plot II. Three ISSR markers were used for DNA fingerprinting of the trees. DNA was extracted from leaf samples of all the trees in the sample plots and used for ISSR fingerprinting. The DNA profiles of the trees were compared using the population genetics software POPGENE version 1.32 and NTSYSpc.

3. Results and discussion

3.1. Ecology of the experimental plot

The 10-ha plot was covered by thick growth of lantana reaching a height of 5-10 ft besides the growth of several miscellaneous tree species. Lantana growth was lesser in intensity in subplot 2, probably due to the dense canopy of miscellaneous trees in several areas. Sandal trees were also more in number in second plot (PLATE I b).

Forest type was predominantly moist deciduous; dry deciduous patches were also seen. Major tree species were *Acacia ferruginea*, *Albizia odoratissima*, *Anogeissus latifolia*, *Acacia leucophloea*, *Careya arborea*, *Cassia fistula*, *Chloroxylon swietenia*, *Chukrasia tabularis*, *Dalbergia latifolia*, *Gmelina arborea*, *Grewia tiliaefolia*, *Lannea grandis*, *Melia azedarach*, *Pterocarpus marsupium*, *Emblica officinalis*, *Terminalia chebula, Dendrocalamus strictus,* etc. Besides lantana, the major undergrowth consisted of *Chromolaena odorata*, *Abutilon* spp., *Dodonaea viscosae*, *Zizyphus* spp., etc. These species also may be functioning as host plants for sandal.

The annual rainfall ranged from 1000mm to 1500 mm. The rainy season extended from May to August and October to December. The site was more or less level ground. The winter nights were cool (15°C) and summer days hot (35°C).

3.2. Natural regeneration

The mean number of seedlings of 5-15 cm height in the 10 sub-plots of 10 m x 10 m size was 2.9 per plot when monitored for a period of 12 months from October 2007 (PLATE I d). The number of naturally growing seedlings in open areas was meager. Seeds may be spreading to open areas mainly through rain water or through birds or monkeys which feed on the ripe, sweet berry. Most of the seedlings, growing under lantana thickets either perished during 4-12 months or were browsed by deer or cattle. The light under lantana thickets was too low for sandal seedlings to grow (see para 3.3).

Presence of sandal seeds on the forest floor under mature sandal trees was often seen. Seeds germinated under the weeds and often below leaf litter during rainy season. A good number of seeds falling on the ground were eaten by rats and other rodents. They broke open the seed coat and consumed the fleshy portion or destroyed them. Seed germination was also affected by mould growth over the seeds as well as infection by pathogenic fungi. If the seeds remained continuously under water, they decayed. Healthy seeds germinated and grew vigorously initially under the weeds but subsequently, the seedlings became unhealthy under lantana shade followed by defoliation, and ultimately they perished. Several of them got browsed by deer or goats.

3.3. Effect of shade on seedling growth

The photosynthetically active radiation (PAR) measured using a quantum sensor showed that in open area under direct sunlight, the mean PAR on non-cloudy day at 12 noon was 1061 μmol $m^{-2}s^{-1}$ while it was 16.6 μmol $m^{-2}s^{-1}$ under lantana thickets and 127 μmol m^{-2} s^{-1} in diffused light under closed canopy of trees (Fig.1). This showed that vast difference occurred in the light intensity among the three locations. The very low PAR observed under lantana thicket could be one of the reasons for the death of the seedlings. The intensity of PAR under diffused light is also too low to support healthy growth of the seedlings after one year growth.

