Identification of suitable tree species and other vegetation for biodrainage in Bargi command area (Jabalpur, M.P.)

FINAL REPORT

Submitted to

Indian National Committee on Irrigation & Drainage, Ministry of Water Resources, New Delhi

Tropical Forest Research Institute
(Indian Council of Forestry Research & Education)
P.O. – RFRC, Mandla Road, Jabalpur

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By

Principal Investigator **Dr. Avinash Jain, Scientist E**

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Tropical Forest Research Institute
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P.O. – RFRC, Mandla Road, Jabalpur

2014

Format for Completion Report

1. **Name and address of the Institute**

   Tropical Forest Research Institute,

   P.O. : R.F.R.C., Mandla Road,

   Jabalpur, 482021 (M.P.)

2. **Name and addresses of the PI and other investigators**

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3. **Title of the scheme:** Identification of suitable tree species and other vegetation for biodrainage in Bargi command area (Jabalpur, M.P.).

4. **Financial details.** (Sanctioned cost; amount released; expenditure; unspent balance (if any) and return of unspent balance).

Sanctioned cost	Rs. 32,77,000
Amount released	Rs. 24,46,000
Expenditure	Rs. 23,24,498
Institutional charge (15%)	Rs. 3,48,675
Unspent balance	Rs. 1,21,502
Return of unspent balance	Nil

* An amount of Rs. 80,351/- as bank interest during the project period (2005-06 to 2011-12) may be adjusted in institutional charge, to be paid to the institute after acceptance of the completion report.

5. Original objectives and methodology as in sanction proposal.

Objectives:

(a) To drain out excess water of the soil in water logged/canal seepage areas through vegetative means.

(b) To reduce or prevent salt concentration in the root zone.

(c) To enhance the site productivity through (a) and (b) above.

During 7th meeting of the working group on biodrainage held on 6-7 February 2007 at Tezpur (Assam), second objective "To reduce or prevent salt concentration in the root zone" was suggested to delete from the present study.

Methodology:

Climatological information of the area including annual and seasonal variation in precipitation, temperature, relative humidity etc. will be procured from weather station and from other reliable sources.

Site and soil characteristics, will be studied by exposing soil profiles and describing them as per F.A.O. (1977). Soil samples will be collected from all horizons and analyzed as per standard procedures (Jackson, 1973; Black, 1965).

Rate of water infiltration in the soil will be determined by cylinder Infiltrometer method. Receding of water level in the cylinder against time at suitable intervals will be recorded and rate of water infiltration in cm/hr using values averaged over time intervals will be expressed as pointed out by Singh (1989).

Hydraulic conductivity/permeability will be measured with the help of permeability apparatus at constant level water supply and collecting water percolated in a beaker. Amount of water percolated will be measured at 30 minute interval and expressed in cm/sec. as described by Singh (1989).

Soil moisture will be measured directly by Neutron Moisture Meter through inserting the probe into soil at various depths. Water table will be measured with the help of Piezometer.

Evapo-transpiration rate of different tree species under available soil and water conditions will be measured directly with the help of Evapotranspirometer by periodic weighing, while rate of evaporation from the soil surface will be measured by Evaporimeter or Evaporation Recorder. Separate experiments will be conducted to estimate rate of evapo-transpiration and salt uptake of different tree species.

Rooting characteristics of selected tree species and their biomass will be estimated by uprooting the sample plants. Leaf area of plants at different stage of growth will be measured with the help of Leaf Area Meter.

Plant samples obtained from different experiments will be oven dried, grinded and analyzed for nutrients and salt uptake as per standard procedures (Black, 1965; Jackson, 1973).

The data obtained from different sources, experiments etc. will be statistically analyzed.

6. Any changes in the objectives during the operation of the scheme

During 7th meeting of the working group on biodrainage held on 6-7 February 2007 at Tezpur (Assam), second objective "To reduce or prevent salt concentration in the root zone" was suggested to delete from the present study. The members of the meeting were of the opinion that since salinity is not a problem in Jabalpur region and CSSRI, Karnal has done considerable work on salinity, there seems to be no need to do salinity studies and as such water logging studies may be done comprehensively.

7. All data collected and used in the analysis with sources of data

All the data collected and used in the present study have either been generated through experimentations or have been collected from different sources, which have been duly acknowledged.

8. Methodology actually followed (observations, analysis, results and inferences)

Two sets of experiments were conducted under the project. As the part of the project, first set of experiments were conducted along canal command area, where a plantation of 10 ha. area was raised along the canal comprising seven tropical forest tree species. Second set of experiments were conducted in TFRI campus, where lysimetric experiments were conducted to simulate the experiments conducted along canal command area.

All the observations recorded during the project period can be summed up in to following points :

Recruitment of Junior Research Fellow (JRF)

One JRF, Akhilesh Kumar Verma was appointed in November 2005 as per MOWR guidelines given in Appendix 7. He worked in the project till April 2007. In August 2007, Anil Kumar Singh joined as JRF and worked till September 2007. After his resignation, Rakesh Kumar Jain joined the project in October 2007 as JRF, promoted to SRF in August 2009 and left the project in November 2010.

Selection of sites

The suitable sites having 10 ha area were selected along the left bank canal of Bargi command area for experimentation and plantation of forest tree species. The sites were selected in 3 villages namely, Jamuniya (23^0 03' 32.5"N; 79^0 41' 59.3"E; Elevation 1276 ft.), Somti (23^0 03' 09.3" N; 79^0 41' 40.1" E; Elevation 1279 ft.) and Dabhola (23^0 04' 54.2" N; 79^0 45' 42.0" E; Elevation 1387 ft.) with the consultation of officers and engineers of Rani Avanti Bai Lodhi Sagar Pariyojana, Jabalpur. The sites were selected at the filling reach of the canal, where the problem of water logging due to lateral seepage was severe. The land was acquired from the office of executive engineer, Rani Avanti Bai Lodhi Sagar Pariyojana, Left Bank Canal, No. 3, Bargi Hills, Jabalpur (M.P.) along the right side of left bank canal in four patches as follows :

1. RD 40.300 to 41.080 km
2. RD 43.200 to 43.700 km
3. RD 46.700 to 47.600 km
4. RD 50.100 to 52.100 km

Vegetation study

The plantation sites and the surrounding areas along left bank canal of Bargi command area were surveyed and vegetation studies were conducted either by Quadrat's method or by random sampling method. The dominant species found in the selected sites are listed below :

Site 1 : Somti village

Upper storey	1. *Ailanthus excelsa*
	2. *Butea monosperma*
	3. *Madhuca latifolia*
Middle Storey	1. *Acacia catechu*
	2. *Acacia nilotica*
	3. *Diospyros melanoxylon*
	4. *Syzygium cumini*
Shrubs	1. *Lantana camara*
	2. *Calotropis procera*
	3. *Carissa spinarum*
Herbs/Grasses	1. *Tephrosia purpurea*
	2. *Cassia tora*
	3. *Evolvulus nummularius*
	4. *Cynodon dactylon*

Site 2 : Jamuniya village

Upper Storey	1. *Cassia siamea*
	2. *Acacia nilotica*
	3. *Madhuca latifolia*
Middle Storey	1. *Diospyros melanoxylon*
Shrubs	1. *Lantana camara*
	2. *Butea monosperma*
	3. *Feronia elephantum*
	4. *Ziziphus jujuba*
	5. *Ipomoea carnea*
Herbs/Grasses	1. *Cyperus rotundus*
	2. *Cyperus iria*
	3. *Cynodon dactylon*
	4. *Desmodium triflorum*
	5. *Evolvulus nummularius*
	6. *Xanthium strumarium*
	7. *Tridax procumbens*
	8. *Heteropogon contortus*

Site 3 : Dabhola village

Upper Storey	1. *Madhuca latifolia*
Middle Storey	1. *Lagerstroemia parviflora*
	2. *Butea monosperma*
	3. *Acacia nilotica*
	4. *Ziziphus jujuba*
	5. *Diospyros melanoxylon*

Shrubs	1. *Lantana camara*
	2. *Ipomoea carnea*
Herbs/Grasses	1. *Cynodon dactylon*
	2. *Desmodium triflorum*
	3. *Alternanthera sessilis*
	4. *Eragrostis ciliaris*
	5. *Sida acuta*
	6. *Evolvulus nummularius*
	7. *Tridax procumbens*

Soil profile study

Three soil profiles were excavated near Somti, Jamuniya and Dabhola villages, about 30 m away from the canal. Physiography, longitude and latitude of the selected sites were studied. Distribution of soils in the selected sites was observed. Different soil horizons were studied in detail.

Physico-chemical characteristics of soil samples

The soil samples from different horizons of profile were collected from the selected sites. The soil samples were processed and subjected to physico-chemical analysis for the quantification of pH, electrical conductivity, salt concentration, CEC, organic carbon, available N, P and K, exchangeable cations *viz.* Na, K, Ca and Mg, mechanical analysis including percent content of sand, silt and clay and texture of the soil samples.

Analysis of water samples

Water samples from the left bank canal were collected and analysed for their physical, chemical and biological parameters. Physical parameters included turbidity, colour, odour and specific conductivity. Chemical parameters included pH, total alkalinity, total hardness, calcium hardness, magnesium hardness, chloride, solids, dissolved solids, suspended solids, ammonical nitrogen, nitrite nitrogen, nitrate nitrogen, B.O.D, C.O.D, sodium, potassium, phosphate and sulphate. Biological parameters included total coliform, faecal coliform and strepto cocci.

Meteorological Data

Meteorological data of Jabalpur during 2005-2011 was collected from Regional Meteorological Centre. The data included mean monthly maximum and minimum temperature, maximum and minimum relative humidity, rainfall, Sunshine hours and wind velocity.

Procurement of instruments

The instruments *viz.* open pan evaporimeter, double ring infiltrometer, pH meter, EC meter, salinity tester and computers with printer were procured under the project to measure solar evaporation rate, infiltration rate, pH, electrical conductivity, salinity and to analyse data and prepare research reports respectively.

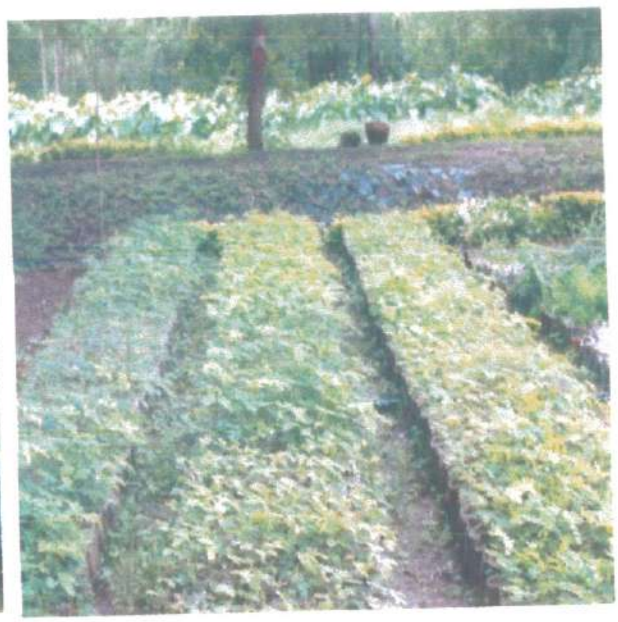
Collection of seeds from superior trees

The seeds from phenotypically superior trees of *Albizia lebbek, Albizia procera, Acacia nilotica, Dalbergia sissoo, Terminalia arjuna, Pongamia pinnata, Ailanthus excelsa, Eucalyptus* hybrid and *Jatropha curcas* were collected. Bulbils from *Agave americana* were also collected. Seeds of FRI-4 and FRI-5 hybrids of Eucalyptus were procured from Forest Research Institute, Dehradun (Uttarakhand).

Raising of seedlings in nursery

About 29000 seedlings of above mentioned species were raised in Modern Technical Nursery of Tropical Forest Research Institute, Jabalpur. These seedlings were maintained for one year in polybags by the skilled technical staff of the institute. Regular watering, weeding, cleaning, shifting etc. was done. The species-wise break up of seedlings is given below :

1.	*Acacia nilotica*	5500
2.	*Ailanthus excelsa*	1900
3.	*Albizia lebbek*	1900
4.	*Albizia procera*	3600
5.	*Dalbergia sissoo*	3900
6.	*Eucalyptus* (Jabalpur)	2300
7.	*Eucalyptus* (FRI-4)	2550
8.	*Eucalyptus* (FRI-5)	2550
9.	*Pongamia pinnata*	3100
10.	*Terminalia arjuna*	1600
	Total	28900



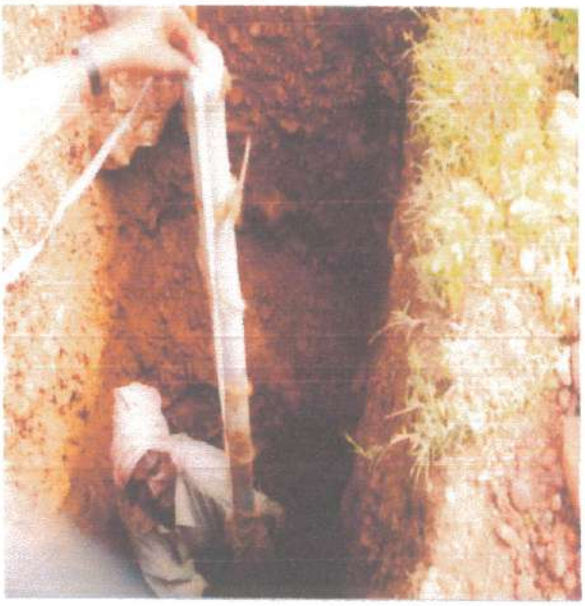
Photos 1: Raising of seedlings in TFRI Nursery

Plantation of forest tree species

A plantation of about 10 ha area was raised along Left Bank Canal (LBC) of Bargi Command Area, Jabalpur *Jatropha curcas* and *Agave americana* were planted surrounding the plantation sites for biofencing. Cattle Protection Trench (CPT) of standard size was also dug to protect the plantation sites from cattle. The planted species included *Pongamia pinnata, Acacia nilotica, Albizia lebbek, Albizia procera, Ailanthus excelsa, Eucalyptus* hybrid (Jabalpur). *Eucalyptus* hybrid (FRI-4 and FRI-5), *Terminalia arjuna* and *Dalbergia sissoo*. *Eucalyptus* hybrid and *Terminalia arjuna* were planted at Dabhola site; *Pongamia pinnata* and *Acacia nilotica* were planted at Jamuniya and *Albizia lebbek, Albizia procera, Ailanthus excelsa, Eucalyptus* hybrid (Jabalpur), *Eucalyptus* hybrid (FRI-4 and FRI-5), *Terminalia arjuna* and *Dalbergia sissoo* were planted at Somti site. *Ailanthus excelsa* did not perform well, hence partly replaced by *Albizia procera*. All species, except *Eucalyptus hybrid* (FRI-4 and FRI-5), were planted at 2 m x 2 m spacing. *Eucalyptus* hybrid (FRI-4 and FRI-5) were planted at both 2 m x 2 m and 1 m x 1 m spacing.

Installation of observation wells

Observation wells were constructed in the laboratory as per standard design and installed at plantation sites and control site (where no plantation was there). The observation wells were installed in the manner so that the effect of plantation of each species could be observed separately. The depth of wells was set to be 10 feet.



Photos 2: Installation of observation well and measurement of underground water table

Regular measurement of underground water table

Underground water table below plantations of different tree species and control area was regularly measured with the help of observation wells. Twenty observation wells were installed in the selected plantation sites, *viz* Somti, Jamuniya and Dabhola villages. The observation wells were installed in such a manner that the effect of each species could be observed individually. Water table was measured with the help of a multi meter. Two parallel copper wires connected with a multi meter were inserted inside the pipes and the fluctuations in multi meter reading showed the depth of water table. The effect of different tree species on water table was observed and compared with control.

Construction of lysimetric tanks

The in filled non-weighing type of lysimeters were used for the experiment. Forty leak proof lysimetric tanks of standard specifications were constructed in the institute's campus to simulate the experiments being conducted along Left Bank Canal (LBC). The experiments were set up in the lysimetric tanks including the similar tree species planted along the canal. The water levels maintained in the lysimetric tanks were : 0 to 0.25 m, 0.25 m to 0.50 m, 0.50 m to 0.75 m and irrigated (control).

Measurement of evaporation rate

The rate of evaporation was measured on the daily basis by Open Pan Evaporimeter installed near the selected sites. Using these data, average mean monthly data of evaporation was calculated and monthly variation was observed.

Table 1 : Average monthly mean data of evaporation

Month	**Rate of evaporation (mm/day)**
February 2007	4.29
March 2007	5.04
April 2007	6.21
May 2007	7.76
June 2007	6.80
July 2007	5.66
August 2007	4.85
September 2007	4.20
October 2007	2.75
November 2007	2.89
December 2007	2.13
January 2008	2.02

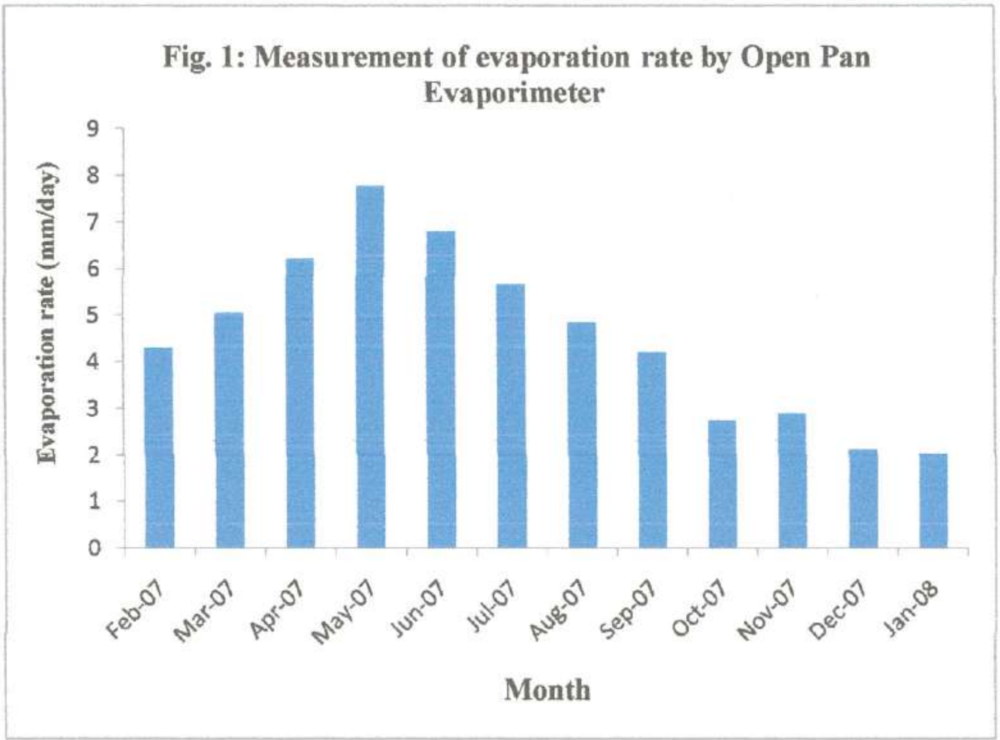


Photo 3 : Measuring evaporation rate by Open Pan Evaporimeter

Measurement of infiltration rate

The infiltration rate of soil at different grid points along right side of LBC was measured with the help of cylinder type Soil Infiltrometer. Two metal cylinders of 30 cm and 45 cm in diameter were driven about 10 cm deep into the soil by hammering. The outer cylinder was used to form the buffer pond. The water was filled inside the inner cylinder as well as in between the cylinders. The receding of water level in the cylinder against time at suitable intervals was recorded and rate of water infiltration in cm/hour was calculated using values averaged over time intervals.

Site	Infiltration rate (cm/hr)
Somti	0.60
Jamuniya	0.85
Dabhola	0.56

Photo 4 : Measurement of soil infiltration rate by Cylinder type Soil Infiltrometer

Transpiration rate of different species

Transpiration rate (E) of the seedlings planted in lysimetric tanks were measured using CID Inc. make Photosynthesis system (CI – 340 PS). Diurnal and species variations were observed in different species planted in lysimetric tanks with varying water levels.

Growth data and biomass studies

Growth data of seedlings of the forest tree species planted along left bank canal of Bargi command area, Jabalpur and in lysimetric tanks were measured. Along the canal, growth was recorded after every three months and in lysimetric tanks growth was measured every month. Biomass studies were also conducted in the plantations raised along canal. Initially, growth data included height, collar diameter, number of leaves and number of branches. But after attaining certain height, only height and girth were measured. Biomass parameters included weight of shoot, branches, leaves (above ground biomass), tap roots, secondary roots (below ground biomass) and total biomass.

Training to farmers

Training on 'Bio-drainage' was organized at village Dabhola along Left Bank Canal (LBC) of Bargi Command Area, Jabalpur (M.P.) for farmers and tree growers. Field trip for the trainees was conducted to plantations raised under the project.

Visit of researchers and dignitaries

Scientists from other institutes, universities, students, officers from state forest department, tree growers and farmers regularly visited the plantation sites and lysimetric experiments and came to know about the concept of biodrainage and its use in the control of water logging. They also discussed about the tree species to be planted in the water logged areas. Madhya Pradesh Forest Minister Shri Sartaj Singh and local MLA also visited lysimetric experiments.

Detailed Report

Profile studies and physico-chemical characteristics of soil

Profile study

Three profiles were excavated near Somti, Jamuniya and Dabhola, about 30 meter away from the canal. The description of profile studies of all the three sites is given below :

Site	Left Bank Canal of Bargi command area
Range	Chargawan
Division/district	Jabalpur
Physiography	Plain to very gently undulating
Longitude	79^0 41' 40.1" to 79^0 45' 42.0" E
Latitude	23^0 03' 09.3" to 23^0 04' 54.2" N
Altitude	1276 to 1387 ft.
Mean annual rainfall	1345 mm

Somti

Description of soils

Soils are deep dark yellowish brown to strong brown sandy clay loam occurring on almost plain areas. The surface layer is 13 cm thick. The subsurface soil is highly gravely 47 cm thick and paralithic contact. These soils have rapid permeability and high erosion potential. Run off potential moderately high. Soils have good water holding capacity. Description of a profile is given below :

Horizon	Depth (cm)	Description
A	0 – 13	10 YR 3/6 (Moist) dark yellowish brown, sandy clay loam, medium week sub angular blocky sticky and plastic when wet, clear and smooth boundary, effervescence with acid.
B_1	13 – 19	10 YR 5/6 (Moist) Yellowish brown, clay loam, medium moderate sub angular blocky, very sticky and very plastic when wet clean and smooth boundary, effervescence with acid.
B_2	19 – 22	7.5 YR 4/6 (Moist) Strong brown , clay loam, medium moderate angular blocky, very sticky and very plastic , clear and smooth boundary effervescence with acid.
$B_2 Ca_1$	22 -42	7.5 YR 5/4 (Wet) Strong brown , gravely sandy loam, medium weak friable, sticky and plastic, gradual and smooth boundary gravels and stones of calcium sulfate and calcium carbonate present .
$B_2 Ca_2$	42 – 69	10 YR 4/6 (Wet) dark yellowish brown, gravely sandy loam, fine week friable slightly sticky and slightly plastic, medium to coarse many gravels and stones of calcium sulfate and calcium carbonate dominantly present.

Jamuniya

Description of soils

Soils are very shallow, dark yellowish brown to yellowish brown, loam to sandy clay loam texture. Below 36 cm depth siliceous and calcareous gravels, pebbles and stony matrix dominated. Due to the presence of paralithic contact, runoff potential and permeability of these soils are very high. Soils have good water holding capacity. Description of a profile is given below :

Horizon	Depth (cm)	Description
A	0 - 16	10 YR 4/2 (Dry) dark yellowish brown loam, medium week sub angular blocky firm when moist, sticky and plastic when wet, slightly hard when dry, clear and smooth boundary, effervescence with acid.
B	16 – 36	10 YR 5/4 (Dry) yellowish brown , sandy clay loam, medium moderate sub angular blocky, firm when moist, sticky and plastic, gradual and smooth boundary effervescence with acid.

Dabhola

Description of soils

Soils of this site comprise of deep dark yellowish brown to yellowish brown clay loam to clay occurring on almost plain. The surface layer is 17 cm thick and subsurface soil is highly gravely 32 cm thick and paralithic contact. These soils have rapid permeability. Runoff potential moderately high, soils have good water holding capacity. Description of a profile is given below :

Horizon	Depth (cm)	Description
A	0 - 17	10 YR 4/6 (Dry) dark yellowish brown clay loam , medium week sub angular blocky, firm when moist, sticky and plastic, clear and smooth boundary, slight effervescence with dilute acid.
B_1	17 – 32	10 YR 4/4 (Slightly moist) dark yellowish brown, silty loam, medium moderate sub angular blocky, firm when moist, very sticky and plastic when wet, clear and smooth boundary, effervescence with dilute acid. .
B_2Ca_1	32 - 49	10 YR 5/4 (Slightly moist) yellowish brown, silt, medium moderate sub angular blocky firm when moist, very sticky and plastic when wet, few fine to medium Fe, Mn concretion, clear and gradual boundary.
B_2Ca_2	49 – 70	10 YR 5/3 (moist) yellowish brown, clay, medium moderate angular blocky, firm when moist, very sticky and very plastic, frequently clay cutons present on ped surface, many fine to coarse Fe, Mn concretions, effervescence with dilute acid.

Photos 5: Conducting soil profile studies at plantation sites

Physico-chemical characteristics of soil

Profile pits were excavated in the plantation site, horizons were demarcated and soil samples were collected from different horizons. Soil samples were processed (shade drying and sieving through 2 mm sieve) in the laboratory for further chemical analysis.

Soil analysis

Standard analytical procedures were used for estimation of soil pH, Organic carbon, Mechanical analysis, Electrical conductivity, Available nitrogen, Available phosphorous, Available potash, Exchangeable calcium, magnesium, sodium, potassium and cation exchange capacity, as described by Jackson (1973), Black (1965), Chopra and Kanwar (1976) and Piper (1950).

(i) Soil Reaction

Hydrogen ion activity or pH value is a measure of soil reaction and any drastic change in soil environment. As pH value increases, activity decreases or vice versa. The pH value of the profile soil of Somti site varies from 8.70 to 8.11 from surface to lower depth (strongly alkaline to moderately alkaline). However in Jamunia site where soil depth is 36 cm only, pH value varies from 7.89 to 7.81 (mildly alkaline). But at Dabhola site pH of the soil increases to 7.30 to 8.17 (mildly alkaline to moderately alkaline) range towards soil depth.