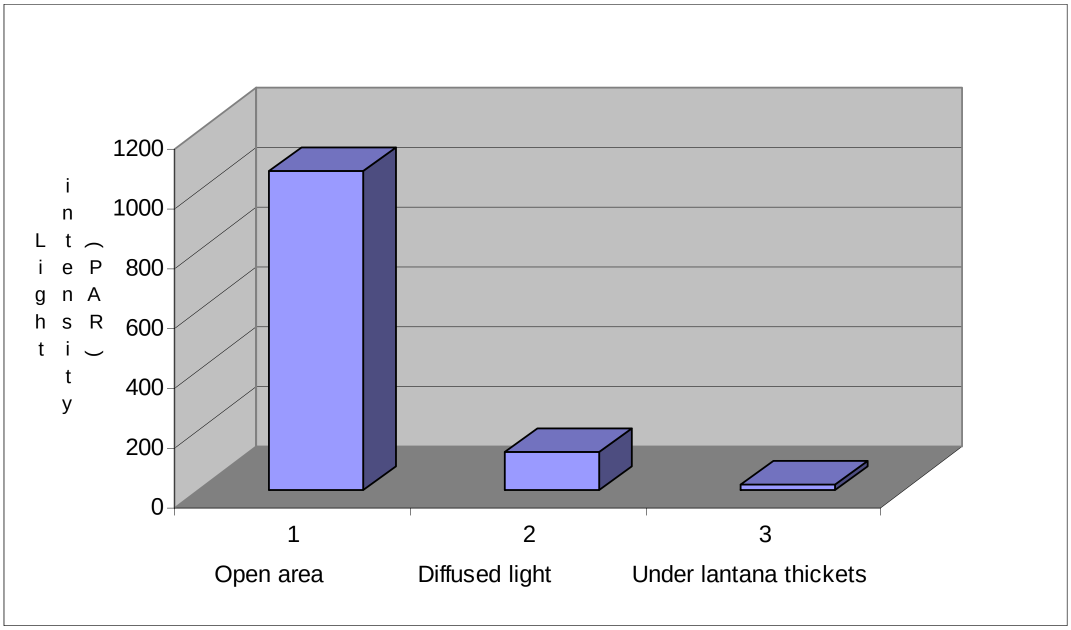

Fig.1. Mean light intensity under different types of vegetation in the plot

3.4. Other factors affecting the survival of natural seedlings

The survival and growth of sandal in the plot were affected by the animals roaming inside the plot. Though it was possible to keep away cattle and goats from the plot using the fishnet fence protection, wild animals created serious problems for the growing seedlings. Sambar deer, spotted deer, barking deer and mouse deer nibbled sandal seedlings of all sizes of their reach. Herds of gaur which frequented the sandal reserve, selectively ate not only sandal seedlings but also saplings. While the deer group of animals was able to jump over the fishnet fence, gaur crashed through the fence tearing it open. Subsequently, cattle and goats could enter through these openings. Gaur fed voraciously on sandal saplings and also occasionally knocked down small sandal trees above their height and devoured the leaves and twigs. While walking inside the plot, they destroyed the thorny fence erected around the mounds of sandal seedlings and trampled the seedlings. Though watchers were engaged, it was not possible to keep vigil round the clock and prevent the animals from entering or drive them away from the plot. However, most of the seedlings which could grow inside thorny bushes managed to escape from the animals and grew up so long as the protection of thorny bush persisted.

3.5. Artificial regeneration by sowing sandal seeds

About 100 seeds were sown on each mound/pit as shown below. All the beds were watered until complete germination.

i. September - October 2006	-- In sub plot I	- 853
ii. February- March 2007	-- In sub plot I and II	- 138 and 600
iii. September – October 2007	-- In sub plot II	- 1025
iv. February – April 2008	-- In sub plot III	- 1605
	Total	**- 4221**

Out of the 853 mounds raised in sub plot I during 2006, germination and growth of sandal seedlings in 810 were monitored every alternate day for about five months (PLATE II a). The sub-plot I had patches free of miscellaneous trees and those devoid of sandal, but major portion was with sandal and host trees giving a suitable microclimate for sandal growth. The *Cajanus cajan* (raised as temporary host) growth and weed growth especially that of lantana and chromolaena was regulated to provide shade during initial growth up to three months. The mean germination was 46 per cent (PLATE II b). Several seedlings perished during the first month itself due to fungal infection and insect/rabbit/rodent attack (PLATE II c,d,e,f). Though the reason for death of the seedlings could be confirmed for one-to two-month-old seedlings, it was not possible to identify the exact cause after three weeks, obviously because no typical symptom or indication of specific cause was seen. The details of seedlings survival in sub plot I are provided in Table 1, Fig. 2 and the cause of death in table 2 and Fig. 3.

Table 1. Per cent mortality of sandal seedlings till second year end in sub plot I

Months after sowing	% Seedling mortality	Cumulative % mortality
During 1st month	32.6	32.36
During 2nd month	10.15	39.4
During 3rd month	44.35	66.29
During 4th month	26.45	75.21
During 5th month to 2nd year end	81.4	95.4

Table 2. Cause of seedling mortality up to four months

Months after sowing	% Mortality due to fungi	% Mortality due to insects, rabbits, rodents, deer, etc.	% Mortality due to unknown reasons
During 1st month	48.3	50.7	1
During 2nd month	16.8	57.3	25.9
During 3rd month	1	40.6	58.36
During 4th month	1	30.89	68.11

From Table 1 and 2, it is seen that mortality of seedlings started during and immediately after germination and it continued every month due to different causes. Almost one-third of the germinated seedlings died during the first month itself and the major causes were fungal infection and combined effect of soil insects such as thrips and crickets, and rodents and rabbits (PLATE III a,b,c,d). While fungi caused damping off and collar rot, the insects and rabbits cut the tiny seedlings and rodents fed on the germinating seeds. *Fusarium oxysporum* was identified as the major cause of fungal infection.

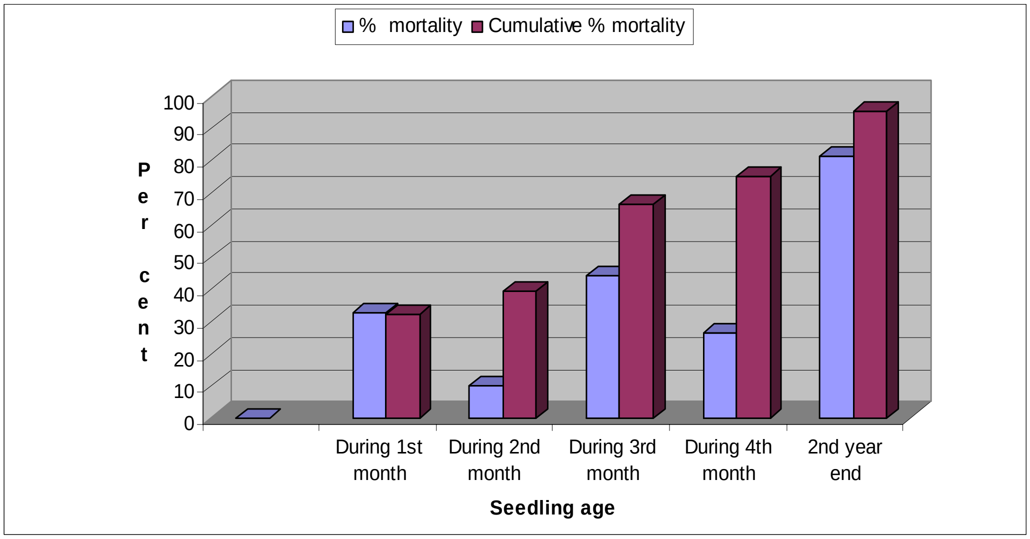

Fig. 2. Per cent mortality and cumulative mortality of sandal seedlings in sub

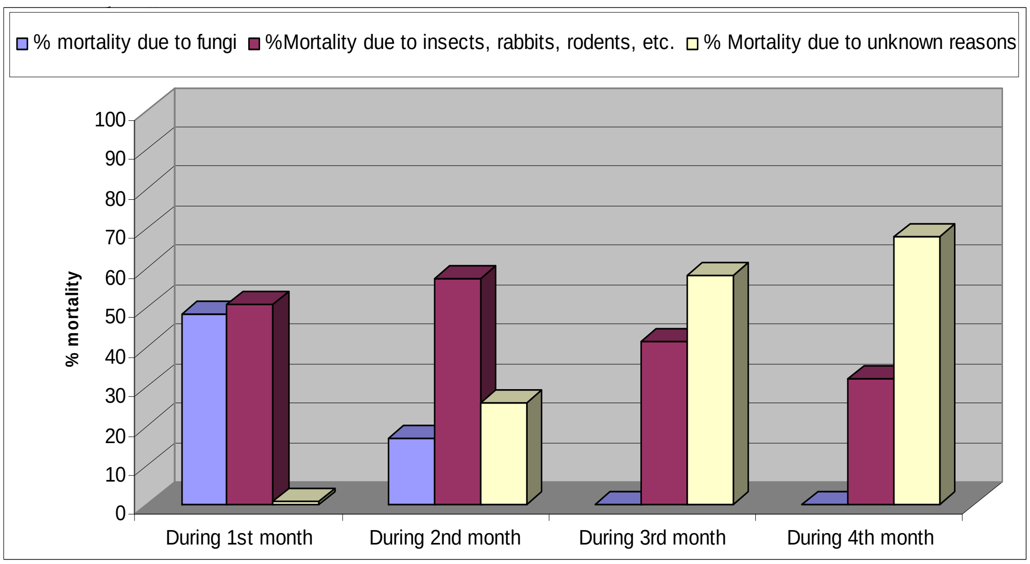

Fig. 3. Per cent seedling mortality caused by fungi and other causes

It is evident from the Tables that mortality was most serious upto four months and cumulative mortality reached 75 per cent indicating that the first four months were the most vulnerable period for the sandal seedling growth if left unprotected. Damage by deer was the main cause of destruction during the third month