(ii) Soil Salinity/ Electrical Conductivity

Salinity is quantified in terms of the total concentration of such soluble salts, or more practically, in terms of the electrical conductivity of the solution, because the two are closely related (US Salinity Laboratory Staff, 1954). If the soil has high electrical conductivity the percent base saturation and pH of the soil will also change to higher side. In the present study, electrical conductivity was measured in soil : water (1 : 2.5) ratio by the method described by Jackson (1973). Electrical conductivity of the soil in the study sites are comparatively low. However, in Somti, Jamunia and Dabhola this varies from 0.07 to 0.25 ds/m, 0.07 to 0.14 ds/m and 0.06 to 0.28 ds/m respectively.

(iii) Mechanical Composition

Mechanical composition of the study soil samples shows clear evidence of good infiltration and drainage condition. The most active fraction of the soil is clay and this is also present either on surface or lower layer in all the study sites for higher quantity (8-54%). In Somti site where soil texture varies from Scl to cl and in the deeper layer it changes to sl texture. Silt and clay percentage increases in the middle layer and this is very important for retaining moisture and survival of any tree species. Moreover in Jamunia site where soil depth is very shallow and texture varies from loam to scl. But at Dabhola site mechanical composition of the soil is little different, where texture of the soil on the surface and lower layer become heavier where as in the middle layer it shows loose texture.

(iv) Organic Carbon

The soil organic carbon plays a very important role to change the soil physico chemical properties of the underlying soil. The organic carbon percentage of the Somti site varies from 0.31 to o.09 %, Jamunia site 0.84 to 0.41 % and in Dabhola site it varies to 0.39 to 0.24 % respectively. In general, soil organic carbon percentage of the study sites are low because crop density of the area are very less. Moreover organic carbon percentage are higher in the surface layer of Somti and Jamunia and it decreases down the depth. But in Dabhola site trend is little different and this may be due to the variation of soil texture of the existing profile.

(v) Available Nutrients

The concentration of available nitrogen is low in all three profile sites because the existing site content very less crop density, however in Somti site nitrogen varies from 156.8 to 62.7 kg/ha, Jamunia varies from 94.08 to 78.40 kg/ha and at Dabhola site nitrogen varies from 125.4 to 47.0 kg/ha. Available phosphorous content is very high in all three studied profile sites because parent rock contains high amount of total phosphorous (Granite). In Somti site available phosphorous varies with the tune of 33.11 kg/ha to 60.22 kg/ha, Jamunia 129.47 to 159.59 and at Dabhola 156.59 to 177.65 range. The concentration of available potassium is medium range ((120-280 kg/ha) in all the three studied profile sites.

(vi) Exchangeable cations

In Somti and Jamunia site exchangeable cations are comparatively higher in the surface layer and it gradually decreases down the profile. But at Dabhola site soil profile shows a drastic change in texture and due to this no definite sequence was noticed.

(vii) Cation exchange capacity

The cation exchange capacity (CEC) of any soil is determined on the basis of replacing all exchangeable cations by NH_4 or Ba^{++}, either of which is likely to be present originally in any soil. The cations that are exchanged for NH_4 are generally Ca^{2+}, Mg^{2+},

K^+, Na^+ and H^+ particularly if the soil pH is in the acidic range. CEC is equal to the sum of the cations expressed as follows.

$$CEC = Ca^{2+} + Mg^{2+} + K^+ + Na^+ + H^+$$

The cation exchange capacity is positively correlated with the type and amount of clay minerals and organic carbon. The CEC also indicates the nutrient status of the soil. However in Somti, Jamunia and Dabhola site the nutrient status of the soil exhibits medium range. The amount and range of the CEC indicates that soil might have contains kaolinite, illite and muscovite type of mixed clay minerals present in all the soil profile. Moreover in Somti, Jamunia and Dabhola CEC varies from 31.8 to 17.3 c mole kg^{-1}, 30.6 to 28.8 and 17.0 to 14.4 c mole kg^{-1} respectively were found.

Table 2 : Physico-chemical characteristics of soil in different horizons of Somti site.

S. No.	Depth (cm)	Horizon	Mechanical composition			Soil texture	Organic carbon (%)	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)	Exchangeable cations (m eq/100 g)				CEC (c mole kg^{-1})
			Sand (%)	Silt (%)	Clay (%)						Ca	Mg	Na	K	
1.	10-13	A	61	26	22	SCL	0.3120	156.80	33.11	132.0	23.6	3.2	3.43	0.44	31.8
2.	13-19	B1	34	34	32	CL	0.2530	62.72	39.13	130.5	17.8	5.2	3.66	0.29	28.0
3.	19-22	B2	32	38	30	CL	0.2170	47.04	48.18	121.5	13.4	2.4	1.51	0.07	18.8
4.	22-42	B2 Ca1	68	24	8	SL	0.1468	94.08	54.20	115.5	16.2	2.4	1.53	0.09	22.0
5.	42-69	B2 Ca2	66	26	8	SL	0.0996	62.72	60.22	132.0	10.2	3.6	1.50	0.07	17.2

Table 3 : Physico-chemical characteristics of soil in different horizons of Jamuniya site.

S. No.	Depth (cm)	Horizon	Mechanical composition			Soil texture	Organic carbon (%)	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)	Exchangeable cations (m eq/100 g)				CEC (c mole kg^{-1})
			Sand (%)	Silt (%)	Clay (%)						Ca	Mg	Na	K	
1.	0 -16	A	34	46	20	L	0.84	94.08	129.47	189.0	24.6	2.8	1.79	0.32	30.6
2.	16 -36	B	62	14	24	SCL	0.41	78.40	159.59	127.5	21.8	2.0	1.23	0.27	28.8

Table 4 : Physico-chemical characteristics of soil in different horizons of Dabhola site.

S. No.	Depth (cm)	Horizon	Mechanical composition			Soil texture	Organic carbon (%)	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)	Exchangeable cations (m eq/100 g)				CEC (c mole kg^{-1})
			Sand (%)	Silt (%)	Clay (%)						Ca	Mg	Na	K	
1.	0 -17	A	28	36	36	CL	0.26	78.40	168.63	172.5	9.40	2.0	1.07	0.36	14.8
2.	17-32	B1	30	64	6	SL	0.40	125.44	177.65	130.5	10.20	2.0	0.95	0.19	14.4
3.	32-49	B2 Cal	10	84	42	SI	0.28	94.08	168.63	136.5	9.98	2.4	1.08	0.28	15.5
4.	49+	B2 Ca2	16	30	54	C	0.25	47.04	156.59	130.5	11.98	2.4	1.18	0.25	17.0

Table 5 : Variation in pH, electrical conductivity and salt concentration in different horizons of soils.

S. No.	Depth (cm)	Horizon	pH	EC (dSm^{-1})	Salt concentration (ppt)
			Somti		
1.	10-13	A	8.70	0.253	0.20
2.	13-19	B1	8.46	0.158	0.20
3.	19-22	B2	7.91	0.085	0.10
4.	22-42	B2 Ca1	8.01	0.105	0.10
5.	42-69	B2 Ca2	8.11	0.075	0.10
			Jamuniya		
1.	0 -16	A	7.89	0.140	0.20
2.	16 -36	B	7.81	0.077	0.20
			Dabhola		
1.	0 -17	A	7.30	0.069	0.10
2.	17-32	B1	7.80	0.106	0.10
3.	32-49	B2 Ca1	7.99	0.286	0.30
4.	49+	B2 Ca2	8.17	0.163	0.10

Physical, chemical and biological characteristics of water samples

Water samples from different places (starting from origin of the canal near Bargi dam till plantation sites) of left bank canal of Bargi command area were collected and mixed in equal proportions to prepare mixed water sample to check the quality of canal water in unbiased manner. Physical, chemical and biological parameters of mixed water sample were assessed. Physical parameters included turbidity, colour, odour and specific conductivity. Chemical parameters included pH, total alkalinity, total hardness, calcium hardness, magnesium hardness, chloride, solids, dissolved solids, suspended solids, ammonical nitrogen, nitrite nitrogen, nitrate nitrogen, Biochemical Oxygen Demand (B.O.D.), Chemical Oxygen Demand (C.O.D.), sodium, potassium, phosphate and sulphate. Biological parameters included total coliform, faecal coliform and strepto cocci.

The water sample was observed to be colourless and odourless with specific conductivity 3680 μ mho/cm. pH of the water sample was found to be 7.33, which was mild alkaline and was within the permissible limits for drinking water. Total alkalinity was found to be 15 mg/l which was much less than the prescribed limit. Total hardness was found to be 80 mg/l, calcium hardness 65 mg/l and magnesium hardness 15 mg/l, which was within the permissible limits, hence water was not categorized as hard water. Dissolved and suspended solids were also found within the Indian standards for drinking water. As far as biological parameter concerned total coliform was found to be 15 MPN/100 ml

Table 6 : Water analysis of mixed sample collected from left bank canal.

S. No.	Particulars	Result	Indian Standard Specifications for Drinking Water IS: 10500
	PHYSICAL PARAMETERS		
1.	Turbidity	1.0 N.T.U	10
2.	Colour	Colourless	5.0
3.	Odour	Odourless	-
4.	Specific Conductivity	368.0 µ mho/cm	-
	CHEMICAL PARAMETERS		
5.	pH	7.33	6.5-8.5
6.	Total Alkalinity	15.0 mg/l	200
7.	Total Hardness($CaCO_3$)	80.0 mg/l	300
8.	Calcium Hardness (as $CaCO_3$)	65.0 mg/l	75
9.	Magnesium Hardness (as $CaCO_3$)	15.0 mg/l	30
10.	Chloride (as Cl^-)	19.96 mg/l	250
11.	Total Solids	262.0 mg/l	-
12.	Total Dissolved Solids	200.0 mg/l	500
13.	Total Suspended Solids	62.0 mg/l	-
14.	Ammonical Nitrogen (as N)	0.06 mg/l	-
15.	Nitrite Nitrogen (as NO_2)	0.03 mg/l	-
16.	Nitrate Nitrogen (as NO_3)	0.50 mg/l	45
17.	B.O.D (3 days 27 °C)	1.0 mg/l	-

18.	C.O.D.	12.0 mg/l	-
19.	Phosphate (as P)	0.04 mg/l	
20	Sulphate (as SO_4)	6.0 mg/l	200
	BIOLOGICAL PARAMETERS		
21.	Total Coliform (Presum./Conf.)	15.0 MPN/100ml	0
22.	Faecal Coliform	Nil MPN/100ml	-
	ANY OTHER TEST		
23.	Sodium	18 ppm	-
24.	Potassium	12 ppm	-

Lysimetric experiments

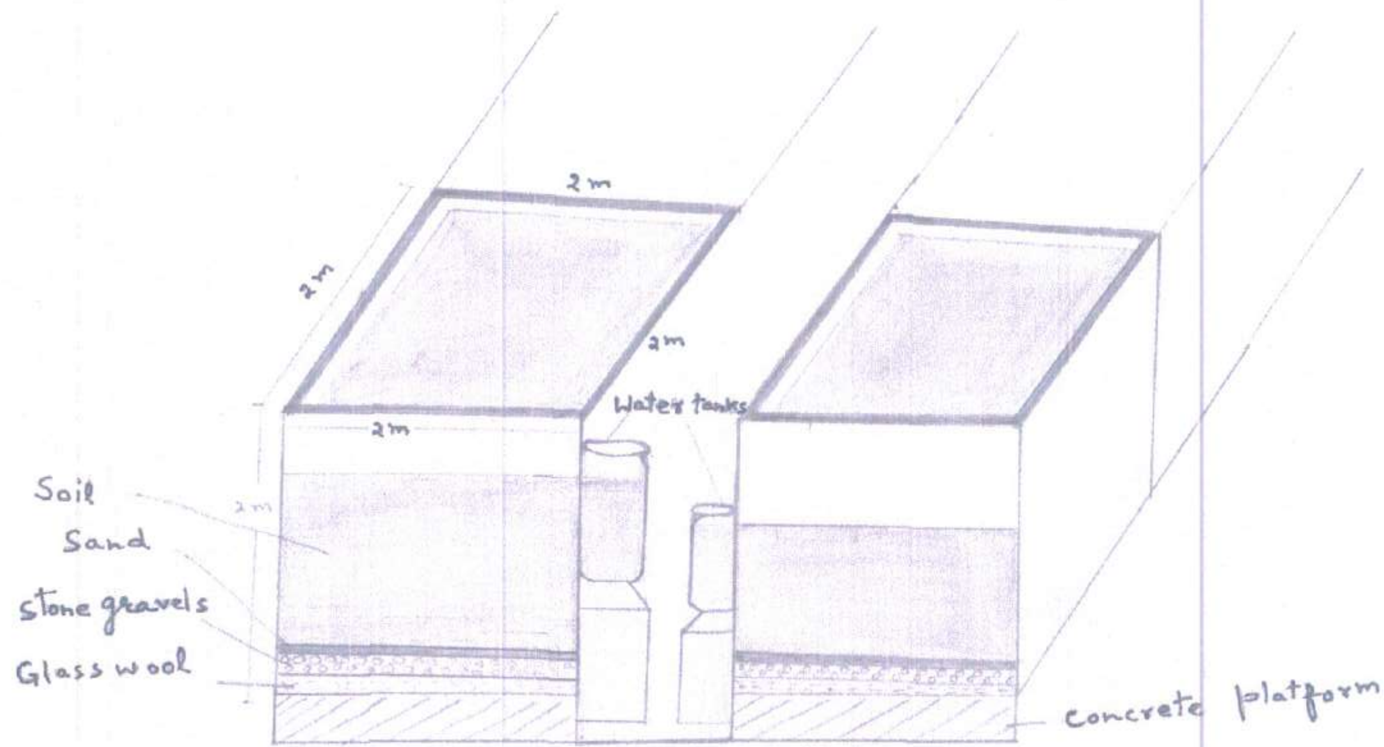
Lysimetric experiments were conducted in the campus of Tropical Forest Research Institute, Jabalpur to simulate the experiments being conducted along left bank canal. To conduct these experiments, forty lysimetric tanks were constructed as per the standard specifications. The experiments were conducted to address following aspects:

a) To assess the growth performance of selected species under different water regimes.
b) To observe transpirational response mechanism of selected tree species under different water regimes and controlled conditions.
c) To assess the species and seasonal variation in water consumption by selected tree species under different water regimes.

The in filled non-weighing type of lysimeters were used for the experiment. Forty leak proof lysimetric tanks were constructed under the project in TFRI campus. They were refilled with soil and almost similar soil profile was maintained in the tanks as that of Bargi canal command area. To provide effective drainage and passage for water movement in and out of the lysimeter tanks, a layer of glass wool was provided at the bottom of the each tank. Over that, a layer of 4 inch of stone gravel and 2 inch of sand was provided. Soil was filled in the lysimetric tanks in such a way that it represents the natural layer composition. These tanks were used to create water logging at surface level, 25 cm and 50 cm soil depth with a control treatment, in which no water logging was created. Water logging in lysimetric tanks was created by placing 100 litre water tanks at desired height in the trench outside the lysimetric tanks. These 100 litre water tanks were connected to these lysimetric tanks by PVC pipe through valve and check nut and used to supple water in to the lysimetric tanks. To maintain the above mentioned water levels in the lysimetric tanks, 0-25 cm, 25-50 cm and 50-75 cm water levels in 100 litre tanks were maintained respectively by adding water to these tanks on daily basis. The amount of water transpired by plants and water evaporated through the surface of lysimetric tanks contributed to amount of water added to each 100 litre lysimetric tank every day. To check the evaporation loss from the soil surface of the lysimetric tanks, the tanks were covered by polythene sheet. Hence the depletion of the water in the 100 litre supply tanks represented water use by individual plant per day. Chhabra and Thakur (1998) conducted experiments for 4 years by installing a series of lysimeters made from RCC hume pipes with diameter of 1.2 m and depth of 2.5 m.

Photos 6: Construction of tanks and conduct lysimetric experiments

Schematic diagram of lysimetric tanks



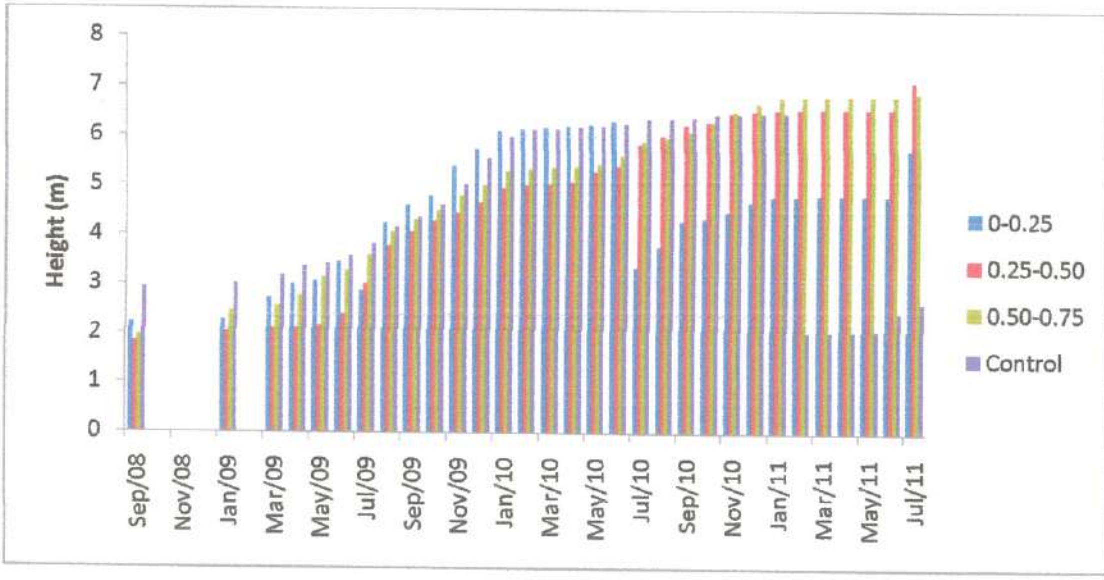
Growth performance of tree species in lysimetric tanks

About one year old seedlings of *Eucalyptus* hybrid, *Pongamia pinnata, Dalbergia sissoo, Acacia nilotica, Albizia procera, Albizia lebbek* and *Terminalia arjuna* were planted in lysimetric tanks in July 2008 and started collecting growth data of the seedlings since September 2008. Plant growth parameters like height, basal girth, Girth at Breast Height (GBH), number of branches and number of leaves were recorded at monthly interval. Although, the growth data were collected on every month, but few months were skipped when the growth data were not collected due to non-significant changes. Height and basal girth were recorded throughout the period (September 2008 to July 2011). GBH was measured since October 2009 in two species and since November 2009 in all the species, when the seedlings reached till breast height. Number of branches and number of leaves were measured from September 2008 till June 2009 because beyond this period it was not possible to enumerate number of leaves accurately due to drastic change in their number. Growth data are given in Appendix A (Table A1 to A31) and Figures 2 to 32.

Height of the *Eucalyptus* seedlings planted in lysimetric tanks increased significantly under different water regimes during the study period. The seedling planted in the control tank was broken from the middle by the speedy wind in January 2011. In July 2011, maximum height was observed in 0.25 m– 0.50 m tank, followed by 0.50 m – 0.75 m and 0 – 0.25 m tanks. The height of *Eucalyptus* seedling planted in 0 - 0.25 m water level tank increased from 2.22 m to 5.75 m, which showed 159% increase in the height. Similarly, the seedlings planted in 0.25 m - 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase in 287%, 253% and 120% (Till January 2011) respectively. The results show that increase in the height of *Eucalyptus* was found in the order :

0.25 m - 0.50 m > 0.50 m - 0.75 m > 0 - 0.25 m > Control

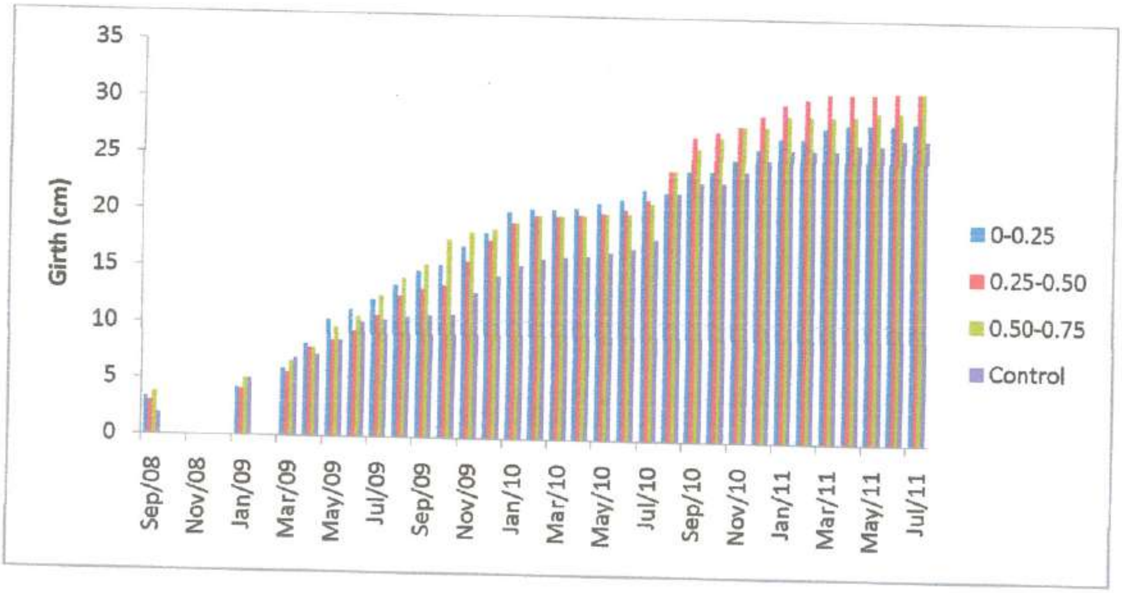
Fig. 2: Monthly variation in height of *Eucalyptus* hybrid seedlings under different water regimes.



In July 2011, maximum basal girth of *Eucalyptus* was found in 0.25 m– 0.50 m and 0.50 m – 0.75 m tanks (31.20 cm), followed by 0 – 0.25 m tank (28.50 cm). Minimum basal girth was observed in control tank. Basal girth of *Eucalyptus* under different water regimes increased from 3.29 cm to 28.50 cm in 0 - 0.25 m tank, 2.98 cm to 31.20 cm in 0.25 m- 0.50 m tank, 3.76 cm to 31.20 cm in 0.50 m - 0.75 m tank and 1.88 cm to 27 cm in control tank. The results show an increase in basal girth of *Eucalyptus* in following decreasing order :

Control (1336%) > 0.25 m- 0.50 m (947%) > 0 - 0.25 m (766%) > 0.50 m - 0.75 m (730%)

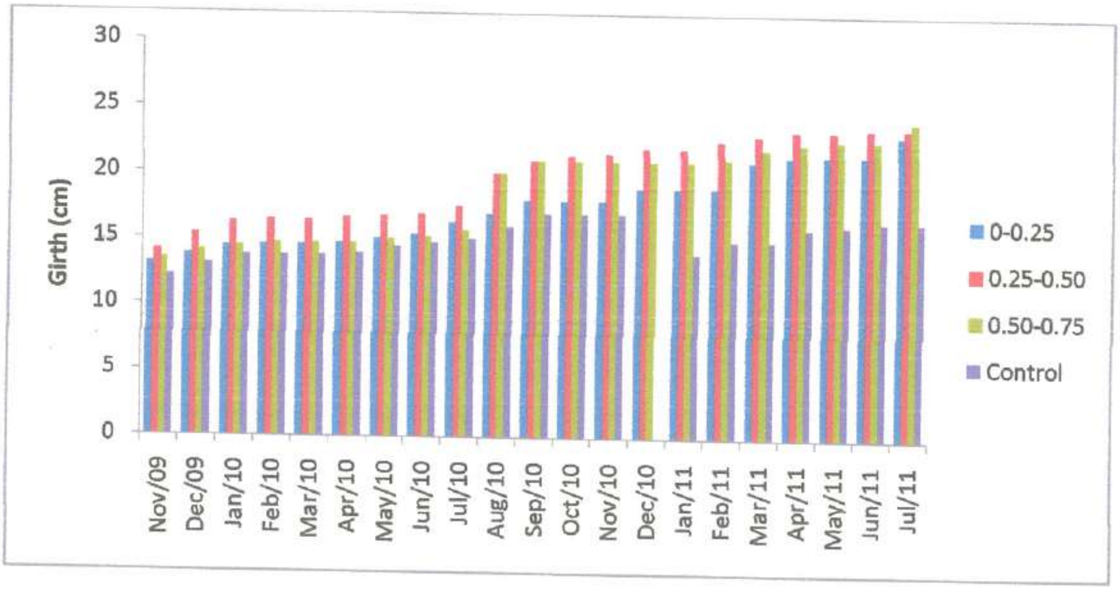
Fig. 3: Monthly variation in basal girth of *Eucalyptus* hybrid seedlings under different water regimes.



GBH of *Eucalyptus* was recorded maximum in 0.50 m – 0.75 m tank (24.10 cm), followed by 0.25 m – 0.50 m tank (23.60 cm) and 0 – 0.25 m tank (23.10 cm) in July 2011. Minimum GBH was recorded in control tank (16.5 cm). GBH of *Eucalyptus* under different water regimes increased from 13.19 cm to 23.10 cm in 0 - 0.25 m tank, 14.13 cm to 23.60 cm in 0.25 m- 0.50 m tank, 13.50 cm to 24.10 cm in 0.50 m - 0.75 m tank and 12.25 cm to 16.50 cm in control tank during November 2009 to July 2011. The increase in GBH of *Eucalyptus* was observed in following decreasing order :

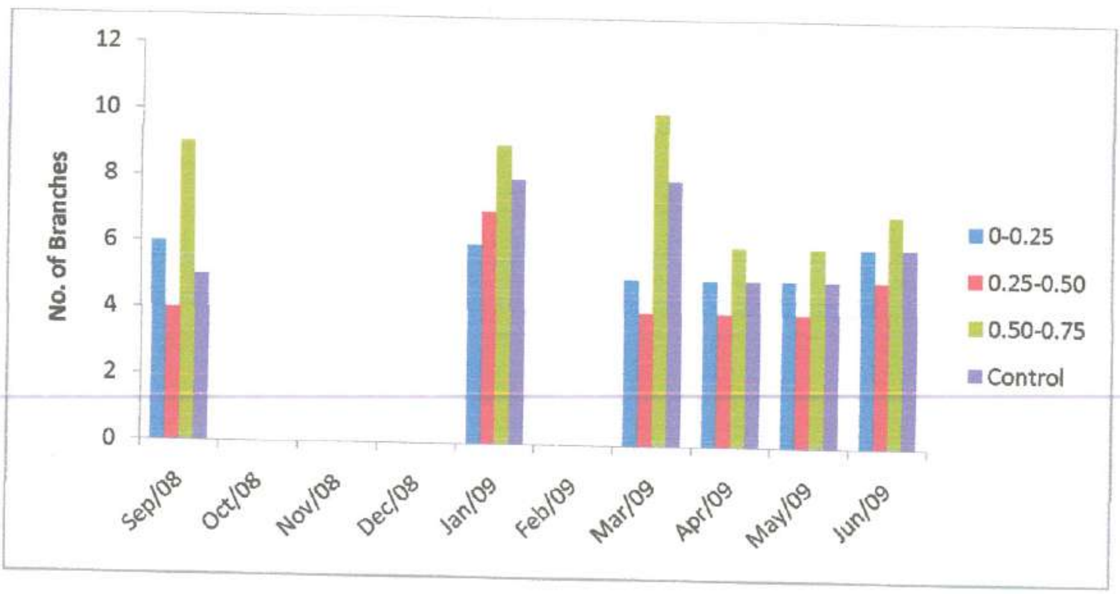
0.50 m - 0.75 m (79%) > 0 - 0.25 m (75%) > 0.25 m- 0.50 m (67%) > Control (35%)

Fig. 4: Monthly variation in GBH of *Eucalyptus* hybrid seedlings under different water regimes.



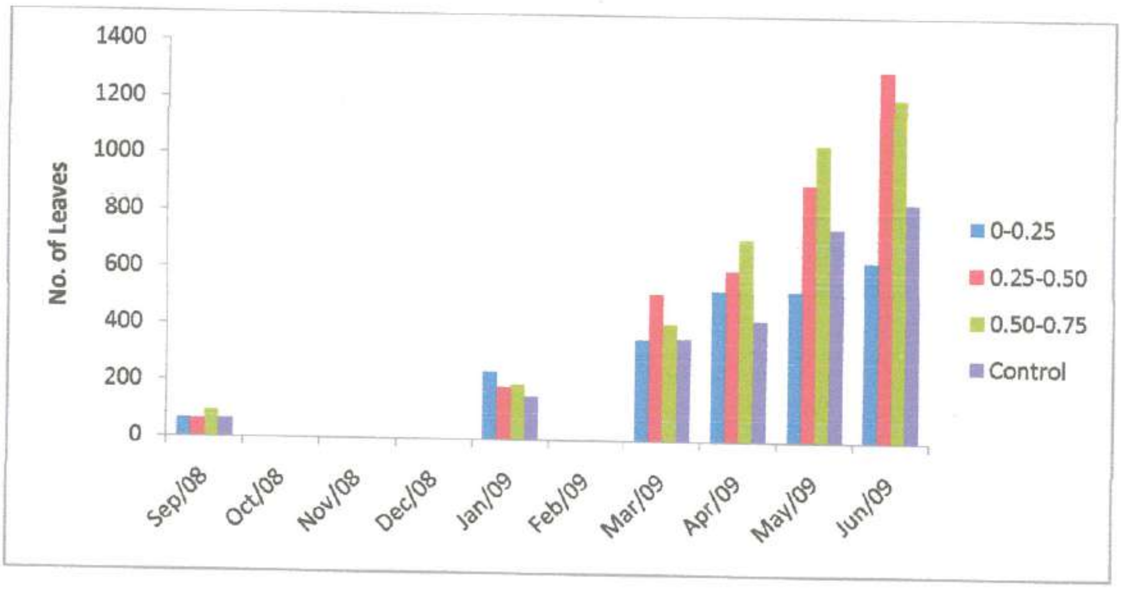
Number of branches was counted from September 2008 till June 2009, which erratically changed with the growth in *Eucalyptus* but was always found maximum in 0.50 m – 0.75 m tank.

Fig. 5: Monthly variation in number of branches of *Eucalyptus* hybrid seedlings under different water regimes.



Number of leaves in *Eucalyptus* was recorded during September 2008 to June 2009 only because after this period it was not possible to count the number of leaves accurately due to its high number. In June 2009, the maximum number was observed in 0.25 m– 0.50 m tank (1310), followed by 0.50 m – 0.75 m tank (1210). The number of leaves increased with the growth of the plants of *Eucalyptus*. Maximum increase was found in 0.25 m- 0.50 m tank (20.13 times), followed by 0.50 m - 0.75 m (11.87 times), control (11.76 times) and 0 - 0.25 m (8.48 times) during September 2008 to June 2009.

Fig. 6: Monthly variation in number of leaves of *Eucalyptus* hybrid seedlings under different water regimes.

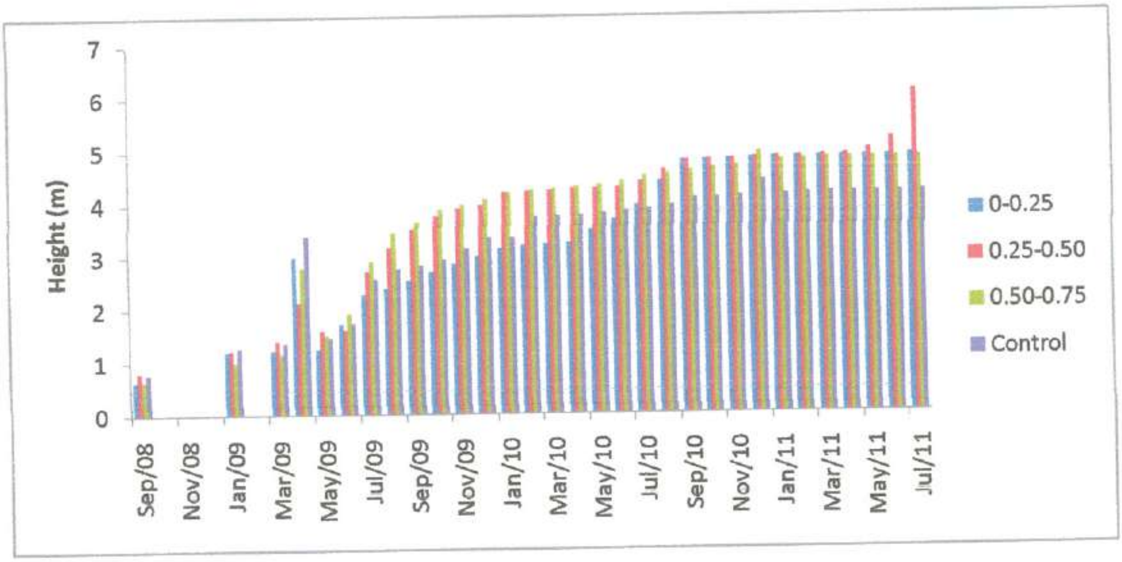


Hence, it was found that maximum growth of *Eucalyptus* trees was recorded in 0.25 m – 0.50 m tank, followed by 0.50 m – 0.75 m and 0 – 0.25 m tanks, while minimum growth was observed in control tank where water was provided to the tree as and when required. *Eucalyptus* trees grew faster under water logged conditions at different water regimes in comparison to controlled conditions. The results are in tune with the fact that *Eucalyptus* consumes more water than any other tree species and agricultural crop.

Height of the *Pongamia pinnata* seedlings planted in lysimetric tanks increased significantly under different water regimes during the study period. In July 2011, maximum height was observed in 0.25 m – 0.50 m tank (6.10 m), followed by 0 – 0.25 m (4.89 m) and 0.50 m – 0.75 m (4.85 m) tanks. The height of *Pongamia pinnata* seedling planted in 0 - 0.25 m water level tank increased from 0.64 m to 4.89 m, which showed 6.64 times increase in the height. Similarly, the seedlings planted in 0.25 m - 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase of 6.44, 6.46 and 4.32 times respectively. The results show that increase in the height of *Pongamia pinnata* was found in the order :

0.25 m - 0.50 m > 0 - 0.25 m > 0.50 m - 0.75 m > Control

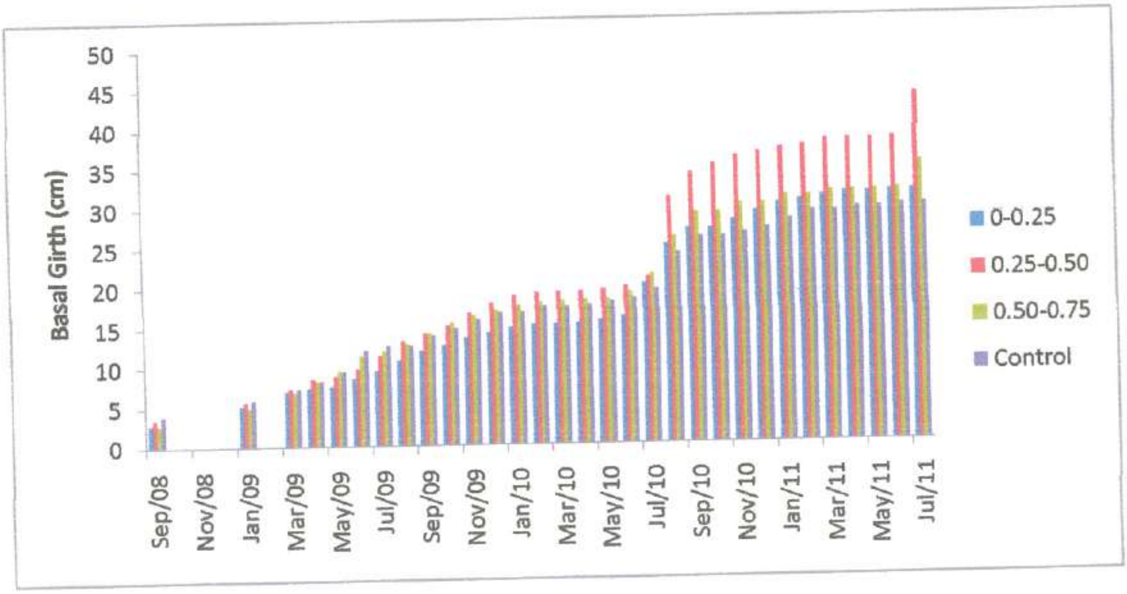
Fig. 7: Monthly variation in height of *Pongamia pinnata* seedlings under different water regimes.



Maximum basal girth of *Pongamia pinnata* was found in 0.25 m – 0.50 m (43.7 cm), followed by 0.50 m – 0.75 m tank (35.20 cm) and 0 – 0.25 m tank (31.50 cm) in July 2011. Minimum basal girth was observed in control tank (29.80 cm). Basal girth of *Pongamia pinnata* increased from 2.82 cm to 31.5 cm in 0 - 0.25 m tank, 3.45 cm to 43.7 cm in 0.25 m- 0.50 m tank, 2.66 cm to 35.2 cm in 0.50 m - 0.75 m tank and 3.92 cm to 29.8 cm in control tank during the study period. The results show an increase in basal girth of *Pongamia pinnata* in following decreasing order :

0.50 m - 0.75 m (12.23 fold) > 0.25 m - 0.50 m (11.67 fold) > 0 - 0.25 m (10.17 fold) > Control (6.60 fold)

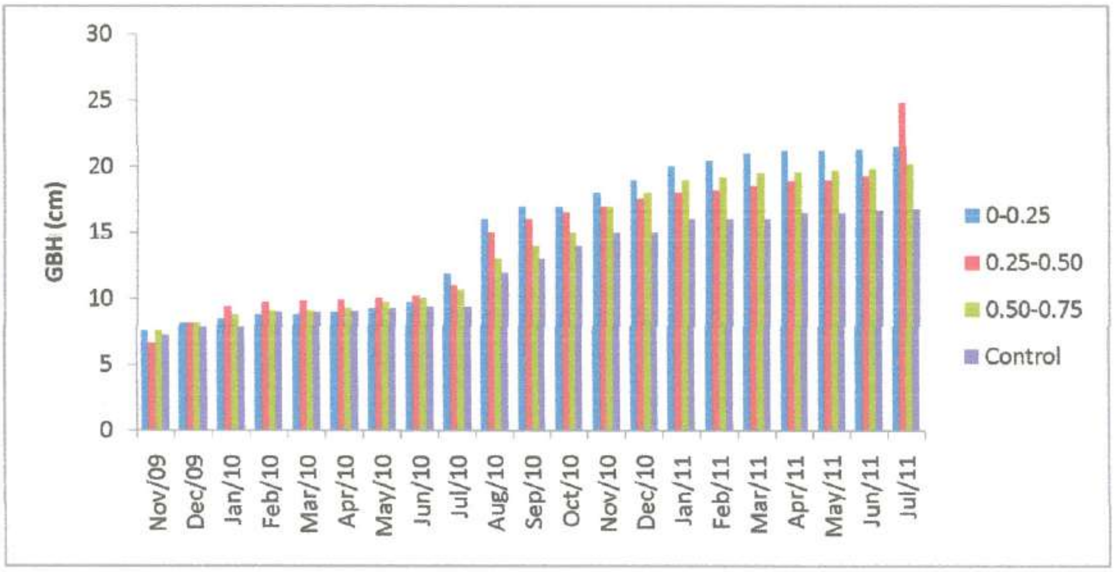
Fig. 8: Monthly variation in basal girth of *Pongamia pinnata* seedlings under different water regimes.



GBH of *Pongamia pinnata* was recorded maximum in 0.25 m– 0.50 m tank (24.9 cm), followed by 0 – 0.25 m tank (21.5 cm) and 0.50 m – 0.75 m tank (20.2 cm) in the last month of observation. Minimum GBH was recorded in control tank (16.8 cm). GBH of *Pongamia pinnata* under different water regimes increased from 7.54 cm to 21.5 cm in 0 - 0.25 m tank, 6.59 cm to 24.9 cm in 0.25 m- 0.50 m tank, 7.54 cm to 20.2 cm in 0.50 m - 0.75 m tank and 7.22 cm to 16.8 cm in control tank during November 2009 to July 2011. The increase in GBH of *Pongamia pinnata* was observed in following decreasing order :

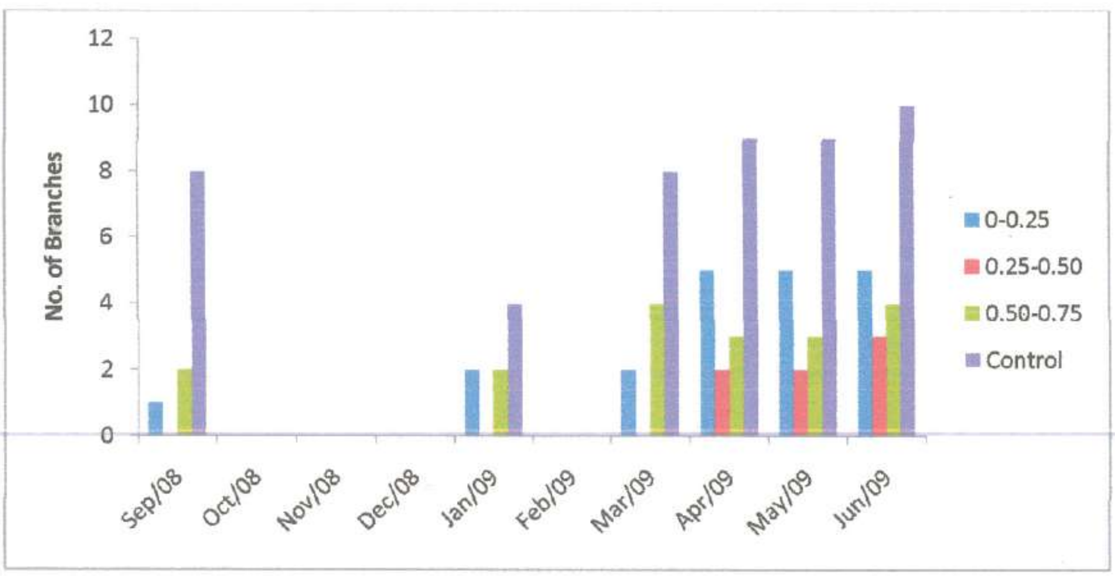
0.25 m- 0.50 m (278 %) > 0 - 0.25 m (185%) > 0.50 m - 0.75 m (168%) > Control (133%)

Fig. 9: Monthly variation in GBH of *Pongamia pinnata* seedlings under different water regimes.



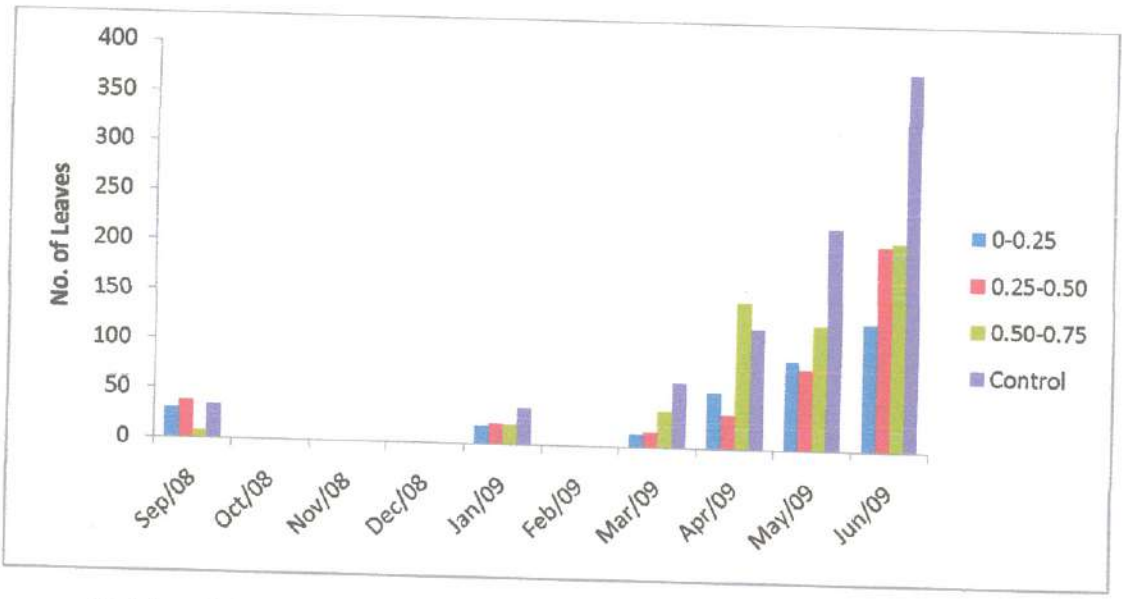
Number of branches changed with the growth in *Pongamia pinnata* but was always found maximum in control tank.

Fig. 10: Monthly variation in No. of branches of *Pongamia pinnata* seedlings under different water regimes.



Number of leaves in *Pongamia pinnata* was recorded during September 2008 to June 2009. In June 2009, the maximum number was observed in Control tank (380), followed by 0.50 m – 0.75 m tank (210), 0.25 m– 0.50 m tank (207) and 0 – 0.25 m tank (128). The number of leaves increased with the growth of the plants of *Pongamia pinnata*. Maximum increase was found in 0.50 m - 0.75 m (25.25 times) followed by control tank (10.17 times), 0.25 m - 0.50 m tank (4.45 times) and 0 - 0.25 m (3.26 times) during September 2008 to June 2009.

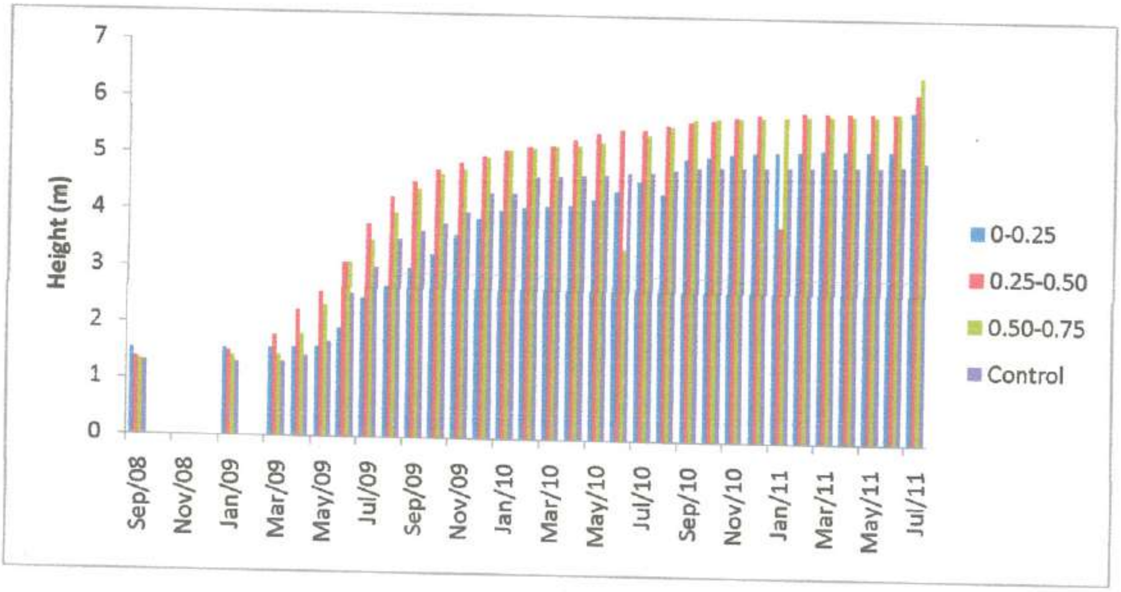
Fig. 11: Monthly variation in number of leaves of *Pongamia pinnata* seedlings under different water regimes.



Height of the *Dalbergia sissoo* seedlings planted in lysimetric tanks increased significantly under different water regimes during the study period. In July 2011, maximum height was observed in 0.50 m – 0.75 m (6.50 m) followed by 0.25 m – 0.50 m tank (6.20 m), 0 – 0.25 m (5.90 m) tanks. The height of *Dalbergia sissoo* seedling planted in 0 - 0.25 m water level tank increased from 1.52 m to 5.90 m, which showed 2.88 times increase in the height. Similarly, the seedlings planted in 0.25 m - 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase in 3.53, 3.88 and 2.82 times respectively. The results show that increase in the height of *Dalbergia sissoo* was found in the order :

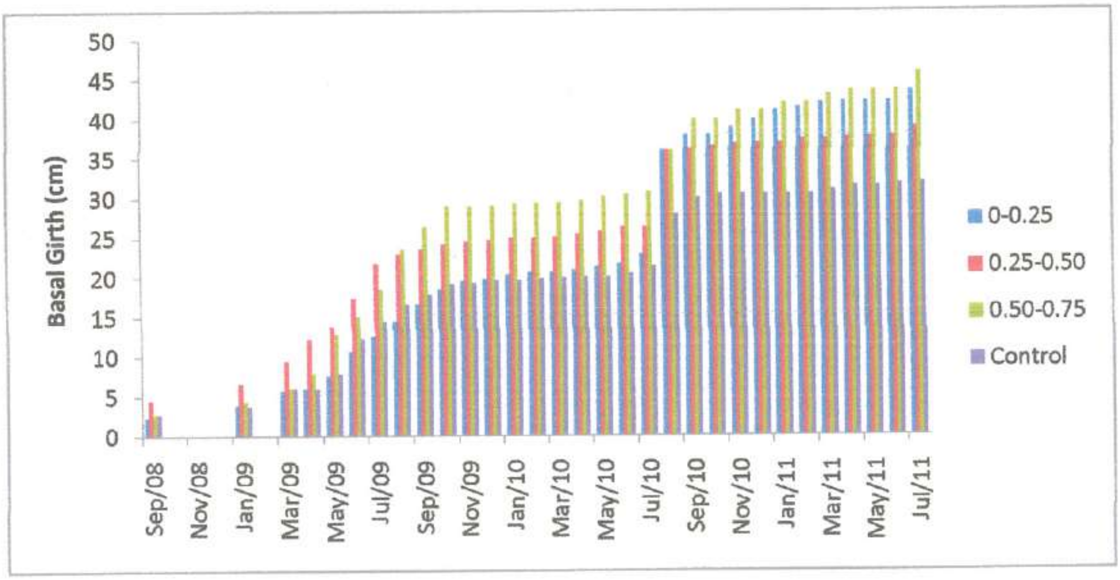
0.50 m - 0.75 m > 0.25 m - 0.50 m > 0 - 0.25 m > Control

Fig. 12: Monthly variation in height of *Dalbergia sissoo* seedlings under different water regimes.



In the last month of observation *i.e.* in July 2011, maximum basal girth of *Dalbergia sissoo* was found in 0.50 m – 0.75 m tank (45.8 cm) followed by 0 – 0.25 m tank (43.6 cm), 0.25 m – 0.50 m (39.0 cm). Minimum basal girth was observed in control tank (32.0 cm). Basal girth of *Dalbergia sissoo* under different water regimes increased from 2.35 cm to 43.6 cm in 0 - 0.25 m tank, 4.45 cm to 39.0 cm in 0.25 m- 0.50 m tank, 2.66 cm to 45.8 cm in 0.50 m - 0.75 m tank and 2.04 cm to 32.0 cm in control tank during the study period.

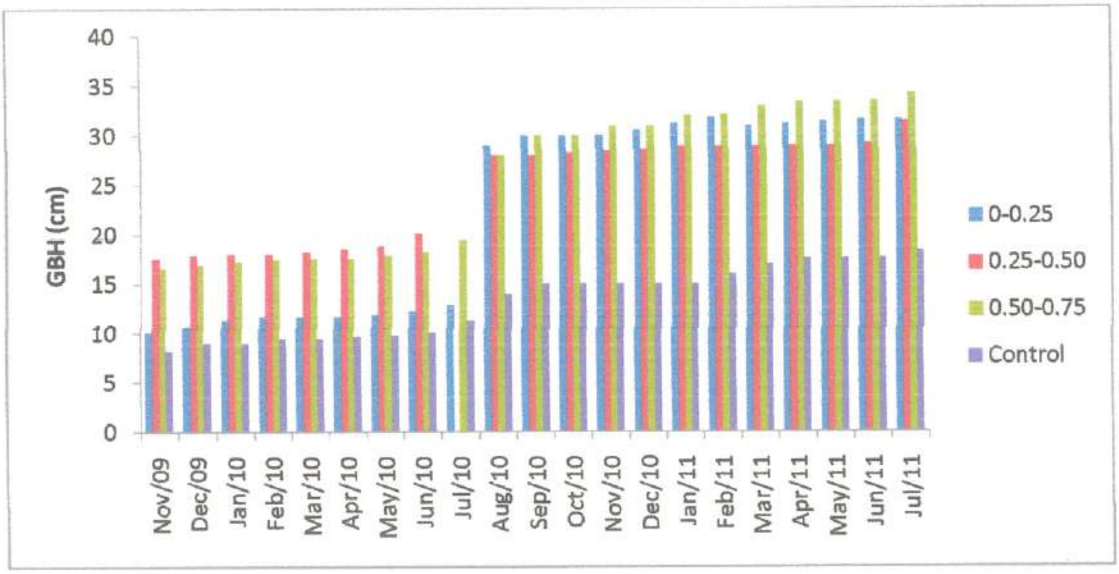
Fig. 13: Monthly variation in basal girth of *Dalbergia sissoo* seedlings under different water regimes.