in addition to the death due to 'unknown reasons' (PLATE III d). The mortality due to the latter was quite substantial reaching upto two-third of the total mortality during the fourth month. The 'unknown reasons' could be inadequate light availability and failure to establish host root connection. As the cattle, deer and gaur problem increased, the only option to save the seedlings after three months was to erect fence around the group of seedlings using thorny bamboo and cover the seedlings to keep them unexposed. This method may prevent light from reaching the seedlings and part of the seedlings may get smothered. The reason for the failure to establish host connection in spite of a large number of potential host plants existing near by, cannot be readily explained.

Table 3. Survival of sandal seedlings/mound at different intervals in sub plot I

Months after sowing	Seedlings per mound/pit*	% Survival
One month	25.8	100
Two months	23.18	89.8
Three months	12.9	50
Four months	9.5	36.8
After two years	1.76	6.82

* Mean of 810 mounds/pits

The mean number of seedlings which were approximately 26 per mound at the end of one month after seed germination plummeted to less than two (average 1.76) at the end of two years after three months growth in spite of providing thorny fence protection. The thorny fence also did not provide 100 per cent protection from smaller animals. Deer and goats which roamed in large numbers in the plot could squeeze their head though the gaps of the fence and nibble the sandal seedlings (PLATE III e, f). Gaur damaged the fences along its path, trampled or devoured the seedlings or exposed them to deer and cattle. Nevertheless, one or more sandal seedlings per mound will form a good population provided they survive the hurdles.