GBH of *Dalbergia sissoo* was recorded maximum in 0.50 m – 0.75 m tank (34.2 cm), followed by 0 – 0.25 m tank (31.6 cm), 0.25 m– 0.50 m tank (31.4 cm) in July 2011.GBH of *Dalbergia sissoo* under different water regimes increased from 10.5 cm to 31.6 cm in 0 - 0.25 m tank, 17.58 cm to 31.4 cm in 0.25 m- 0.50 m tank, 16.64 cm to 34.2 cm in 0.50 m - 0.75 m tank and 8.16 cm to 18.3 cm in control tank during November 2009 to July 2011. The increase in GBH of *Dalbergia sissoo* was observed in following decreasing order :

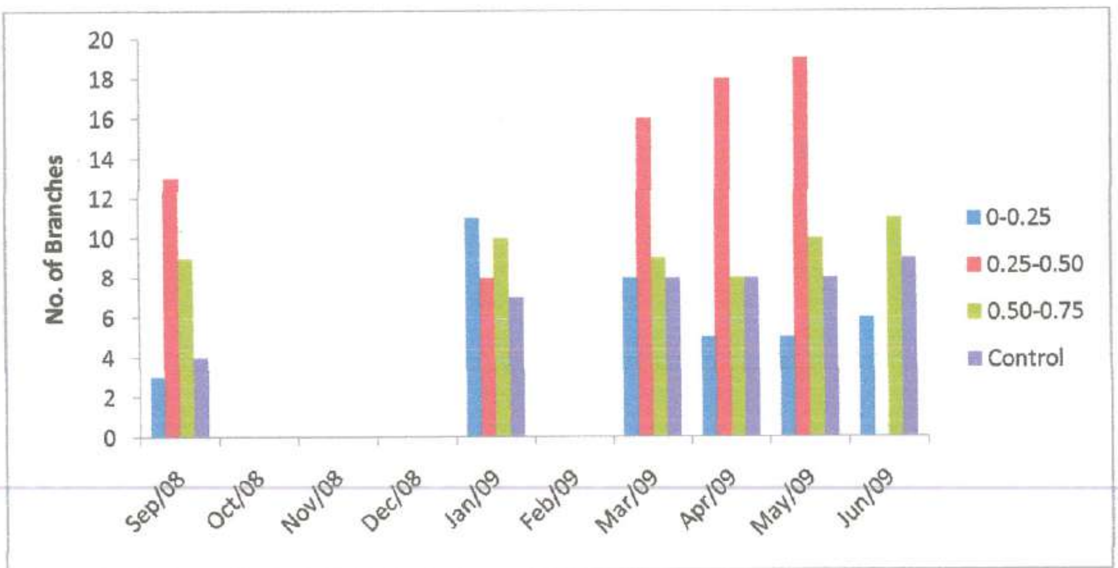
0 - 0.25 m (214%) > Control (124%) > 0.50 m - 0.75 m (106%) > 0.25 m- 0.50 m (79 %)

Fig. 14: Monthly variation in GBH of *Dalbergia sissoo* seedlings under different water regimes.



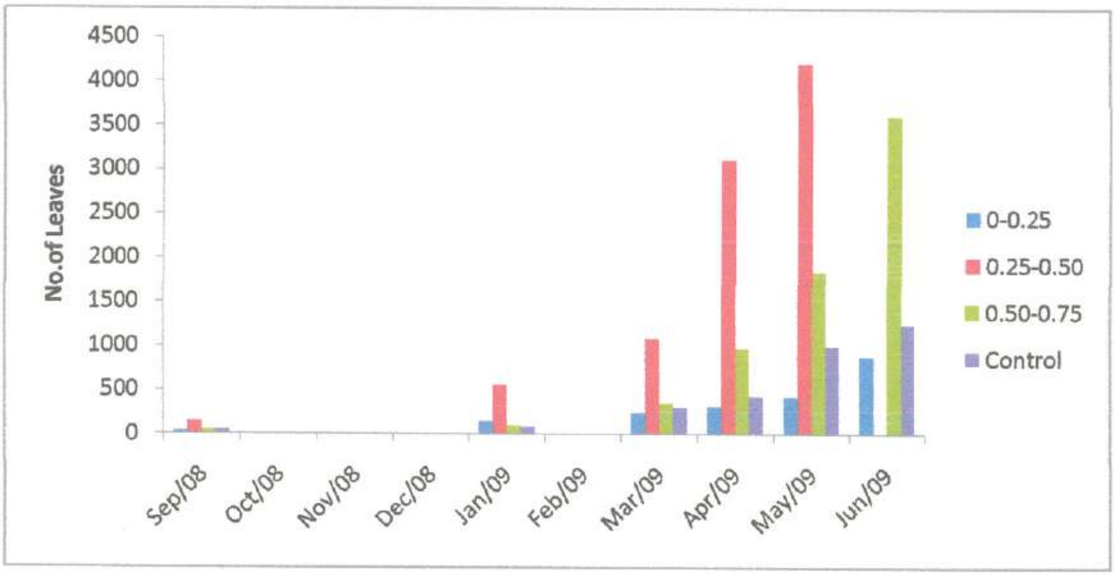
Number of branches erratically changed with the growth in *Dalbergia sissoo* but was found maximum in 0.25 – 0.50 m tank during most of the observation months.

Fig. 15: Monthly variation in number of branches of *Dalbergia sissoo* seedlings under different water regimes.



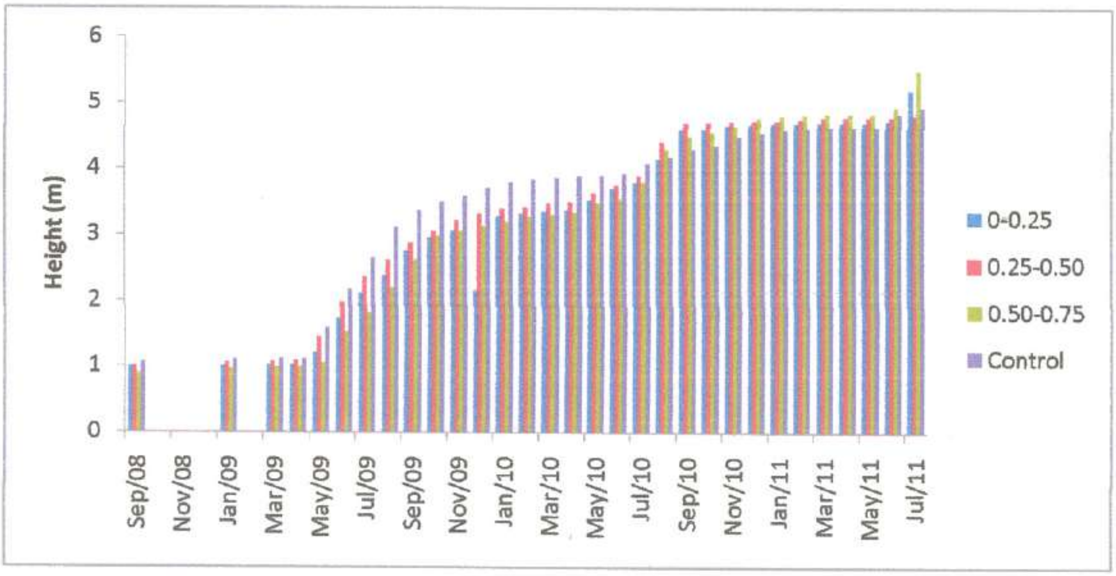
Number of leaves in *Dalbergia sissoo* was recorded during September 2008 to June 2009 only. In June 2009, the maximum number was observed in 0.25 m – 0.50 m tank (4200), followed by 0.50 m – 0.75 m tank (3610), Control tank (1246) and 0 – 0.25 m tank (883). The number of leaves increased with the growth of the plants of *Dalbergia sissoo*. Maximum increase was found in 0.50 m - 0.75 m (69.78 times) followed by 0.25 m - 0.50 m tank (27.76 times), control tank (22.50 times) and 0 - 0.25 m (21.64 times) during September 2008 to June 2009.

Fig. 16: Monthly variation in number of leaves of *Dalbergia sissoo* seedlings under different water regimes.



In July 2011, maximum height of *Acacia nilotica* seedlings was observed in 0.50 m – 0.75 m (5.50 m), followed by 0 – 0.25 m tank (5.20 m), control tank (4.94 m) and 0.25 m – 0.50 m tank (4.82 m). The height of *Acacia nilotica* seedling planted in 0 - 0.25 m, 0.25 m - 0.50 m, 0.50 m - 0.75 m and control tanks showed 4.25, 3.77, 5.11 and 3.62 times increase in the height respectively during the observation period.

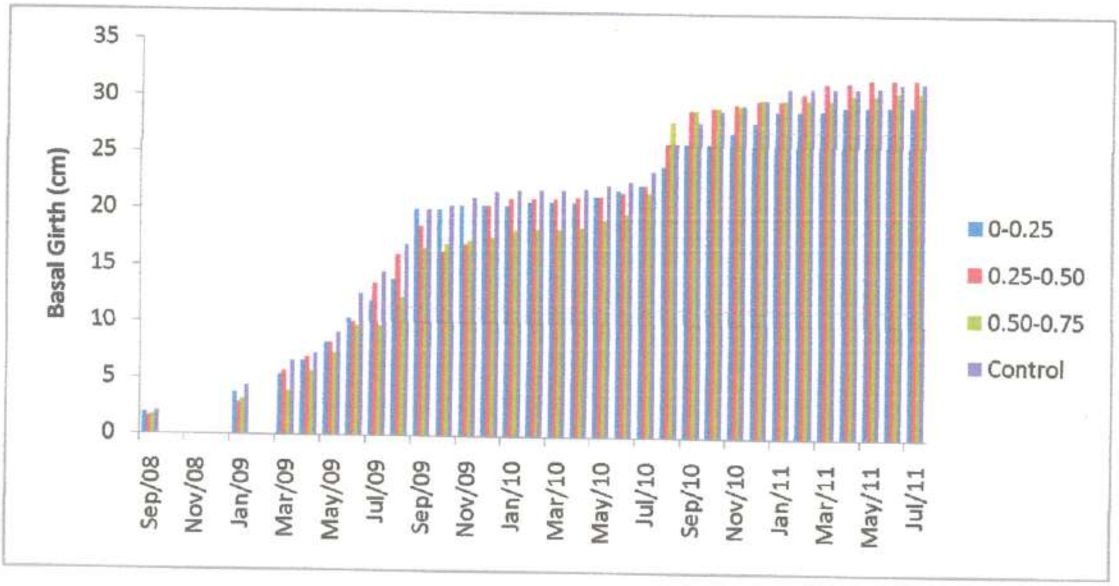
Fig. 17: Monthly variation in height of *Acacia nilotica* seedlings under different water regimes.



The basal girth of *Acacia nilotica* was found maximum in 0.50 m – 0.75 m tank (30.7 cm), followed by 0 – 0.25 m tank (29.5 cm), 0.25 m – 0.50 m (31.9 cm) in July 2011. Basal girth of *Acacia nilotica* under different water regimes increased from 2.35 cm to 43.6 cm in 0 - 0.25 m tank, 4.45 cm to 39.0 cm in 0.25 m - 0.50 m tank, 2.66 cm to 45.8 cm in 0.50 m - 0.75 m tank and 2.04 cm to 32.0 cm in control tank. The results show an increase in basal girth of *Acacia nilotica* in following decreasing order :

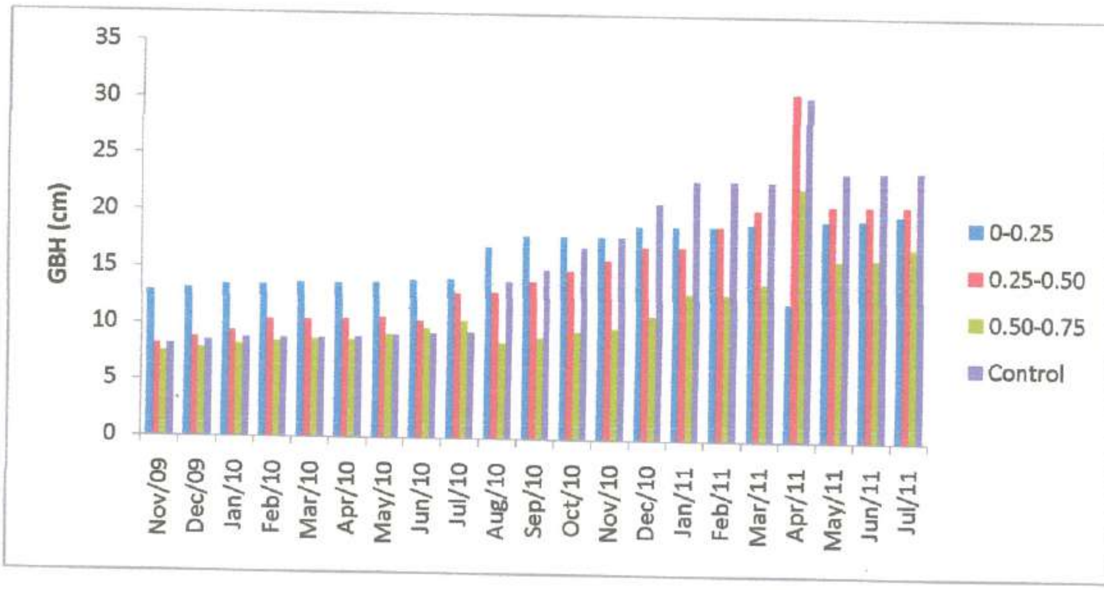
0.25 m- 0.50 m (19.32 fold) > 0.50 m - 0.75 m (16.84 fold) > 0 - 0.25 m (14.69 fold) > Control (14.49 fold)

Fig. 18: Monthly variation in basal girth of *Acacia nilotica* seedlings under different water regimes.



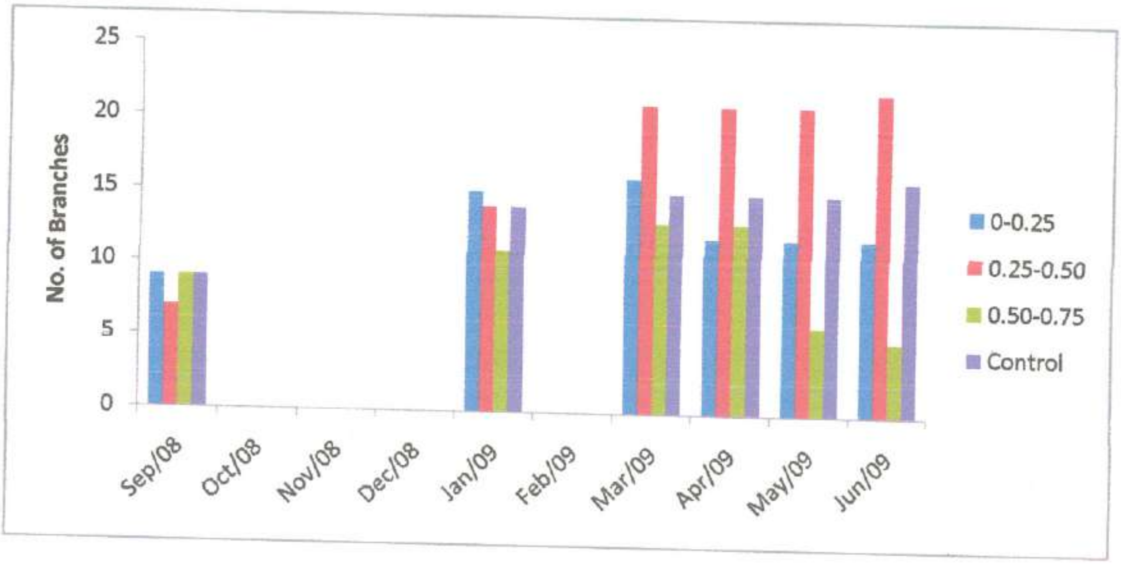
GBH of *Acacia nilotica* was recorded maximum in control tank (24.0 cm), followed by 0.25 m – 0.50 m tank (20.9 cm), 0 – 0.25 m tank (20.1 cm) and 0.50 m – 0.75 m tank (17.2 cm) in July 2011. GBH of *Acacia nilotica* under different water regimes increased from 12.87 cm to 20.1 cm in 0 - 0.25 m tank, 8.16 cm to 20.9 cm in 0.25 m- 0.50 m tank, 7.54 cm to 17.2 cm in 0.50 m - 0.75 m tank and 8.16 cm to 24.0 cm in control tank during November 2009 to July 2011.

Fig. 19: Monthly variation in GBH of *Acacia nilotica* seedlings under different water regimes.



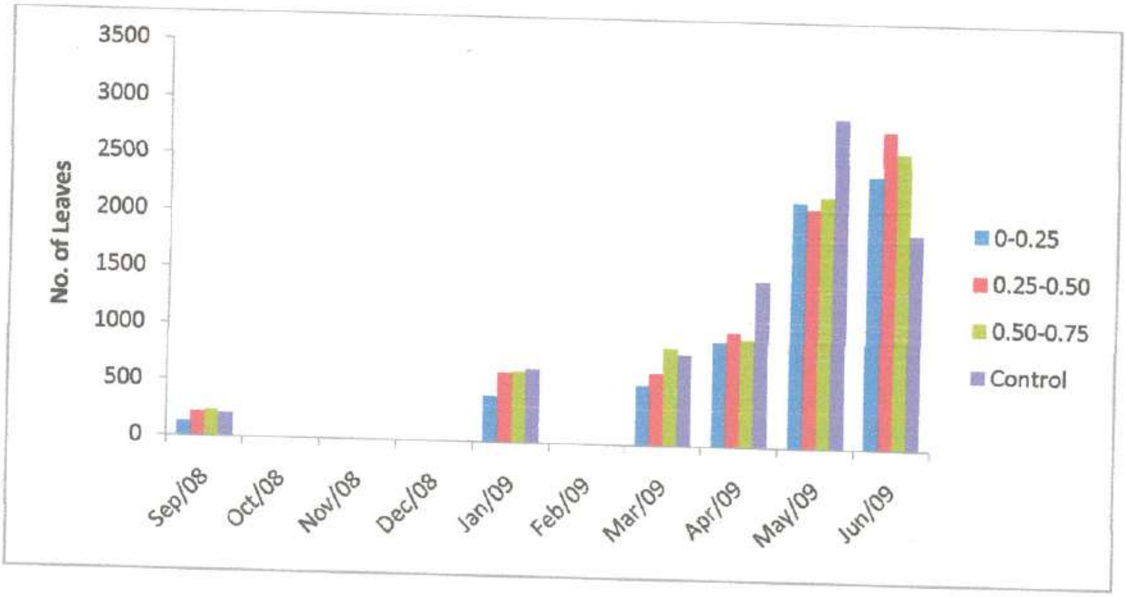
Number of branches was counted from September 2008 till June 2009, which increased with the growth in *Acacia nilotica* but was found maximum in 0.25 – 0.50 m tank, especially during later period of growth.

Fig. 20: Monthly variation in number of branches of *Acacia nilotica* seedlings under different water regimes.



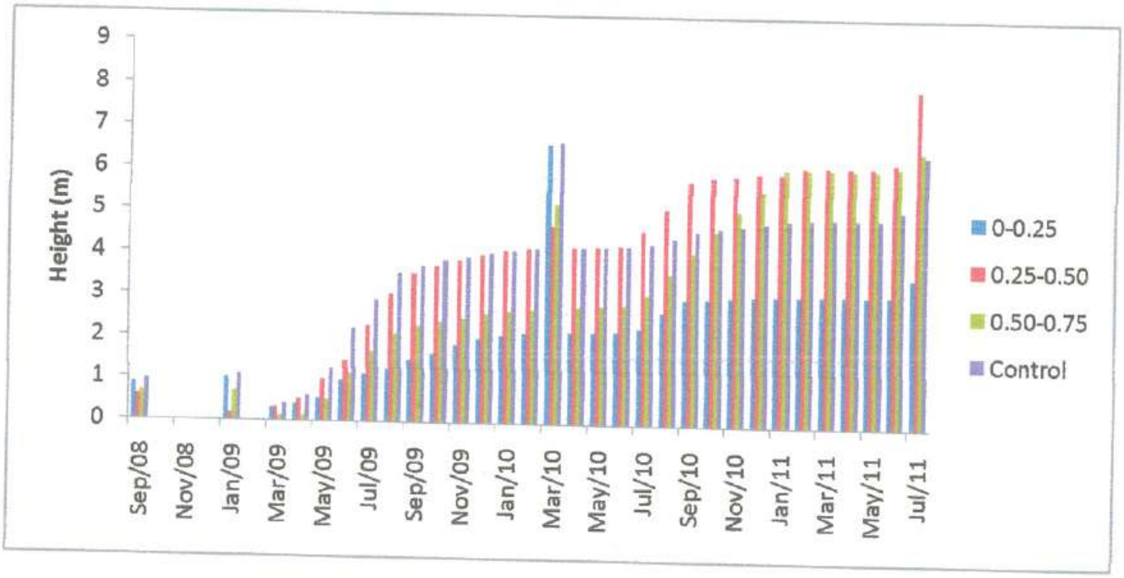
Number of leaves in *Acacia nilotica* was recorded during September 2008 to June 2009 only. In June 2009, the maximum number was observed in 0.25 m – 0.50 m tank (2800), followed by 0.50 m – 0.75 m tank (2613), 0 – 0.25 m tank (2410) and Control tank (1900). The number of leaves increased with the growth of the plants of *Acacia nilotica*. Maximum increase was found in 0 - 0.25 m (17.39 times), followed by 0.25 m- 0.50 m tank (12.08 times), 0.50 m - 0.75 m (10.02 times) and control tank (7.96 times) during September 2008 to June 2009.

Fig. 21: Monthly variation in number of leaves of *Acacia nilotica* seedlings under different water regimes.



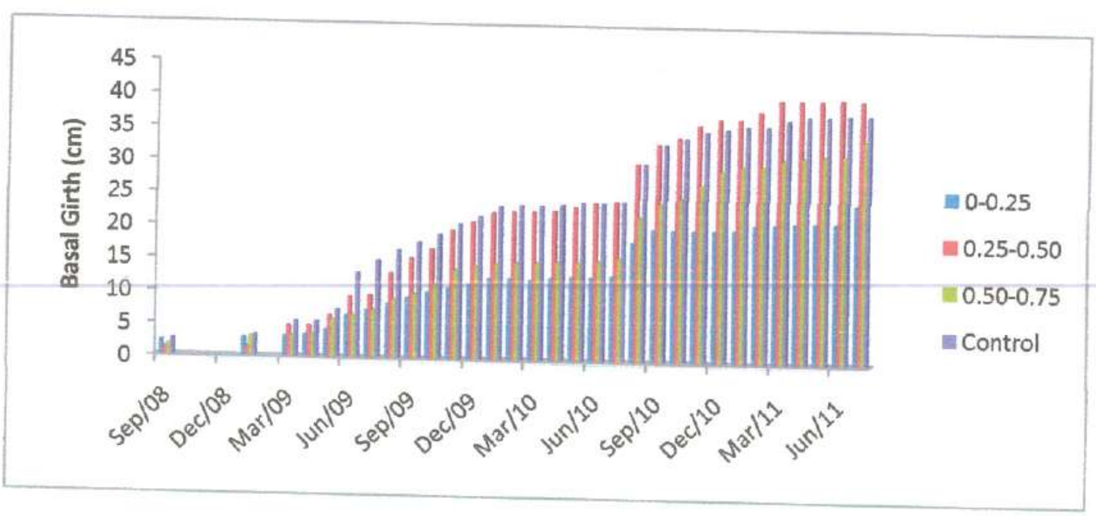
In July 2011, maximum height of *Albizia procera* seedlings was observed in 0.25 m – 0.50 m tank (8.00 m), followed by 0.50 m – 0.75 m (6.55 m). The height of *Albizia procera* seedling planted in 0 - 0.25 m water level tank increased from 0.88 m to 3.55 m, which showed 3.03 times increase in the height. Similarly, the seedlings planted in 0.25 m - 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase in 12.55, 8.63 and 5.64 times respectively.

Fig. 22: Monthly variation in height of *Albizia procera* seedlings under different water regimes.



In July 2011, maximum basal girth of *Albizia procera* was found in 0.25 m – 0.50 m (40.0 cm), followed by control tank (37.8 cm), 0.50 m – 0.75 m tank (34.0 cm) and 0 – 0.25 m tank (24.1 cm). Basal girth of *Albizia procera* under different water regimes increased from 2.19 cm to 24.1 cm in 0 - 0.25 m tank, 1.25 cm to 40.0 cm in 0.25 m- 0.50 m tank, 1.72 cm to 34.0 cm in 0.50 m - 0.75 m tank and 2.51 cm to 37.8 cm in control tank during observation period.

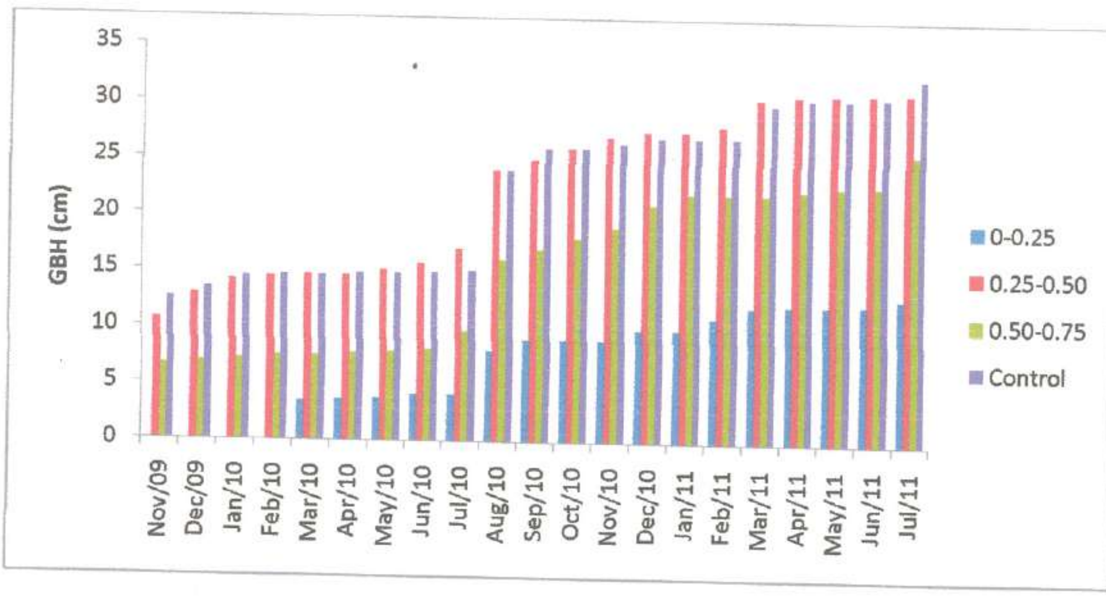
Fig. 23: Monthly variation in basal girth of *Albizia procera* seedlings under different water regimes.



GBH of *Albizia procera* was recorded maximum in control tank (32.4 cm), followed by 0.25 m– 0.50 m tank (31.1 cm) and 0.50 m – 0.75 m tank (25.7 cm) in July 2011. Minimum GBH was recorded in 0 – 0.25 m tank (12.9 cm). GBH of *Albizia procera* under different water regimes increased from 3.45 cm to 12.9 cm in 0 - 0.25 m tank, 10.68 cm to 31.1 cm in 0.25 m- 0.50 m tank, 6.59 cm to 25.7 cm in 0.50 m - 0.75 m tank and 8.16 cm to 32.4 cm in control tank during November 2009 to July 2011. The increase in GBH of *Albizia procera* was observed in following decreasing order :

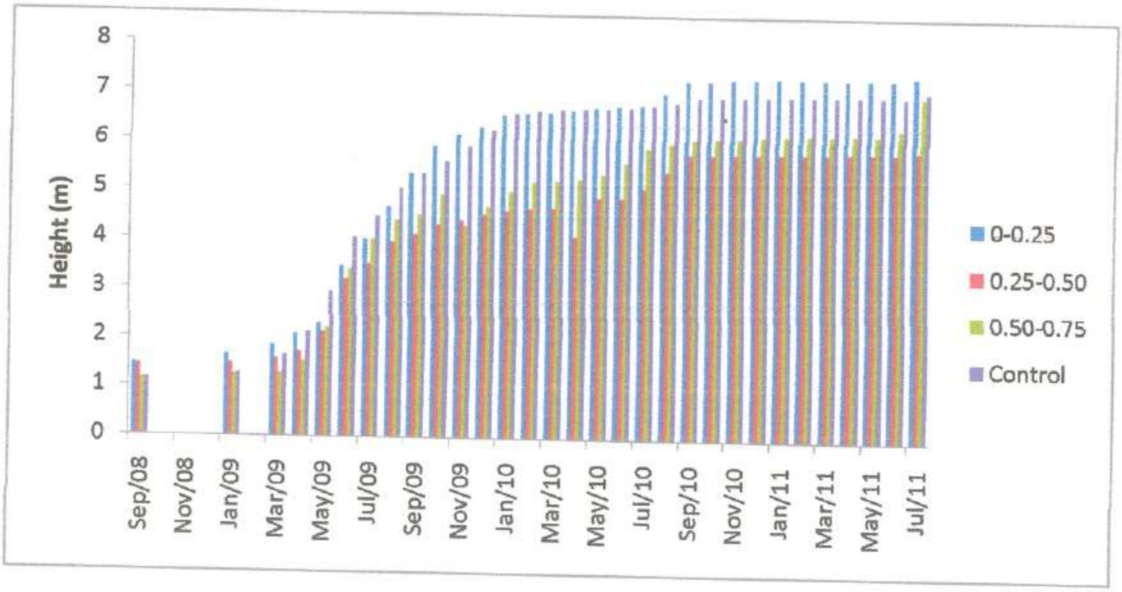
0.50 m - 0.75 m (290 %) > 0 - 0.25 m (274 %) > 0.25 m- 0.50 m (191 %) > Control (158%)

Fig. 24: Monthly variation in GBH of *Albizia procera* seedlings under different water regimes.



Maximum height of the *Albizia lebbek* seedlings was observed in 0 – 0.25 m tank (7.40 m), followed by control tank (7.10 m), 0.50 m – 0.75 m (7.00 m) and 0.25 m– 0.50 m tank (5.90 m) in the last month of the study period. The height of *Albizia lebbek* seedling planted in 0 - 0.25 m water level tank increased from 1.46 m to 7.40 m, which showed 4.06 times increase in the height. Similarly, the seedlings planted in 0.25 m- 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase in 3.13, 5.09 and 5.12 times respectively.

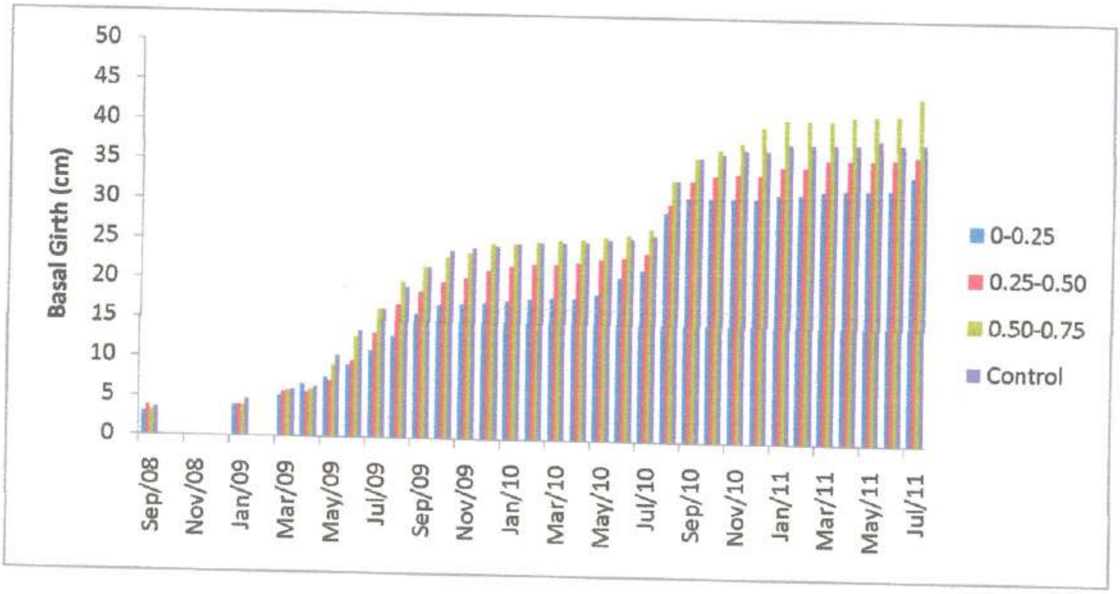
Fig. 25: Monthly variation in height of *Albizia lebbek* seedlings under different water regimes.



The basal girth of *Albizia lebbek* was found maximum in 0.50 m – 0.75 m tank (44.0 cm), followed by control tank (38.2 cm), 0.25 m – 0.50 m (36.5 cm) in July 2011. Minimum basal girth was observed in 0 – 0.25 m tank (34.0 cm). Basal girth of *Albizia lebbek* under different water regimes during observation period increased in following order :

0.50 m - 0.75 m (13.01 fold) > 0 - 0.25 m (10.40 fold) > Control (10.07 fold) > 0.25 m-0.50 m (8.70 fold)

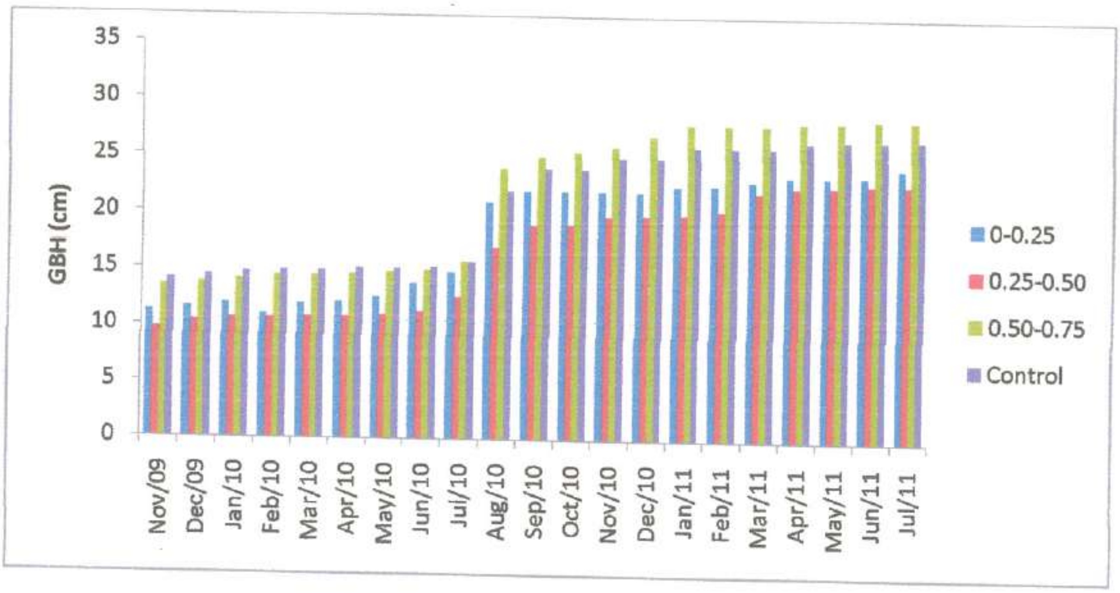
Fig. 26: Monthly variation in basal girth of *Albizia lebbek* seedlings under different water regimes.



GBH of *Albizia lebbek* was recorded maximum in 0.50 m – 0.75 m tank (28.5 cm), followed by control tank (26.8 cm), 0 – 0.25 m tank (24.2 cm) and 0.25 m– 0.50 m tank (22.8 cm) in July 2011. GBH of *Albizia lebbek* under different water regimes increased from 11.30 cm to 24.2 cm in 0 - 0.25 m tank, 9.73 cm to 22.8 cm in 0.25 m-0.50 m tank, 13.50 cm to 28.5 cm in 0.50 m - 0.75 m tank and 14.13 cm to 26.8 cm in control tank during November 2009 to July 2011, which was found in the following order :

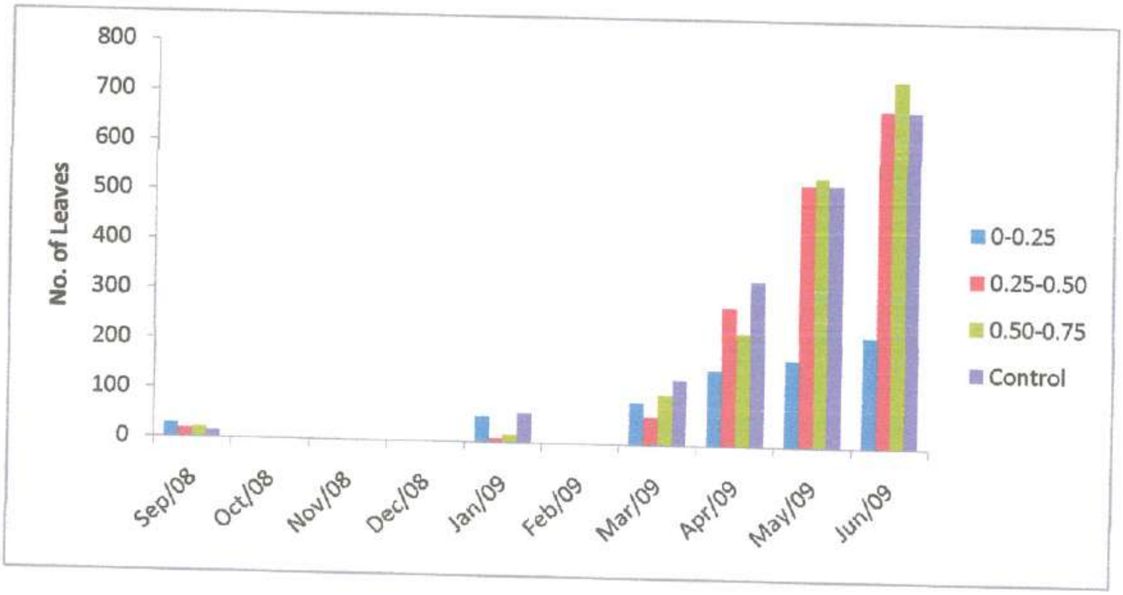
0.25 m- 0.50 m (134 %) > 0 - 0.25 m (114 %) > 0.50 m - 0.75 m (111 %) > Control (90%)

Fig. 27: Monthly variation in GBH of *Albizia lebbek* seedlings under different water regimes.



Number of leaves in *Albizia lebbek* was recorded during September 2008 to June 2009 only. In the last month of its observation, the maximum number was observed in 0.50 m – 0.75 m tank (740), followed by 0.25 m – 0.50 m tank (680), Control tank (678) and 0 – 0.25 m tank (224). Maximum increase was found in control tank (44.20 times), followed by 0.25 m - 0.50 m tank (34.78 times), 0.50 m - 0.75 m (32.63 times) and 0 - 0.25 m (6.72 times) during September 2008 to June 2009.

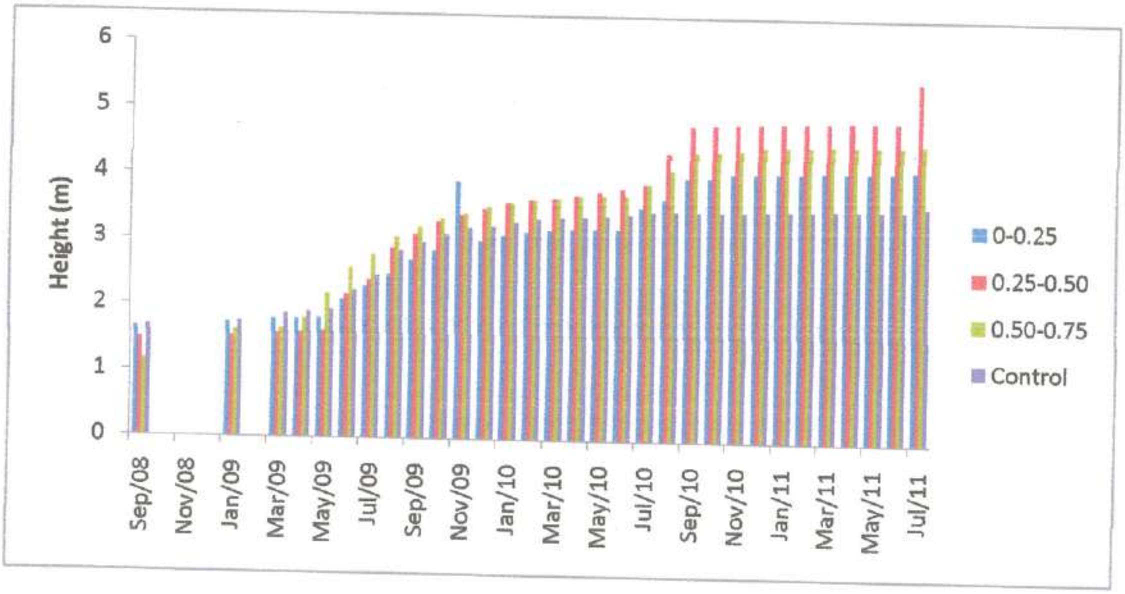
Fig. 28: Monthly variation in number of leaves of *Albizia lebbek* seedlings under different water regimes.



Height of the *Terminalia arjuna* seedlings planted in lysimetric tanks increased significantly under different water regimes during the study period. In July 2011, maximum height was observed in 0.25 m– 0.50 m tank (5.50 m), followed by 0.50 m – 0.75 m (4.55 m), 0 – 0.25 m tank (4.15 m) and control tank (3.60 m). The height of *Terminalia arjuna* seedlings planted in 0 - 0.25 m water level tank increased from 1.66 m to 4.15 m, which showed 1.50 times increase in the height during the observation period. Similarly, the seedlings planted in 0.25 m- 0.50 m, 0.50 m - 0.75 m and control tanks showed an increase in 2.69, 2.92 and 1.13 times respectively. The results show that increase in the height of *Terminalia arjuna* was found in the order :

0.50 m - 0.75 m > 0.25 m - 0.50 m > 0 - 0.25 m > Control

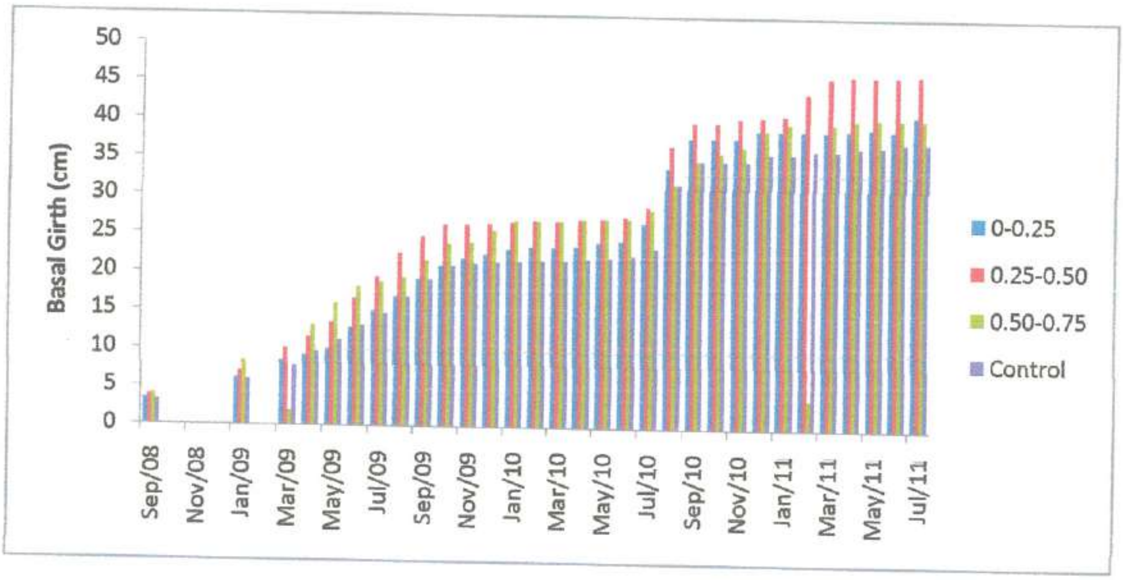
Fig. 29: Monthly variation in height of *Terminalia arjuna* seedlings under different water regimes.



In the last month of its observation, maximum basal girth of *Terminalia arjuna* was found in 0.25 m – 0.50 m (46.4 cm), followed by 0 – 0.25 m tank (41.1 cm), 0.50 m – 0.75 m tank (40.7 cm). Minimum basal girth was observed in control tank (37.6 cm). Increase in basal girth of *Terminalia arjuna* under different water regimes showed the following pattern :

0 - 0.25 m (10.91 fold) > 0.25 m - 0.50 m (10.83 fold) > Control (10.42 fold) > 0.50 m - 0.75 m (8.97 fold)

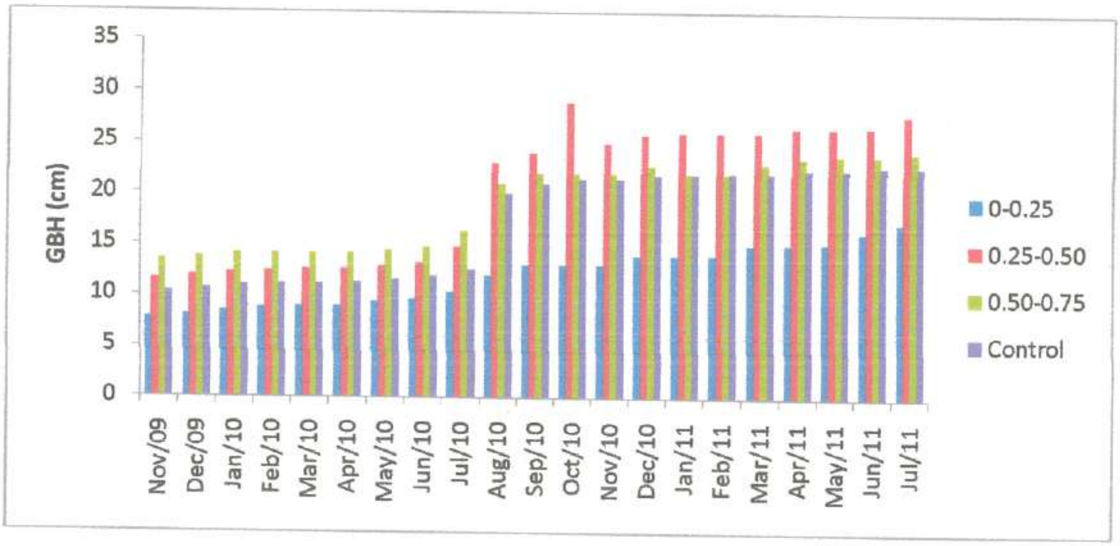
Fig. 30: Monthly variation in basal girth of *Terminalia arjuna* seedlings under different water regimes.



GBH of *Terminalia arjuna* was recorded maximum in 0.25 m – 0.50 m tank (27.8 cm) followed by, 0.50 m – 0.75 m tank (24.2 cm), control tank (22.8 cm) in July 2011. Minimum GBH was recorded in 0 – 0.25 m tank (17.2 cm). Increase in GBH of *Terminalia arjuna* under different water regimes during November 2009 to July 2011 showed following decreasing order :

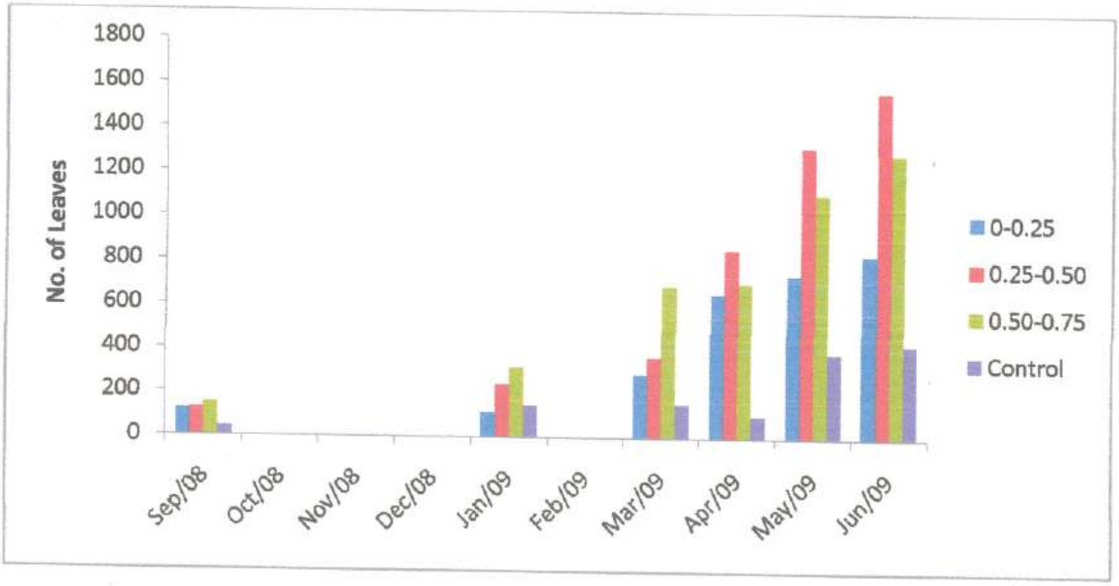
0.25 m - 0.50 m (139 %) > Control (120%) > 0 - 0.25 m (119 %) > 0.50 m - 0.75 m (79 %)

Fig. 31: Monthly variation in GBH of *Terminalia arjuna* seedlings under different water regimes.



Number of leaves in *Terminalia arjuna* was recorded during September 2008 to June 2009 only because after this period it was not possible to count the number of leaves accurately due to its high number. In June 2009, the maximum number was observed in 0.25 m– 0.50 m tank (1570), followed by 0.50 m – 0.75 m tank (1135), 0 – 0.25 m tank (833) and Control tank (383). Maximum increase was found in 0.25 m - 0.50 m tank (11.36 times), followed by Control tank (8.51 times), 0.50 m - 0.75 m (7.56 times) and 0 - 0.25 m (5.66 times), during the observation period.

Fig. 32: Monthly variation in number of leaves of *Terminalia arjuna* seedlings under different water regimes.



The growth data of the seedlings of the selected tropical forest tree species planted in lysimeters exhibited variation in height, basal girth and GBH. Species variation and variation due to different water regimes was observed. Most of the species performed better under water logged conditions compared to control, which could be due to their high water requirement. *Eucalyptus* hybrid, *Pongamia pinnata, Albizia procera* and *Terminalia arjuna* exhibited their maximum growth values under 0-0.25 m water regime, while *Dalbergia sissoo* and *Albizia lebbek* performed better under 0.50 m-0.75 m water level. Least growth under control conditions was found in *Eucalyptus* hybrid, *Pongamia pinnata*, *Dalbergia sissoo* and *Terminalia arjuna*. When species variation was observed, maximum height was found in *Albizia procera*, followed by *Albizia lebbek* and *Eucalyptus* hybrid; maximum basal girth was observed in *Terminalia arjuna*, followed by *Dalbergia sissoo* and *Albizia lebbek*. Similarly, maximum GBH was recorded for *Dalbergia sissoo* followed by *Albizia procera*.

Annual increment in height of the selected species from 2010 to 2011 under 0 - 0.25 m water level was found maximum in *E.* hybrid (73.13%), followed by *A. procera* (57.89%) and *A. nilotica* (36.84%), while radial increment during this period was observed maximum in *A. procera*, followed by *D. sissoo* and *P. pinnata*. Under 0.25 m - 0.50 m water regime, maximum height increased in *A. procera* (73.54%), followed by *T. arjuna* (41.03%) and maximum girth increased in *P. pinnata*, followed by *T. arjuna*. Similarly, under 0.50 m - 0.75 m water level, maximum increase in height was recorded in *A. procera,* followed by *A. nilotica* and *D. sissoo* and maximum increase in girth was observed in *A. procera*, followed by *P. pinnata* and *A. lebbek.*

Transpirational response of tree species under different water regimes

Transpiration rate was recorded using CID make CO_2 gas analyzer (Model 340). The instrument was warmed up for 20 minutes before using to measure the transpiration rate. The leaf of the seedling of tree species was put into the chamber before start the measurement so that the leaf has time to acclimatize to the leaf chamber conditions and the instrument has time to react to the changes the leaf causes. After the initial warm up time, the flow rate was maintained between 0.25 litre per minute (lpm) – 0.30 lpm. Transpiration rate (E) (milimol/m^2/s) was calculated with following formula :

$$E = \frac{e_0 - e_i}{P - e_0} \times W \times 10^3$$

Where, e_0 (e_i) – outlet (inlet) water vapour (bar)

P – Atmosphere pressure (bar)

W – Mass flow rate per leaf area (mol/m^2/s)

Diurnal and species variation of the selected tree species was observed in the seedlings planted under different water regimes and controlled conditions from 6 AM till 8 PM. Peak transpiration was observed at 12 hour during the period for most of the species, but for some species the peak period shifted to 11 hour or 13 hour (Figs. 33 to 39).