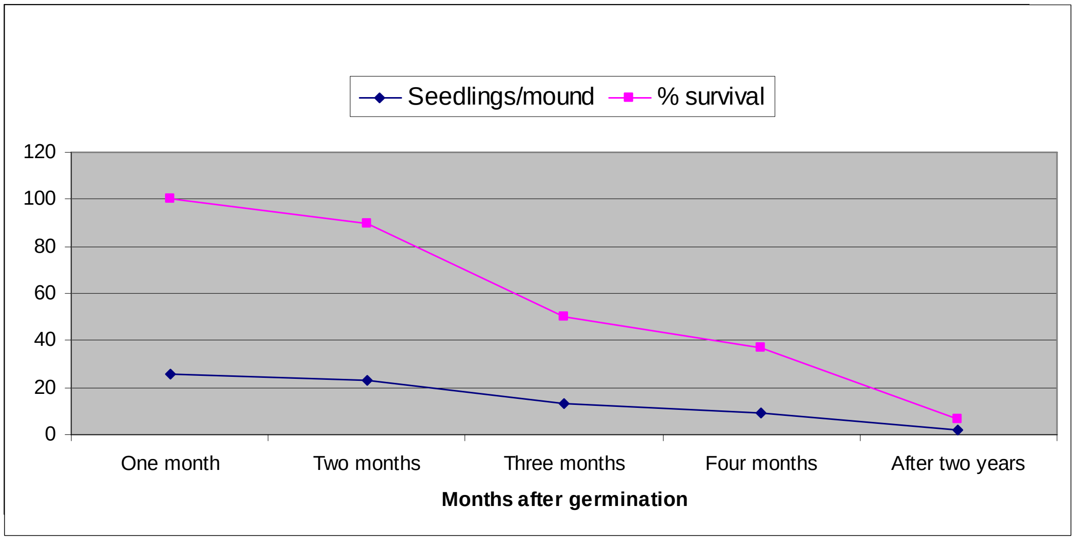

Fig. 4. Number of seedlings per mound at the end of two years in sub plot I.

In order to minimize the threat posed by gaur and deer to the growing seedlings stronger protection was provided around 100 mounds using granite poles and barbed wire fence. Deer managed to reach the seedlings through the gaps and gaur devoured branches which almost reached above the 1.0 m high barbed wire fence. Nevertheless, there was improvement in survival of seedlings. The average number of seedlings per mound was 3 due to the improved seedling survival within barbed wire fence; the height of seedlings ranged between 30cm-1.05m (PLATE IV a, b).

3.6. Survival and growth of seedlings in the other sub-plots

The second sub plot (Sub plot II) (Fig. 1) had 1625 and the third subplot 1605 mounds/pits. Among the three types of protection provided to the sown seeds such as spreading plastic net over the bed and providing 60 cm-height protection around the bed using plastic sack and shade net, the method of spreading plastic net over the bed prevented rodents and rabbits from chewing the seeds and germinating seedlings. However, this practice did not increase seed germination and seedling survival. The net was a hurdle for germination and restricted seedling growth.

There was marked difference in the survival of seedlings between sub plot II and subplot III. In sub-plot II, the pattern of seed germination and initial growth of the seedlings were at par with sub-plot I and sub-plot III. But the survival of the seedlings in the sub-plot II dwindled rapidly after a few rains due to two reasons. The first cause was rain splash from the large tree canopy which displaced the seeds and the seedlings from the mounds. The humidity within the plot which was higher than that in the other two plots increased disease and pest incidence. Above all, the closed canopy of large number of miscellaneous trees brought down the light intensity. The PAR ranged between 110 – 195 µmol $m^{-2}s^{-1}$ in diffused light which prevailed in the sub-plot II generally, except in the summer season when defoliation took place in miscellaneous trees. At the end of second year, the seedlings were confined to partially open canopy areas. In sub-plot II and sub-plot III, thorny bamboo fences were provided after the germination of the seeds. This practice had partially protected the seedlings in both the plots during the initial months. The condition was better in sub-plot III where miscellaneous tree growth was lesser.

3.7. Number of seedlings at the end of third year

Partial weeding of lantana close to the mounds of surviving seedlings was done once in six months which reduced the shade around them. But the thorny fence and the weeds inside prevented sufficient light for sandal seedlings after one year growth. Sandal seedlings required 25-75 per cent light with increasing intensity till it reached one year growth. About 25-50 % per cent light is optimum upto 6 months, and after one year it requires good sunlight. Though, shade due to thorny fence was not a serious problem up to one year, covering the seedlings from sunlight was harmful to the seedlings. At the end of third year, there were 905 mounds without any seedlings out of the total 4221; the majority of them were in sub-plot II with too much of canopy shade. Average number of seedlings per mound in the 10 ha plot was

1.1 including in the barbed wire-fenced mounds. The mean height of seedlings was 47cm and the height ranged between 0.25 m to 1.05 m. The estimated total number of seedlings at the end of third year was approximately 4600 including on mounds protected by barbed wire fencing (approximately 300 seedlings).