Species wise rate of transpiration was found maximum in *E. hybrid*, followed by *P. pinnata* and *T. arjuna* in control treatments. Minimum transpiration rate was observed in *A. nilotica* (Fig. 40). Diurnal variation in transpiration rate was found in the species under test. Peak transpiration was observed at 12 hour during the period for most of the species, but for some species the peak period shifted to 11 hour or 13 hour. Maximum rate was observed in 0 - 0.25 m water level, followed by 0.25 m - 0.50 m, 0.50 m - 0.75 m and control. The results showed that with the increase in water logging, transpiration rate increased in all seven species. Peak transpiration rate in control treatments varied from 1.05 to 2.69 mmol H_2O m^{-2} s^{-1}, the maximum values recorded for *E. hybrid* and minimum for *A. nilotica*. Peak transpiration rate in 0 - 0.25 m water level was found maximum in *P. pinnata* (3.75 mmol H_2O m^{-2} s^{-1}) and minimum in *A. nilotica* (2.17 mmol H_2O m^{-2} s^{-1}). Peak transpiration rate in 0.25 m - 0.50 m water logging was observed maximum for *E. hybrid* (3.03 mmol H_2O m^{-2} s^{-1}) and minimum for *T. arjuna* (1.77 mmol H_2O m^{-2} s^{-1}), while in 0.50 m - 0.75 m water regime, it was recorded maximum in *D. sissoo* (2.12 mmol H_2O m^{-2} s^{-1}) and minimum in *A. nilotica* (1.13 mmol H_2O m^{-2} s^{-1}).

Few studies have been conducted on the effect of water logging on the physiological processes of plants. Moezel *et al.* (1989) reported that long term tolerance of tree species to water logging may be related to the degree to which transpiration and other physiological functions are related. Morphological changes are usually preceded by changes in stomatal aperture, photosynthesis and transpiration. He observed low transpiration rate in *E. camaldulensis* in saline and water logged seedlings compared to water logged seedlings under green house condition. Planting of *E. camaldulensis* in highly saline, water logged areas would adversely affect the physiological processes and ultimately growth and biomass. As indicated by the observations of present experiment, Moezel *et al.* (1989) also suggested that *E. camaldulensis* would be more suitable species for planting in areas subjected to water logging by fresh areas.

Photo 7 : Measuring transpiration rate of seedlings planted in lysimeters by CO_2 has analyser

Fig. 33: Diurnal variation in transpiration rate of *E.* hybrid under different water regimes

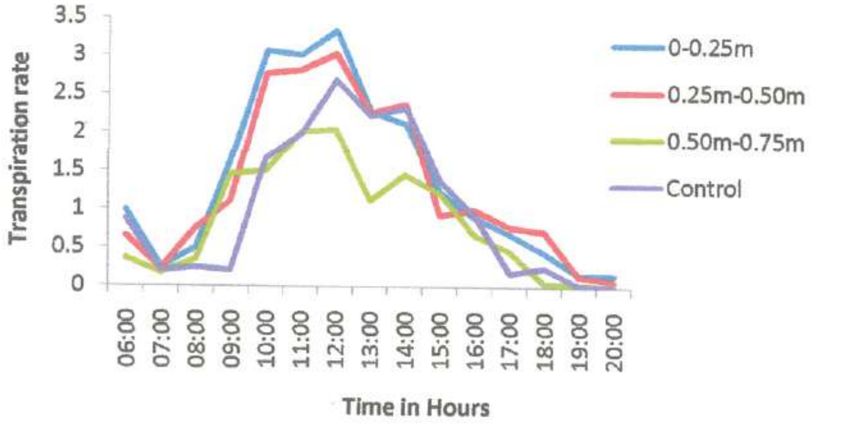
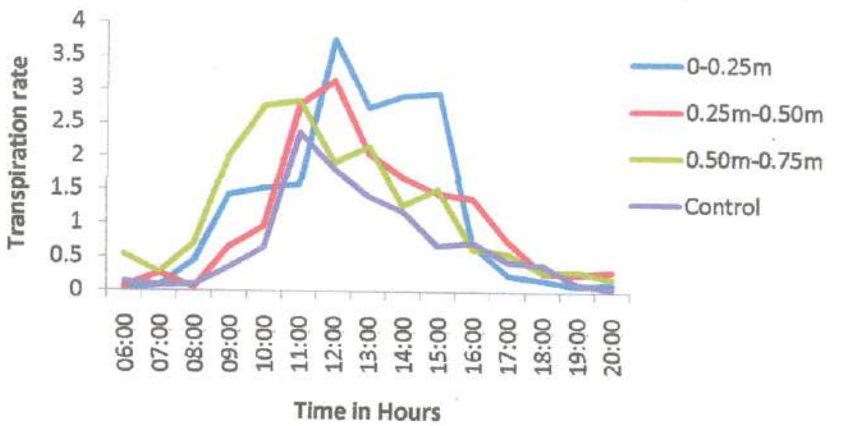


Fig. 34: Diurnal variation in transpiration rate of *P. pinnata* under different water regimes



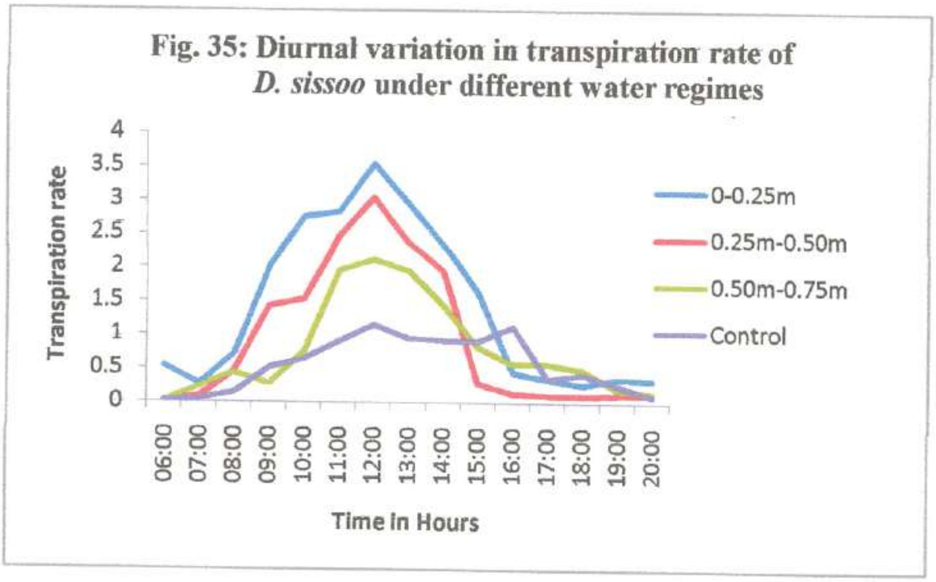


Fig. 35: Diurnal variation in transpiration rate of D. sissoo under different water regimes
Transpiration rate
4
3.5
3
2.5
2
1.5
1
0.5
0
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
Time in Hours
0-0.25m
0.25m-0.50m
0.50m-0.75m
Control

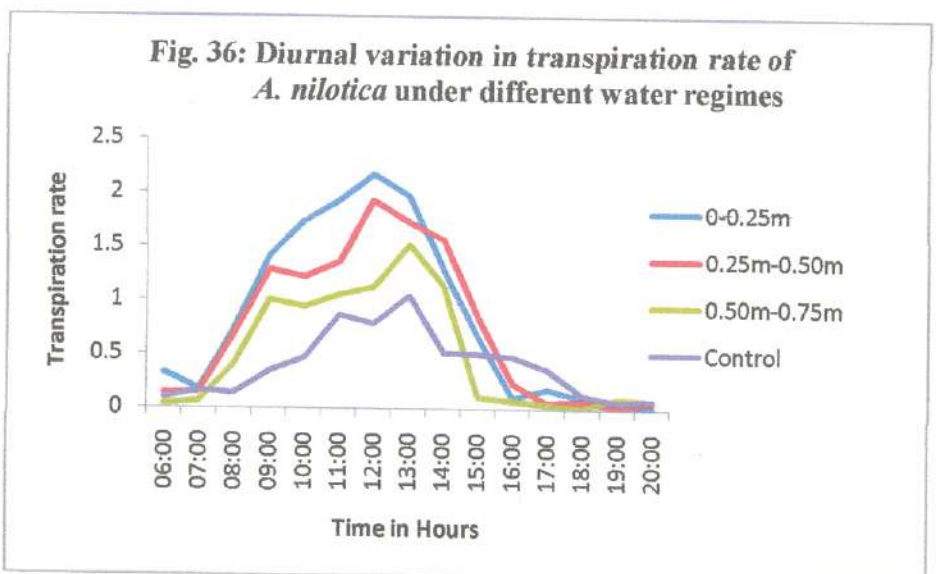


Fig. 36: Diurnal variation in transpiration rate of A. nilotica under different water regimes
Transpiration rate
2.5
2
1.5
1
0.5
0
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
Time in Hours
0-0.25m
0.25m-0.50m
0.50m-0.75m
Control

Fig. 37: Diurnal variation in transpiration rate of *A. procera* under different water regimes

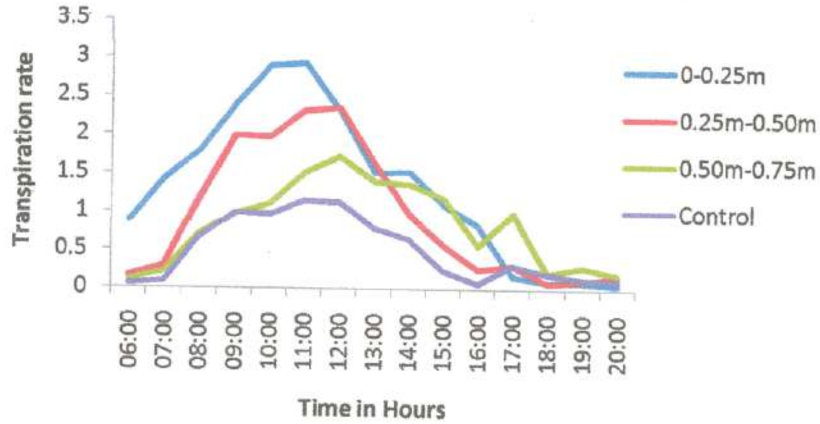


Fig. 38: Diurnal variation in transpiration rate of *A. lebbek* under different water regimes

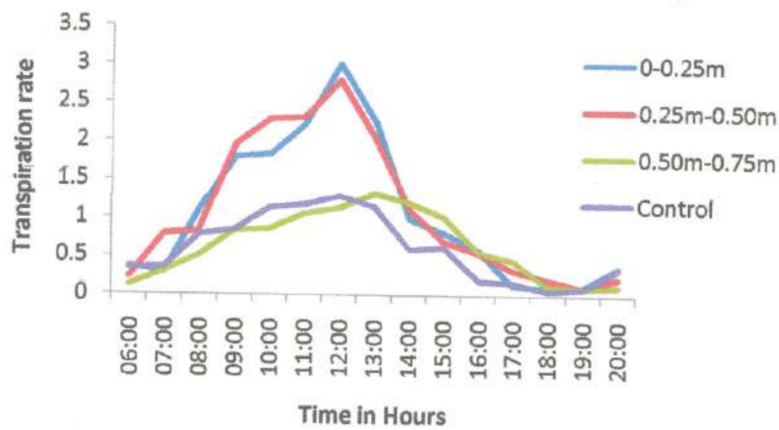


Fig. 39: Diurnal variation in transpiration rate of *T. arjuna* under different water regimes

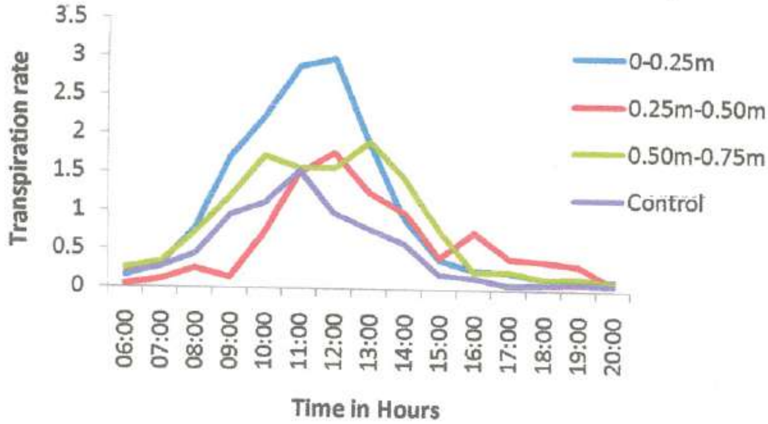
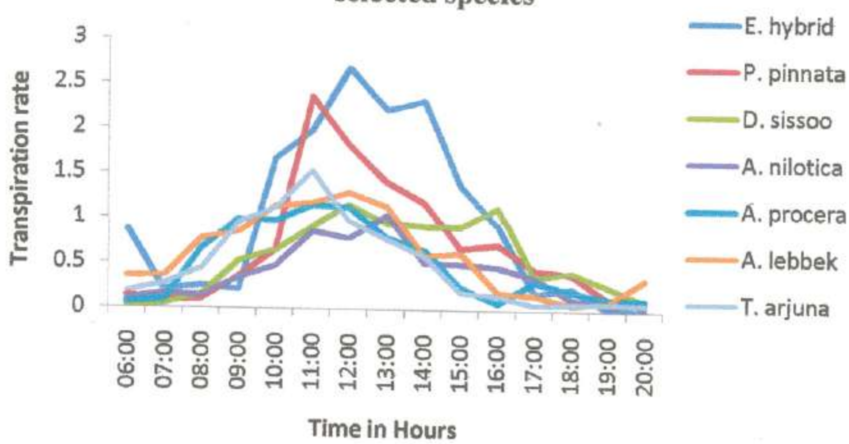


Fig. 40: Species variation in transpiration rate of selected species



Water use by tree species under different water regimes

Species and seasonal variation in water use by the selected seven tree species under 3 water regimes was observed in lysimeters. The species under study showed diverse response to water logging with respect to water use on per day basis. Per day water use by the species was significantly affected by the depth of water logging in lysimetric tanks. Different tree species responded differently to different treatments of water logging. With the increase in age of tree species, above and below ground biomass also increased, which affected the water use on daily basis. Prolonged water logging in the tanks also had influence in water use by the tree species.

Maximum water use on per day basis was found in *Eucalyptus* hybrid, followed by *Pongamia pinnata* and *Albizia lebbek*, while minimum water use was observed in *Acacia nilotica* under different depths of water logging in lysimeters (Figs. 44 to 50). As far as depth of water logging is concerned, maximum water use was found in 0 - 0.25 m, followed by 0.25 m - 0.50 m and 0.50 m – 0.75 m water levels for all the selected tree species (Figs. 41 to 43). Water use by the species decreased with increase in depth of water logging, which could be due to more surface area of roots in contact with soil water. Although, lysimetric tanks were covered by polythene sheet to avoid water loss from the surface of the soil through evaporation, but partial water loss through evaporation cannot be avoided, which could be maximum in 0 - 0.25 m, followed by 0.25 m- 0.50 m and 0.50 m – 0.75 m water levels.

Significant monthly variation in water use was observed in the species under test, which was directly related to the climatic conditions. A depression in water use by all the species was observed during July to September, which could be due to high rainfall (July – 442 mm, August – 472 mm and September – 511 mm) and less Sun shine hours during these months. High water use by the selected species during April to June was due to high maximum and minimum temperature during these months (Appendix B, Table B1).

In *Eucalyptus* hybrid, water use under 0 - 0.25 m water regime varied from 29 to 64 litres/day, while it varied from 31 to 61 litres/day under 0.25 m - 0.50 m and 27 to 58 litres/day under 0.50 m – 0.75 m regime.

Fig. 41: Monthly variation in average water use by the selected tree species under 0-0.25m water regime

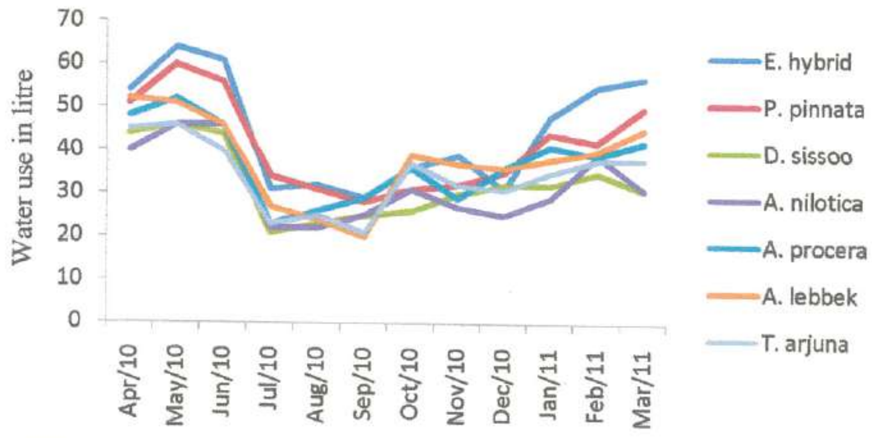


Fig. 42: Monthly variation in average water use by the selected tree species under 0.25-0.50m water regime

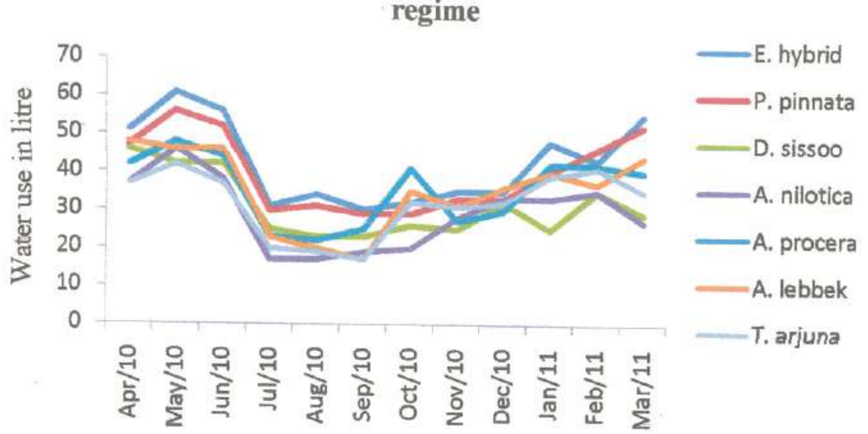


Fig. 43: Monthly variation in average water use by the selected tree species under 0.50-0.75 water regime

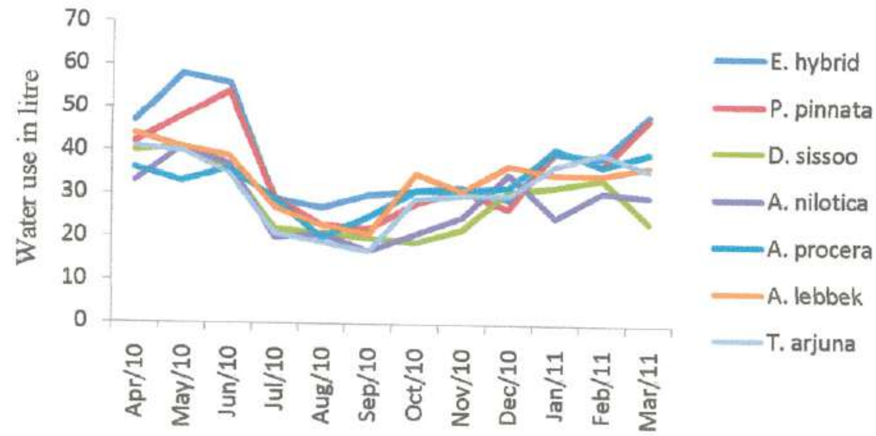


Fig. 44: Monthly variation in average water use by *E.* hybrid under different water regimes

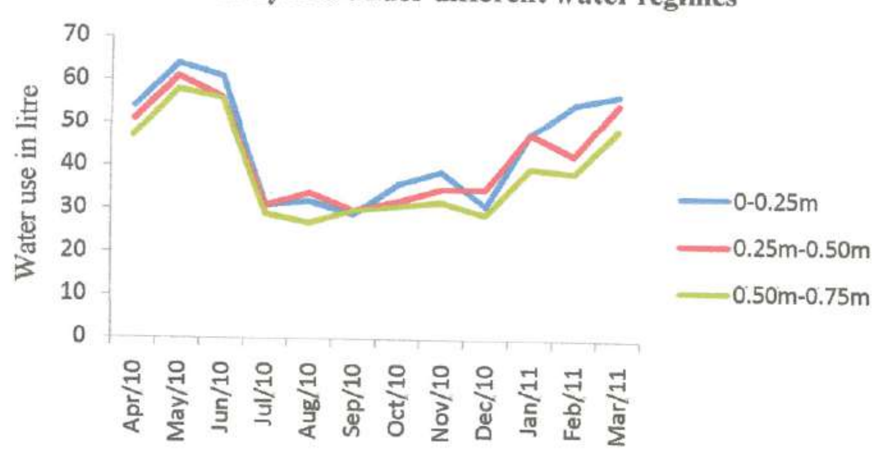


Fig. 45: Monthly variation in average water use by *P. pinnata* under different water regimes

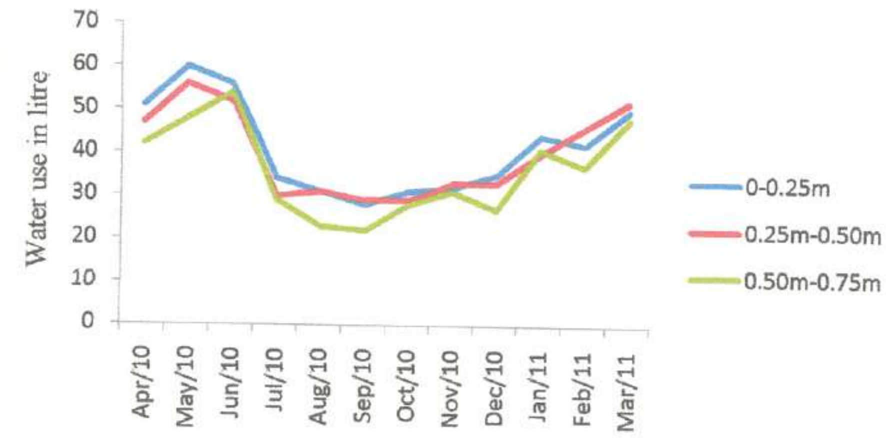
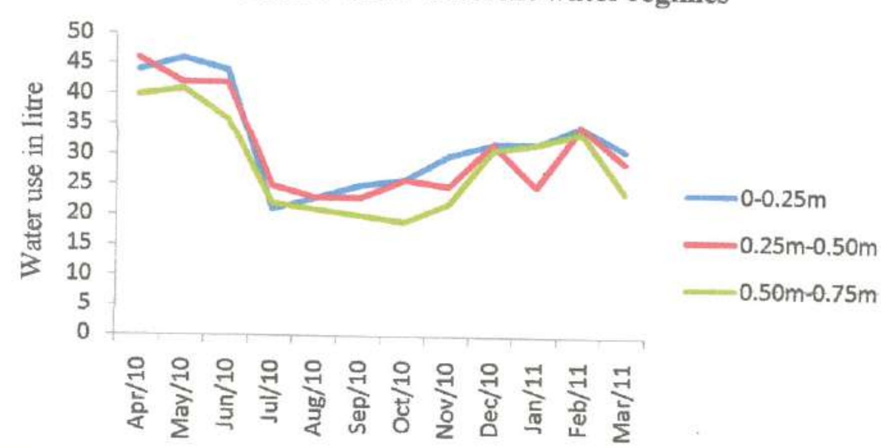


Fig. 46: Monthly variation in average water use by *D. sissoo* under different water regimes



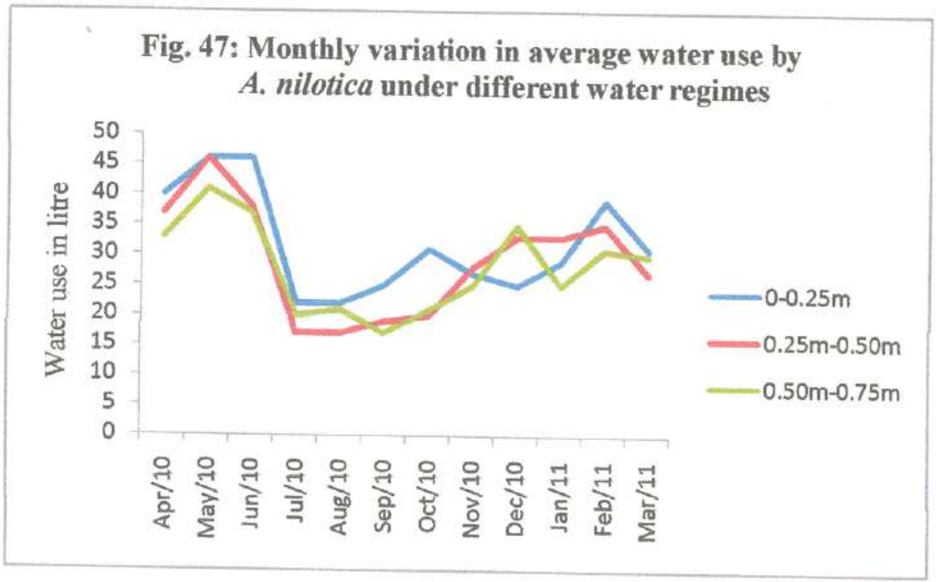


Fig. 47: Monthly variation in average water use by
A. nilotica under different water regimes
Water use in litre
50
45
40
35
30
25
20
15
10
5
0
Apr/10
May/10
Jun/10
Jul/10
Aug/10
Sep/10
Oct/10
Nov/10
Dec/10
Jan/11
Feb/11
Mar/11
0-0.25m
0.25m-0.50m
0.50m-0.75m

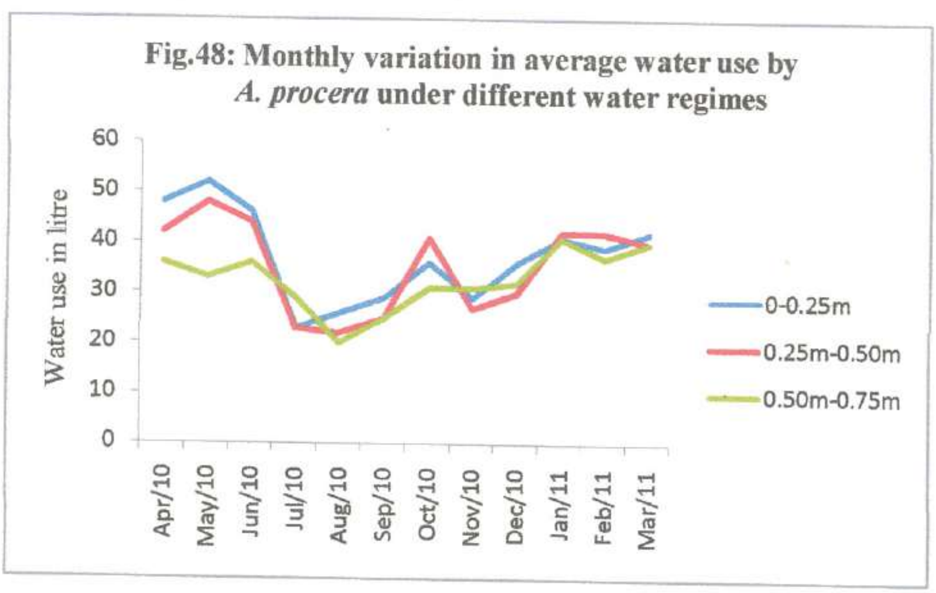


Fig.48: Monthly variation in average water use by
A. procera under different water regimes
Water use in litre
60
50
40
30
20
10
0
Apr/10
May/10
Jun/10
Jul/10
Aug/10
Sep/10
Oct/10
Nov/10
Dec/10
Jan/11
Feb/11
Mar/11
0-0.25m
0.25m-0.50m
0.50m-0.75m

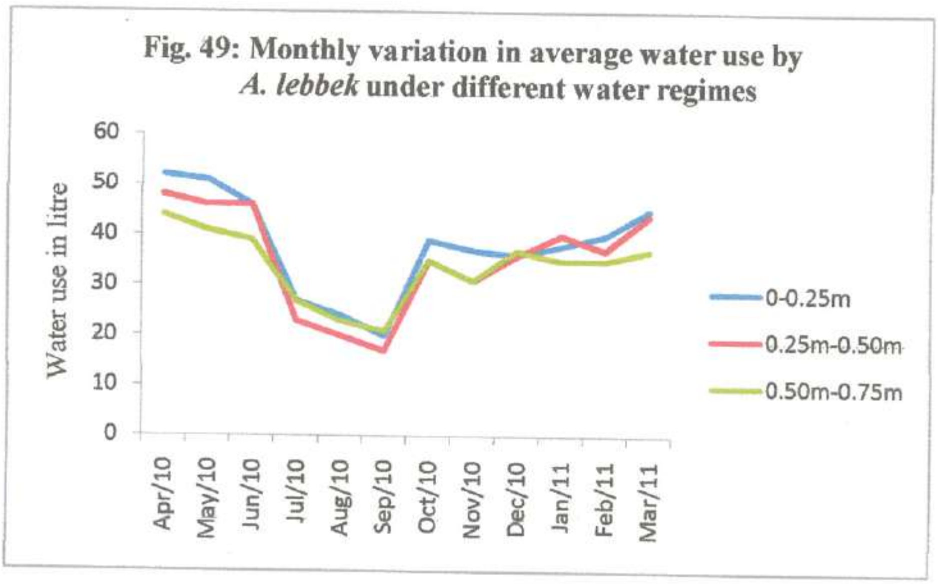


Fig. 49: Monthly variation in average water use by
A. lebbek under different water regimes
Water use in litre
60
50
40
30
20
10
0
Apr/10
May/10
Jun/10
Jul/10
Aug/10
Sep/10
Oct/10
Nov/10
Dec/10
Jan/11
Feb/11
Mar/11
0-0.25m
0.25m-0.50m
0.50m-0.75m

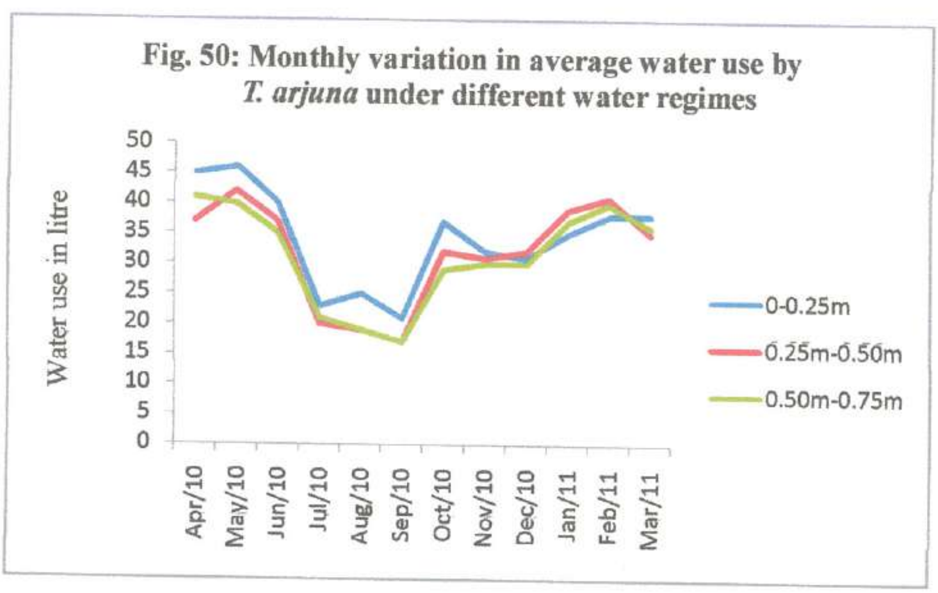


Fig. 50: Monthly variation in average water use by
T. arjuna under different water regimes
Water use in litre
50
45
40
35
30
25
20
15
10
5
0
Apr/10
May/10
Jun/10
Jul/10
Aug/10
Sep/10
Oct/10
Nov/10
Dec/10
Jan/11
Feb/11
Mar/11
0-0.25m
0.25m-0.50m
0.50m-0.75m

Table 7 : Average water use (litre/day) by tree species under different water regimes in lysimeters.

Month	Water level (m)		
	0 - 0.25	0.25 – 0.50	0.50 – 0.75
***Eucalyptus* hybrid**			
April 2010	54	51	47
May 2010	64	61	58
June 2010	61	56	56
July 2010	31	31	29
August 2010	32	34	27
September 2010	29	30	30
October 2010	36	32	31
November 2010	39	35	32
December 2010	31	35	29
January 2011	48	48	40
February 2011	55	43	39
March 2011	57	55	49
Average	44.75	42.58	38.92
Pongamia pinnata			
April 2010	51	47	42
May 2010	60	56	48
June 2010	56	52	54
July 2010	34	30	29
August 2010	31	31	23
September 2010	28	29	22
October 2010	31	29	28
November 2010	32	33	31
December 2010	35	33	27
January 2011	44	40	41
February 2011	42	46	37
March 2011	50	52	48
Average	41.17	39.83	35.83
Dalbergia sissoo			
April 2010	44	46	40
May 2010	46	42	41
June 2010	44	42	36
July 2010	21	25	22
August 2010	23	23	21
September 2010	25	23	20
October 2010	26	26	19
November 2010	30	25	22
December 2010	32	32	31
January 2011	32	25	32

February 2011	35	35	34
March 2011	31	29	24
Average	32.42	31.08	28.50
	Acacia nilotica		
April 2010	40	37	33
May 2010	46	46	41
June 2010	46	38	37
July 2010	22	17	20
August 2010	22	17	21
September 2010	25	19	17
October 2010	31	20	21
November 2010	27	28	25
December 2010	25	33	35
January 2011	29	33	25
February 2011	39	35	31
March 2011	31	27	30
Average	31.92	29.17	28.00
	Albizia procera		
April 2010	48	42	36
May 2010	52	48	33
June 2010	46	44	36
July 2010	23	23	29
August 2010	26	22	20
September 2010	29	25	25
October 2010	36	41	31
November 2010	29	27	31
December 2010	36	30	32
January 2011	41	42	41
February 2011	39	42	37
March 2011	42	40	40
Average	37.25	35.50	32.58
	Albizia lebbek		
April 2010	52	48	44
May 2010	51	46	41
June 2010	46	46	39
July 2010	27	23	27
August 2010	24	20	23
September 2010	20	17	21
October 2010	39	35	35
November 2010	37	31	31
December 2010	36	36	37
January 2011	38	40	35
February 2011	40	37	35
March 2011	45	44	37

Average	37.92	35.25	33.75
Terminalia arjuna			
April 2010	45	37	41
May 2010	46	42	40
June 2010	40	37	35
July 2010	23	20	21
August 2010	25	19	19
September 2010	21	17	17
October 2010	37	32	29
November 2010	32	31	30
December 2010	31	32	30
January 2011	35	39	37
February 2011	38	41	40
March 2011	38	35	36
Average	34.25	31.83	31.25
For Species			
$CD_{0.05}$	1.2462		
$CD_{0.01}$	1.6466		
SE$\pm$	0.6300		
For Water level			
$CD_{0.05}$	0.8158		
$CD_{0.01}$	1.0779		
SE$\pm$	0.4124		
For Months			
$CD_{0.05}$	1.6317		
$CD_{0.01}$	2.1559		
SE$\pm$	0.8249		

Evaluation of species for biodrainage along Left Bank Canal of Bargi Command Area

(i) Growth characteristics of planted trees

The seeds from phenotypically superior trees of *Albizia lebbek* (Kala siris), *Albizia procera* (Safed siris), *Acacia nilotica* (Babul), *Dalbergia sissoo* (Shisham), *Terminalia arjuna* (Arjun), *Pongamia pinnata* (Karanj), *Ailanthus excelsa* (Maha neem), *Eucalyptus* species (Nilgiri) and *Jatropha curcas* (Ratanjyot) were collected in 2006. Bulbils from *Agave Americana* (Agave) were also collected. Seeds of FRI-4 and FRI-5 hybrids of *Eucalyptus* were procured from Forest Research Institute, Dehradun. The seedlings were raised in Modern Technical Nursery of Tropical Forest Research Institute, Jabalpur and maintained for one year in polybags to strengthen them for plantation along canal command area.

A plantation of about 10 hectare (ha) area was raised along Left Bank Canal (LBC) of Bargi Command Area, Jabalpur in the rainy season of 2007. Cattle Protection Trench (CPT) of standard size was also dug to protect the plantation sites from cattle. The planted species included *Pongamia pinnata, Acacia nilotica, Albizia lebbek, Albizia procera, Ailanthus excelsa, Eucalyptus* hybrid (Jabalpur), *Eucalyptus* hybrid (FRI-4 and FRI-5), *Terminalia arjuna* and *Dalbergia sissoo*. *Eucalyptus* hybrid and *Terminalia arjuna* were planted at Dabhola site; *Pongamia pinnata* and *Acacia nilotica* were planted at Jamuniya and *Albizia lebbek, Albizia procera, Ailanthus excelsa, Eucalyptus* hybrid (Jabalpur), *Eucalyptus* hybrid (FRI-4 and FRI-5), *Terminalia arjuna* and *Dalbergia sissoo* were planted at Somti site. *Ailanthus excelsa* did not perform well, hence partly replaced by *Albizia procera*. All species, except *Eucalyptus hybrid* (FRI-4 and FRI-5), were planted at 2 m x 2 m spacing. *Eucalyptus* hybrid (FRI-4 and FRI-5) were planted at both 2 m x 2 m and 1 m x 1 m spacing. *Jatropha curcas* and *Agave americana* were planted surrounding the plantation sites for biofencing. Growth parameters including height (m) and girth (cm) of the planted seedlings were measured since September 2007 till June 2011 on quarterly basis.

Eucalyptus belonging to family Myrtaceae, sub-family Myrtoideae is an exotic tree species. Over the last twenty years, large-scale planting of *Eucalyptus*, as a fast growing exotic, has occurred in India, as part of a drive to reforest the subcontinent, and create an adequate supply of fuel and timber for rural communities under the augur of 'social forestry'. The large plantations of *Eucalyptus* have given rise to a debate, particularly between environmentalists and foresters. Foresters maintain that *Eucalyptus* can help meet increasing wood demands from dwindling natural forests, supplying local communities and industry (Shyam Sunder and Parameswarappa, 1989). Environmentalists, however, oppose to *Eucalyptus* due to perceived ecological hazards. In the present study, *Eucalyptus* seedlings were planted along the canal in between Jamuniya and Somti villages at low lying areas. This area remains water logged most of the times when the canal runs. *Eucalyptus* was also planted in the field of a farmer at village Dabhola, which was again a low lying area. Near Jamuniya village, *Eucalyptus* was planted with the spacing of 2 m x 2 m and 1 m x 1 m. Initially, *Eucalyptus* planted with both spacing grew together but after about 2 years the growth of *Eucalyptus* in 1m x 1m spacing restricted to some extent because of competition for nutrients and overlapping of canopy. The seedlings raised from the seeds collected from Jabalpur and nearby areas showed poor performance in comparison to seedlings raised from the seeds of FRI-4 and FRI-5 clones, which could be due to their genetic superiority over other one. Infestation of invasive insect, *Leptocybe invasa* severely deformed the Jabalpur seeds raised *Eucalyptus* seedlings and attacked leaves, petioles and stem. Few severely infested seedlings were removed to control spread of this insect to non-infested seedlings. The seedlings raised from FRI-4 and FRI-5 clones were rarely attacked and were found resistant for this insect. Average height of *Eucalyptus* seedlings increased from 1.05 m to 4.53 m during this period, which exhibited the increase of 331%. Girth increased from 1.98 cm to 22.48 cm and showed the increase of 1035% (Table 8 and Figs. 51 & 52).

Pongamia pinnata belonging to family Leguminosae, subfamily Papilionoideae, is a medium sized nitrogen fixing tree species, which are normally planted along the highways, roads and canals to stop soil erosion. In the present study, its seedlings were planted near Jamuniya village on the land with very shallow soil. The actual soil was used to construct the canal and unfertile land filled with boulders was left along the canal. Initially the growth of *Pongamia pinnata* was slow, but after establishment of roots in the soil, the growth rapidly increased. Average height of *Pongamia pinnata* was recorded to be 0.35 m at the time of plantation, which increased to 4.22 m in July 2011. An increase of about 11 times was observed in the height of *Pongamia pinnata* during 45 months period after its plantation at village Jamuniya. Similarly, average girth of *Pongamia pinnata* increased from 2.10 cm to 25.15 cm during this period and showed about 11 times increase (Table 9 and Figs. 53 & 54).

Dalbergia sissoo Roxb. (Leguminosae, subfamily Papilionoideae) is a medium to large deciduous timber and nitrogen fixing tree species. Due to the high fodder value of its leaves, it is the preferred tree species for animals/cattle and the protection of its plantation from the village cattle is difficult. *Dalbergia sissoo* seedlings were planted near Somti village at low lying areas, where the problem of water logging was severe. The growth of *Dalbergia sissoo* was found slower than *Eucalyptus* and *Pongamia pinnata* which attained the average height of 2.85 m in July 2011. Average girth of *Dalbergia sissoo* increased from 1.91 cm (at the time of plantation) to 31.90 cm and observed the 16 fold increase (Table 10 and Figs. 55 & 56).

Acacia nilotica belonging to family Fabaceae is a medium size tree with Branches spreading, forming a dense flat or rounded crown. In Indian Subcontinent, this species is found in India, Pakistan and Nepal. This tree species has been highly valued as fodder and fuel wood in India. In the present study, its seedlings were planted near Jamuniya village on the land with very shallow soil. The actual soil was used to construct the canal and unfertile land filled with boulders was left along the canal. Initially the growth of *Acacia nilotica* was slow, but after establishment of roots in the soil, the growth rapidly increased. Height of this tree increased from 0.51 m in September 2007 (At the time of plantation) to 3.45 m in June 2011, which showed 5.76 times increase. Girth increased from 0.77 cm to 15.86 cm showing 19.60 times increase during this period (Table 11 and Figs. 57 & 58).

Albizia procera belonging to family Fabaceae, subfamily Mimosoideae is a large, fast growing nitrogen fixing tree species. This tree species is very useful for reforestation and agroforestry activities and provides wood for a variety of purposes, nutritious fodder for livestock and shade for tea plantations. In India, *Albizia procera* is dominant to co-dominant in mixed deciduous forest or found as scattered individuals or in small groups in savanna woodlands (Benthall 1933, Bor 1953). In the present study, this tree species was planted in between Jamuniya and Somti villages, where the soil was shallow and underground water level was low in comparison to other sites. At the time of its plantation (September 2007), the average height of *Albizia procera* seedlings was 0.67 m which increased to 1.15 m in March 2008. Die back occurred in *Albizia procera* plantation. In June 2007, new sprouting started from 0.55 m height, then gradually increased and reached to 2.35 m in June 2011. Where sufficient moisture is not available, the plants die-back during the first and second year in summers, and re-sprout in the following rainy season. Girth increased from 0.62 cm to 21.23 cm during study period, showing about 33 fold increase (Table 12 and Figs. 59 & 60).

Albizia lebbek, commonly known as Kala Siris, belonging to family Fabaceae, subfamily - Mimosoideae is a nitrogen fixing deciduous tree species. This tree is valued for shade, quality hardwood, fuel wood and forage. It prefers well drained soils and is not adapted to heavy clay or water logged soils. At the time of its plantation, the average height of *Albizia lebbek* seedlings was 0.48 m which increased to 0.92 m in March 2008. Die back occurred in *Albizia lebbek* plantation. In June 2007, new sprouting started from 0.36 m height, then gradually increased and reached to 1.96 m in June 2011. Girth continuously increased from its plantation (1.55 cm) till last observation under study period (18.98 cm) (Table 13 and Figs. 61 & 62).

Terminalia arjuna belonging to family Combretaceae, is a large size deciduous tree attaining height of about 20 - 25 m and having wide canopy (Biswas *et al.*, 2011). This is a slow growing tree and is commonly found along rivers, streams, nallahs throughout the country. It is used for disorders of the heart and blood vessels (cardiovascular disease), high blood pressure and high cholesterol. It is also used for earaches, dysentery and diseases of the urinary tract. In the present study, *Terminalia* *arjuna* seedlings were planted along the nallah crossing below the canal, because this tree species can survive under half submergence conditions for long periods. The growth of this tree species was found slow reaching the height of 2.19 m and attaining girth of 13.06 cm in June 2011. Seedlings of this species survived even under submergence conditions especially during rainy season, when overflow in the nallah occurred (Table 14 and Figs. 63 & 64).

In June 2011, maximum height was attained by *E.* hybrid (4.53 m), followed by *P. pinnata* (4.22 m) and *A. nilotica* (3. 45 m), while minimum height was recorded in *A. lebbek* (1.96 m). During this period, maximum girth was found in *D. sissoo* (31.90 cm), followed by *P. pinnata* (25.15 cm) and *E.* hybrid (22.48 cm), while minimum radial increment was observed in *T. arjuna* (13.06 cm). The results partially corroborate the growth characteristics of similar tree species planted in lysimetric tanks, where during this period maximum increase in height was found in *E.* hybrid, followed by *A. procera* and *A. nilotica* under 0 – 0.25 m water regime.

Photo 8: *Jatropha curcas* planted surrounding plantation areas for bio-fencing.

Photo 9: Plantation areas protected by digging Cattle Protection Trench

Photo 10 : *Agave americana* planted surrounding plantation areas for bio-fencing.

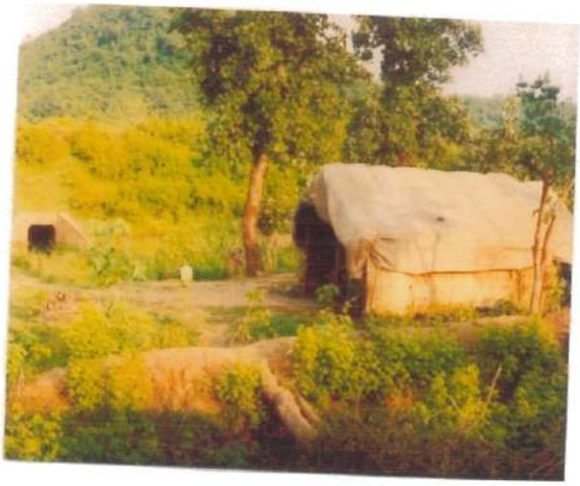


Photo 11 : Temporary hut for chowkidar constructed in plantation sites.

Photos 12 : Plantations of different tree species raised along left bank canal of Bargi command area.

Table 8: Growth characteristics of seedlings of *Eucalyptus* hybrid planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	1.05	1.98
2.	Dec. 2007	1.19	2.59
3.	March 2008	1.30	4.31
4.	June 2008	1.40	5.03
5.	Sept. 2008	1.63	7.02
6.	Dec. 2008	1.75	8.85
7.	March 2009	1.92	9.14
8.	June 2009	2.21	9.79
9.	Sept. 2009	2.26	10.92
10.	Dec.2009	2.49	12.15
11.	March 2010	2.56	13.97
12.	June 2010	2.62	15.35
13.	Sept. 2010	3.19	17.55
14.	Dec. 2010	3.92	19.18
15.	March 2011	4.01	19.56
16.	June 2011	4.53	22.48

Fig. 51: Height of *E.* hybrid seedlings

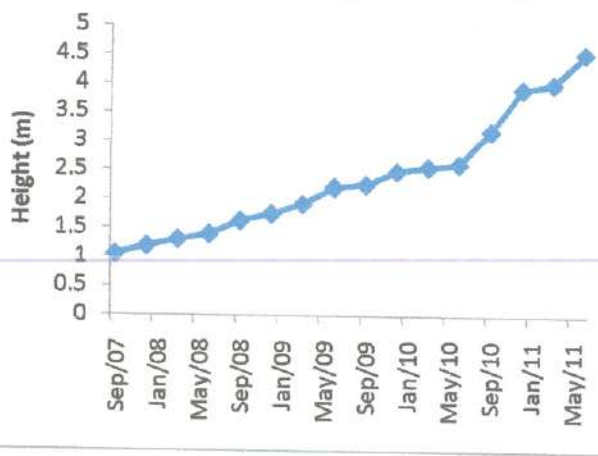


Fig. 52: Girth of *E.* hybrid seedlings

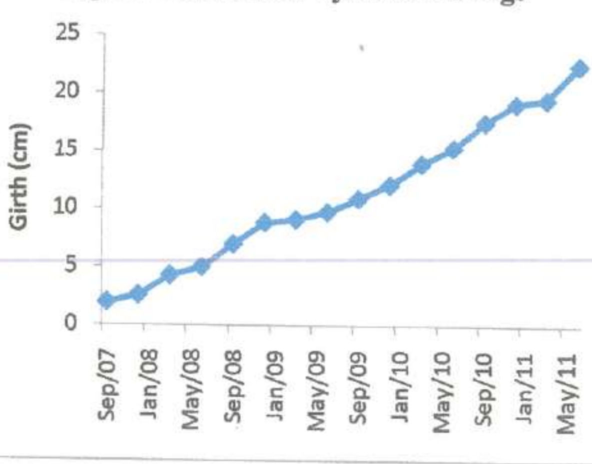


Table 9 : Growth characteristics of seedlings of *Pongamia pinnata* planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.35	2.10
2.	Dec. 2007	0.65	3.32
3.	March 2008	0.79	3.45
4.	June 2008	0.92	5.96
5.	Sept. 2008	1.25	8.62
6.	Dec. 2008	1.63	11.26
7.	March 2009	1.81	12.26
8.	June 2009	2.02	13.42
9.	Sept. 2009	2.65	15.26
10.	Dec.2009	3.09	17.46
11.	March 2010	3.21	18.52
12.	June 2010	3.43	19.73
13.	Sept. 2010	3.75	21.26
14.	Dec. 2010	4.10	23.82
15.	March 2011	4.16	24.65
16.	June 2011	4.22	25.15

Fig. 53: Height of *P. pinnata* seedlings

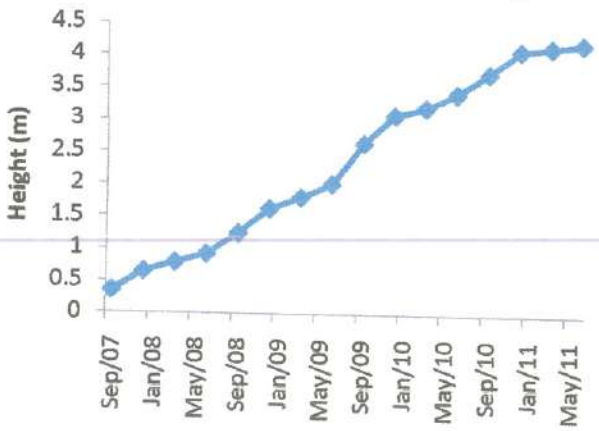


Fig. 54: Girth of *P. pinnata* seedlings

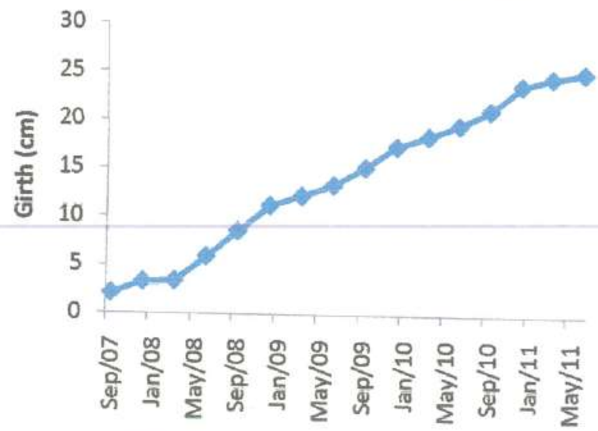


Table 10: Growth characteristics of seedlings of *Dalbergia sissoo* planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.10	1.91
2.	Dec. 2007	0.33	6.23
3.	March 2008	0.39	9.21
4.	June 2008	0.42	12.69
5.	Sept. 2008	0.61	15.08
6.	Dec. 2008	0.78	17.49
7.	March 2009	0.84	18.32
8.	June 2009	0.90	19.01
9.	Sept. 2009	1.12	21.9
10.	Dec.2009	1.26	23.1
11.	March 2010	1.31	24.5
12.	June 2010	1.35	25.8
13.	Sept. 2010	1.89	27.5
14.	Dec. 2010	2.60	29.8
15.	March 2011	2.72	30.1
16.	June 2011	2.85	31.9