3.8. Clonality of sandal in seed stand

One of the reasons for the poor sandal regeneration in natural forests is the high seedling mortality. The present study has shown that only about 7 per cent of the seedlings survived by the end of second year from the time of seed germination. The high seedling mortality demands large quantity of seeds for sowing in new localities as well as in sandal forests, where practically very little regeneration takes place. Lack of availability of good quality seeds have been reported from forest ranges. Two seed stands had been established in Nachivayal II Reserve now coming under Marayur Sandal Division.

But recently it has been reported that the expected quantity of seeds are unavailable from these seed stands. Most of the sandal trees flower profusely, but they do not set seeds proportionate to the flowering. As sandal is a cross pollinated plant, fruit setting and seed formation will take place usually if pollination and fertilization take place between genetically unrelated genotypes. Though, failure to develop mature seeds may occur due to unsuccessful pollination and fertilization, pathogenic infection of developing fruits, premature flower and fruit fall, etc., such major problems did not come to our notice in Marayur.

In several places of Nachivayal seed stand, sandal trees were growing in clusters with individual trees of a cluster located very close to a mother tree and several smaller trees around them within 1- to 1.5 m radius. Such prominent conglomeration of trees of different sizes prompted us to investigate whether the trees around a larger tree are clones which have arisen from the roots of the mother tree as root suckers.

The ISSR profiling of sandal trees in 20 m x 20 m plot in one of the seed stand showed identity of DNA profiles of 12 trees in plot I and 8 trees in plot II indicating that they could be clones which might have arisen from root suckers (PLATE IV d,e). Amplicons from such trees were monomorphic. The percentage of polymorphism in Plot I was 44 per cent and in Plot II, 48 per cent. The mean genetic diversity was 0.1478 and 0.17 in Plot I and in Plot II respectively. Low percentage of polymorphism and low genetic diversity showed very high chance of inbreeding in the seed stand which could be the major reason for low seed production in the seed stands.

Root suckers arise from sandal roots in natural forests as a result of injury caused by wild animals to the surface roots. But chances of occurrence of such high proportion (70.58 per cent in plot I and 47.05 per cent in plot II) of root suckers caused by wild animals trampling are very remote. Induction of root suckers in sandal reserves by taking trenches around mature sandal trees for enhancing natural regeneration was carried out for the last several decades by the Forest Department. Such activities year after year might have produced root suckers from the injured roots and these clones have reduced the genetic diversity in the seed stands reducing seed setting. Considering the adverse impact of root sucker induction on genetic diversity of sandal, it will be better to discontinue the practice. Instead, we should improve the genetic diversity in our sandal reserves introducing new genotypes through seed route.

3.9. Conclusions and recommendations

The study has shown that partial removal of lantana thickets for providing optimum shade, and prevention of cattle and wild animals from browsing will improve the natural regeneration of sandal inside lantana- infested sandal reserves where seed bearing trees are present. In locations where sandal trees are few in number, sowing sandal seeds in mounds and protecting them from browsing animals will be a better option. Providing thorny bamboo fencing around seedlings is inadequate for protecting the growing seedlings because deer and goats can nibble the seedlings through the gaps while gaur and large animals trample them or feed on them. Sandal seedlings require partial shade (75-50% during the first six months and 50-25% after that up to one year) for fast growth and host root connection. After one year, seedlings require good sunlight for healthy growth. Complete removal of lantana from sandal forest is equally harmful not only for seedlings but also for growing sandal trees because the profusely rooting lantana also is an efficient host plant for sandal. Partial weeding or strip weeding so as to regulate shade requirement to the growing seedlings will be a better option.

Enhancing regeneration through root sucker induction is not a good option in reserve forests because this practice reduces genetic diversity, affects seed production and causes inbreeding. Moreover, sandal root injury may cause root rot which may spread to the main stem, inviting termite attack. Hence, root sucker induction as a practice for sandal regeneration in reserve forests may be discontinued.

4. References

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