Fig. 55: Height of *D. sissoo seedlings*

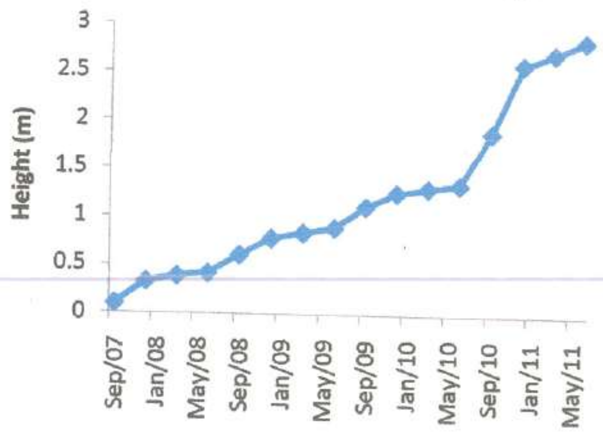


Fig. 56: Girth of *D. sissoo* seedlings

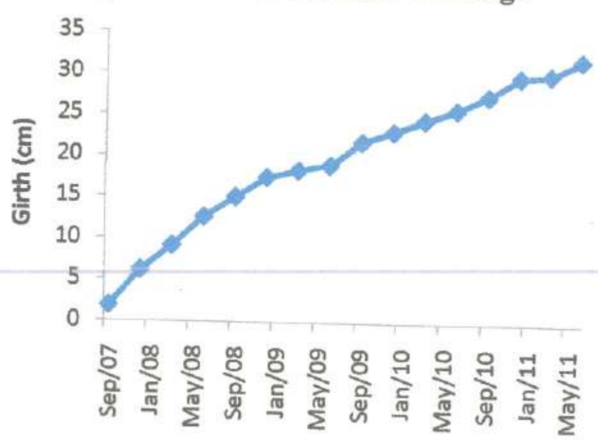


Table 11: Growth characteristics of seedlings of *Acacia nilotica* planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.51	0.77
2.	Dec. 2007	0.62	1.98
3.	March 2008	0.73	2.42
4.	June 2008	0.87	3.39
5.	Sept. 2008	1.04	4.02
6.	Dec. 2008	1.31	5.89
7.	March 2009	1.43	6.29
8.	June 2009	1.68	7.45
9.	Sept. 2009	2.08	8.06
10.	Dec.2009	2.46	9.98
11.	March 2010	2.59	10.59
12.	June 2010	2.72	11.37
13.	Sept. 2010	2.89	12.01
14.	Dec. 2010	3.21	13.89
15.	March 2011	3.32	14.23
16.	June 2011	3.45	15.86

Fig. 57: Height of *A. nilotica* seedlings

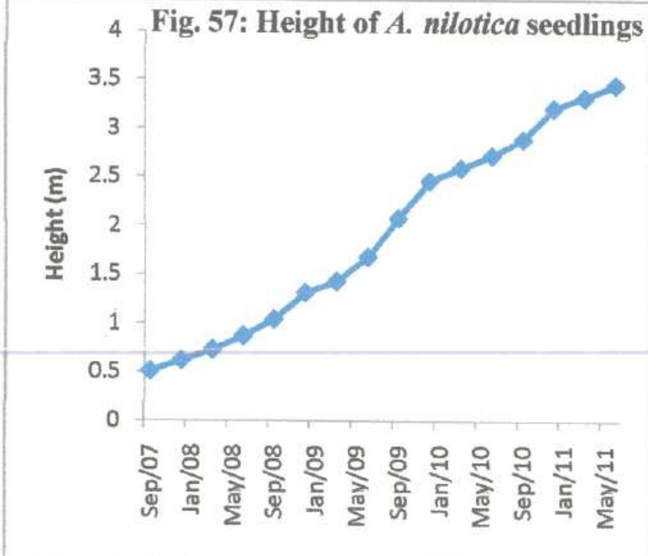


Fig. 58: Girth of *A. nilotica* seedlings

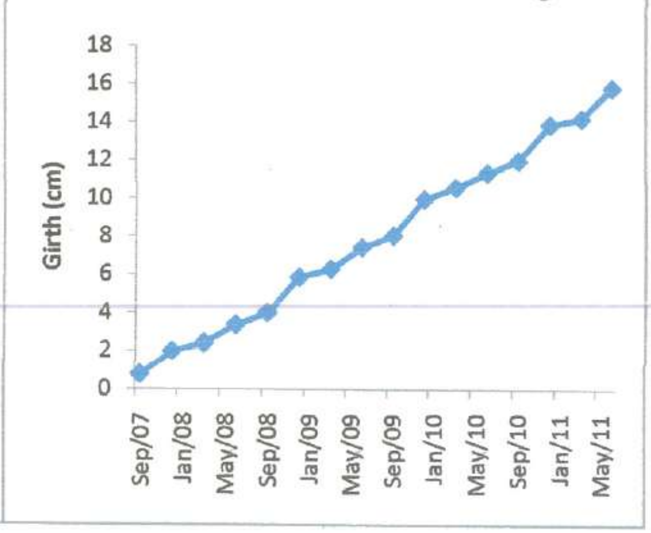


Table 12: Growth characteristics of seedlings of *Albizia procera* planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.67	0.62
2.	Dec. 2007	0.83	0.79
3.	March 2008	1.15	0.82
4.	June 2008	0.55	1.01
5.	Sept. 2008	0.83	1.97
6.	Dec. 2008	1.12	2.91
7.	March 2009	1.26	3.69
8.	June 2009	1.33	4.52
9.	Sept. 2009	1.59	7.09
10.	Dec.2009	1.88	10.76
11.	March 2010	1.99	12.45
12.	June 2010	2.09	15.89
13.	Sept. 2010	2.18	16.63
14.	Dec. 2010	2.29	18.23
15.	March 2011	2.31	20.61
16.	June 2011	2.35	21.23

Fig. 59: Height of *A. procera* seedlings

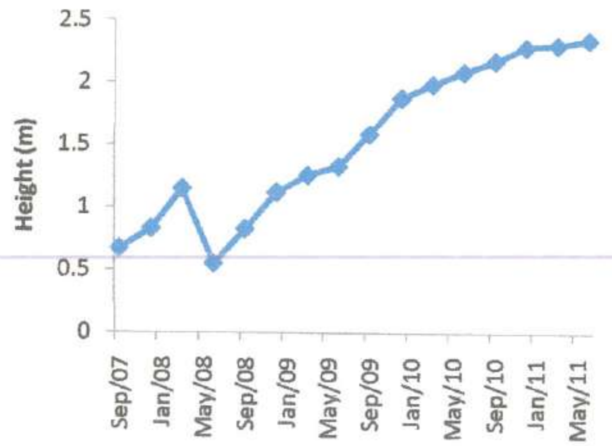


Fig. 60: Girth of *A. procera* seedlings

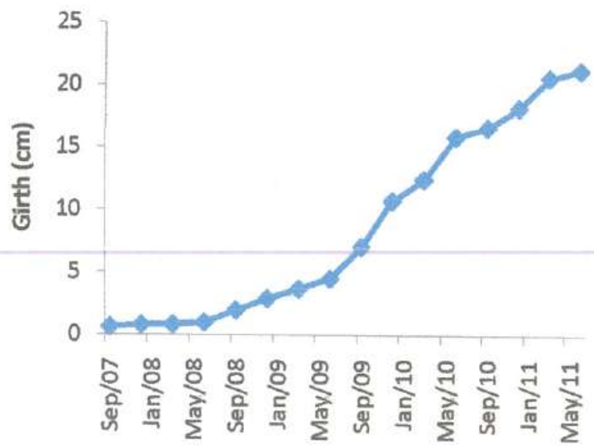


Table 13: Growth characteristics of seedlings of *Albizia lebbek* planted along left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.48	1.55
2.	Dec. 2007	0.63	2.04
3.	March 2008	0.92	2.51
4.	June 2008	0.36	3.38
5.	Sept. 2008	0.59	3.83
6.	Dec. 2008	0.87	4.23
7.	March 2009	0.99	5.67
8.	June 2009	1.17	6.91
9.	Sept. 2009	1.34	9.49
10.	Dec.2009	1.57	12.26
11.	March 2010	1.60	13.72
12.	June 2010	1.68	14.69
13.	Sept. 2010	1.73	16.52
14.	Dec. 2010	1.84	17.75
15.	March 2011	1.91	18.25
16.	June 2011	1.96	18.98

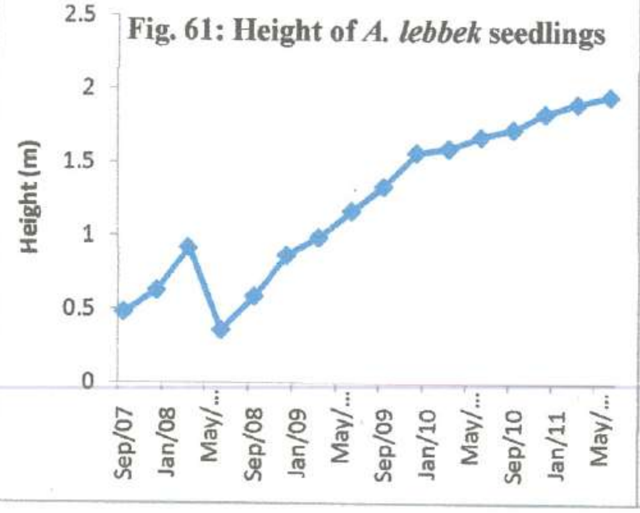


Fig. 61: Height of *A. lebbek* seedlings

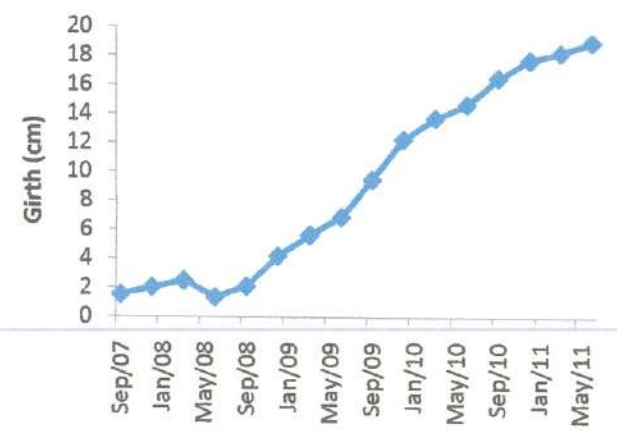


Fig. 62: Girth of *A. lebbek* seedlings

Table 14: Growth characteristics of seedlings of *Terminalia arjuna* planted in left bank canal of Bargi command area

S. No.	Month	Height (m)	Girth (cm)
1.	Sept. 2007	0.57	1.92
2.	Dec. 2007	0.78	2.68
3.	March 2008	0.82	3.01
4.	June 2008	0.87	3.49
5.	Sept. 2008	0.98	5.06
6.	Dec. 2008	1.15	7.11
7.	March 2009	1.20	8.24
8.	June 2009	1.24	8.69
9.	Sept. 2009	1.46	9.35
10.	Dec.2009	1.69	10.03
11.	March 2010	1.71	10.19
12.	June 2010	1.75	10.67
13.	Sept. 2010	1.94	11.89
14.	Dec. 2010	2.09	12.56
15.	March 2011	2.11	12.91
16.	June 2011	2.19	13.06

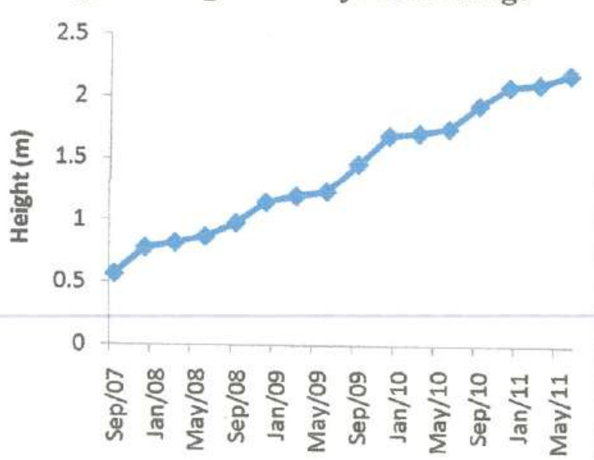


Fig. 63: Height of *T. arjuna* seedlings

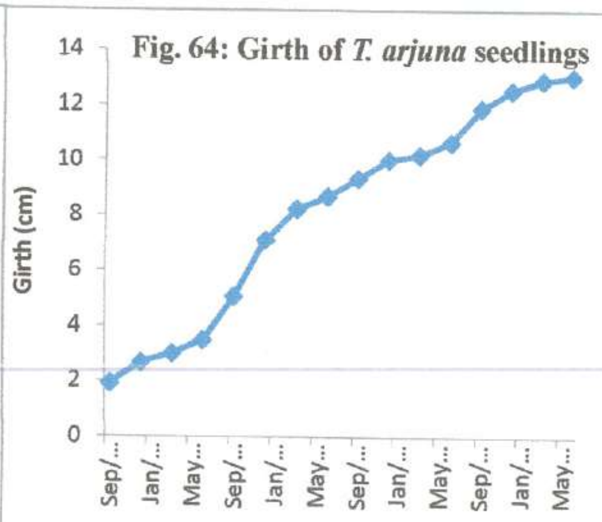


Fig. 64: Girth of *T. arjuna* seedlings

(ii) Biomass studies

Among the seven tree species planted along left bank canal of Bargi command area, the highest biomass was found in *E.* hybrid (50.91 kg), followed by *P. pinnata* (20.24 kg) and *D. sissoo* (16.09 kg) (Table 15). Minimum biomass was observed for *A. lebbek* (13.16 kg) and *A. nilotica* (13.20 kg), but these species were found to have maximum root : shoot ratio among the selected species (Table 16). The biomass of *E.* hybrid was recorded to be about 4 times in comparison to *A. lebbek* and *A. nilotica*, while the biomass of *P. pinnata* was recorded to be 1.5 times as compared to these species. Component wise biomass allocation to leaves + branches was maximum in *P. pinnata* (39.77% of total biomass), followed by *T. arjuna* (39.50% of total biomass) and *D. sissoo* (38.41% of total biomass), while it was found minimum in *A. nilotica* (20.76% of total biomass). Biomass allocation to stem component compared to total biomass was recorded the highest in *E.* hybrid (58.59%), followed by *A. nilotica* (47.35%).

Annual biomass produced by four and half years old trees of different species considering 2 m x 2 m distance between trees and accommodating 2500 trees in 1 hectare was quantified. *E.* hybrid accumulated 28.28 t/ha biomass annually, which was the maximum among the selected species, followed by *P. pinnata* (11.24 t/ha), *D. sissoo* (8.94 t/ha), *T. arjuna* (8.23 t/ha), *A. procera* (8.12 t/ha), *A. nilotica* (7.33 t/ha) and *A. lebbek* (7.31 t/ha). Toky *et al.* (2011) also estimated above ground biomass in high density plantations of *Eucalyptus tereticornis*, irrigated with secondary treated sewage water to be 24.1 t/ha, followed by *A. excelsa* (21.8 t/ha) and *Melia azedarach* (12.6 t/ha).

Higher biomass in *E.* hybrid and *P. pinnata* and proportionately higher allocation to leaves and branches in *P. pinnata* might have resulted the higher transpiration rate by these species. Moreover, higher water use by these tree species support the fact that these species exhibited steady rate of transpiration throughout the year in comparison to other species. If rate of transpiration is the indicator of plant water use, it was found maximum for *E.* hybrid and *P. pinnata.* Unlike these species, *A. nilotica* was found to have minimum biomass, which resulted the least transpiration rate and the lowest water use. The tree species having high transpiration coupled with greater biomass are the desirable species for the reclamation of water logged areas. In the present study, *E.* hybrid and *P. pinnata* had steady rate of transpiration, more water use and higher biomass, hence can be used for plantation purpose for reclaiming water logged areas. The present results corroborate the study conducted by George (1990), who concluded that *E. spathulata* had faster growth and four times greater leaf area in comparison to the other eucalyptus species, which resulted in 4 - 5 times greater water use by the species in a water logged area of western Australia. Jeet Ram *et al.* (2011) found that roots of *E. tereticornis* penetrated in the soil profile up to a depth of 3.30 m below the top level of 0.50 m high ridge or 2.80 m below the field surface.

Photos 13 : Biomass studies conducted at plantations

Table 15: Growth and dry biomass (kg / plant) of four and half year old plants at Somti and Jamuniya.

S. No.	Species	Growth data				Above ground biomass (kg)			Below ground biomass (kg)	Total biomass (kg)	Average annual biomass (t/ha)
		Height (m)	GBH (cm)	Basal girth (cm)	Root length (cm)	Stem	Branches	Leaves	Roots		
1.	*Eucalyptus* hybrid	7.51	40.0	52.2	136.1	29.83	6.31	7.75	7.02	50.91	28.28
2.	*Pongamia pinnata*	4.73	22.5	31.3	147.0	7.66	5.51	2.54	4.53	20.24	11.24
3.	*Dalbergia sissoo*	2.95	35.6	39.1	96.0	6.40	4.95	1.23	3.51	16.09	8.94
4.	*Acacia nilotica*	2.75	21.6	33.1	119.2	6.25	2.46	0.28	4.21	13.20	7.33
5.	*Albizia procera*	2.51	24.8	32.3	88.0	6.20	3.81	1.01	3.60	14.62	8.12
6.	*Albizia lebbek*	2.06	21.4	31.7	72.0	5.40	3.50	0.95	3.31	13.16	7.31
7.	*Terminalia arjuna*	2.33	15.8	20.2	66.4	5.90	3.73	2.12	3.06	14.81	8.23
	$CD_{0.05}$	0.3781	3.6614	2.3542	20.9020	1.8461	0.1886	0.1333	0.3456		
	$CD_{0.01}$	0.5301	5.1330	3.3005	29.3040	2.5882	0.2644	0.1869	0.4845		
	SE±	0.1735	1.6805	1.0805	9.5935	0.8473	0.0866	0.0612	0.1586		

* Mean value of 10 trees per species.

Table 16: Root shoot dry biomass (kg) ratio of selected tree species at Somti and Jamuniya.

S. No.	Species	Root	Shoot	Root : shoot Ratio
1.	*Eucalyptus* hybrid	7.02	29.83	0.24
2.	*Pongamia pinnata*	4.53	7.66	0.59
3.	*Dalbergia sissoo*	3.51	6.40	0.55
4.	*Acacia nilotica*	4.21	6.25	0.67
5.	*Albizia procera*	3.60	6.20	0.58
6.	*Albizia lebbek*	3.31	5.40	0.61
7.	*Terminalia arjuna*	3.06	5.90	0.52

(iii) Water table measurements

Observation wells were installed in the field to measure water table fluctuations on regular basis. Each observation well comprised of about 10 feet long and 8 cm diameter PVC pipe, the bottom of which was sealed with a PVC end cap. The lower 3 feet portion of the well pipe was drilled with 10 mm diameter perforations at a distance of 2 x 2 cm. This portion was tightly wrapped with jute rope. This perforated wrapped part worked like a ground water filter. These pipes were placed below the ground manually by digging the soil. About 30 cm of the observation well pipe projected above the soil surface. Sand and gravel mixture was filled in between the pipe and soil space to avoid clogging of the filter. At the level of soil a platform of 30 x 30 x 30 cm size surrounding the projected part of the pipe was prepared using cement and gravel to prevent the entrance of surface water into the well and also to reinforce the pipe with the soil. Upper part of the pipe was closed with a cap using screws.

Twenty observation wells were installed in the selected plantation sites, *viz* Somti, Jamuniya and Dabhola villages. The observation wells were installed in such a manner that the effect of each species could be observed individually. In the Jamuniya site, five wells were installed, out of them two were installed in *P. pinnata* plantation, two in *A. nilotica* plantation and one well was installed outside the plantation area for comparison. Again out of two wells installed in each tree species, one well was placed near the canal and the other one was installed away from the canal. Likewise, 12 observation wells were installed in Somti site in *A. procera, A. lebbek, Eucalyptus* (1 x 1 m), *Eucalyptus* (2 x 2 m), *T. arjuna* and *D. sissoo* plantations. One well installed outside the plantation area was treated as control to compare the data. Similarly, 3 wells were installed in Dabhola site, one each in *Eucalyptus* and *T. arjuna* plantation and one as control. Out of 20 observation wells, 3 wells were treated as control in 3 different plantation sites.

Water table was measured with the help of a multi meter. Two parallel copper wires connected with a multi meter were inserted inside the pipes and the fluctuations in multi meter reading showed the depth of water table.

Few areas of plantation sites experienced severe water logging. The areas near to canal faced the problem of ponding. The plantation areas in Dabhola site also faced the severe problem of water logging due to low lying areas. Out of the selected species, *Eucalyptus* hybrid, *Pongamia pinnata* and *Terminalia arjuna* showed the remarkable tolerance to water logging. Most susceptible tree species were found to be *Albizia procera* and *Albizia lebbek*, which exhibited the maximum mortality in the 1st year of their plantation. Apart from the selected seven species, *Ailanthus excelsa* (Maha Neem) was also planted in Somti site, but this species showed the maximum mortality in the 1st year of its plantation, hence was replaced by *Albizia procera* and *Albizia lebbek*.

Water table readings were measured after every 15 days. Simultaneously, the depth of canal was also measured because in the 1st and 2nd years (*i.e.* during 2007 and 2008), the canal depth varied throughout the year and for a couple of months, the canal was closed due to certain reasons. But in 2010, the canal ran throughout the year, except during June to August, when the depth was quite low. But during this period, the impact of high rainfall was more than the canal on underground water table. Species and monthly variation in water table was observed, but for *Eucalyptus*, diurnal variation was also recorded.

Slight change in water table due to different tree plantations was observed, which could be due to continuous in flow of water because of horizontal seepage from the running canal. Change in water table due to *E.* hybrid and *T. arjuna* plantations was observed at Dabhola site and the change was compared with the control observation well installed at the site (Table 17 and Fig. 65). Change in water table due to these two species was observed simultaneously because these species were planted at nearby places, however impact of individual species on percent change in water table is presented in Table 20. Similarly, effect of *P. pinnata* & *A. nilotica* and *D. sissoo*, *A. procera* & *A. lebbek* plantations was observed together on underground water table. Change in water table due to *P. pinnata* and *A. nilotica* plantations was observed at Jamuniya site and was compared with the nearby observation well (Table 18 and Fig. 66). Similarly, the effect of *D. sissoo*, *A. procera* and *A. lebbek* plantations was observed at Somti site (Table 19 and Fig. 67). When species variation was concerned, increase in depth of water table was observed in *E.* hybrid, followed by *P. pinnata*. *T. arjuna* was also found to have significant effect on lowering down the water table. The impact of plantations of other species on underground water table was not found in the systematic manner when compared with the nearby control observation wells (Table 20 and Fig. 68).

Monthly variation in water table due to tree plantations along left bank canal of Bargi command area was recorded from January to December 2010 and this change was found directly related to temperature, humidity and rainfall. Depth of water table in plantations of all the tree species gradually increased from January to mid June, with the increase in maximum and minimum temperature. After this period, water table suddenly increased due to decrease in temperature and onset of rainfall in the second half of June. In July, August and September the water table continued increasing in all the plantations due to high rainfall. During this period, the water table rose to ground level at Dabhola site, where *E.* hybrid and *T. arjuna* have been planted. From October onwards, the water table again started decreasing till December 2010 (Table 17 to 19 and Figs. 65 to 67). Jeet Ram *et al.* (2007) also observed lower ground water table underneath the plantations in comparison to adjacent fields.

During rainy season, the recharge to ground water due to rainfall and horizontal seepage from left bank canal was found to have a significant impact on ground water level fluctuations, which might have dwarfed the impact of tree plantations in lowering down the ground water table.

In May 2010, diurnal variation in water table in *E.* hybrid plantation was observed during 6.00 hours till 18.00 hours, and it was found that maximum decline in water table was observed at 14.00 – 16.00 hours. From morning till evening, initially water table slightly increased then continuously decreased till 14.00 – 16.00 hours and then decreased. Although, the change in water table throughout the day was very low, but it could be due to continuous rise in temperature in the month of May and increase in evapo-transpiration rate (Fig. 69).

Table 17 : Monthly variation in water table in *E.* hybrid and *T. arjuna* plantations

Month	*Eucalyptus* hybrid	*Terminalia arjuna*	Control
1 Jan-10	270	281	261
15 Jan-10	313	306	298
1 Feb-10	291	278	270
15 Feb-10	309	310	300
1 Mar-10	330	319	319
15 Mar-10	330	333	319
1 Apr-10	417	409	395
15 Apr-10	463	444	440
1 May-10	449	447	438
15 May-10	529	510	510
1 Jun-10	619	608	600
15 Jun-10	444	427	415
1 Jul-10	131	119	120
15-Jul-10	0	0	0
1 Aug-10	0	0	0
15 Aug-10	0	0	0
1 Sep-10	0	0	0
15 Sep-10	0	0	0
1 Oct-10	151	141	136
15 Oct-10	173	173	169
1 Nov-10	227	219	210
15 Nov-10	236	215	213
1 Dec-10	257	253	246
15 Dec-10	273	269	260

Fig. 65: monthly variation in water table in *E.* hybrid and *T. arjuna*

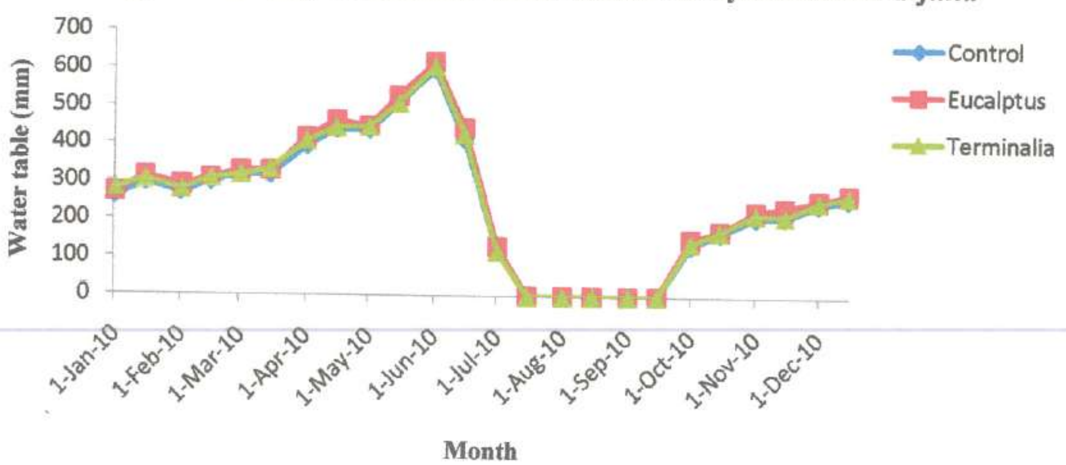


Table 18 : Monthly variation in water table in *P. pinnata* and *A. nilotica* plantations

Month	*Pongamia pinnata*	*Acacia nilotica*	Control
1 Jan-10	851	845	822
15 Jan-10	851	845	820
1 Feb-10	897	879	844
15 Feb-10	879	873	856
1 Mar-10	919	909	877
15 Mar-10	927	923	896
1 Apr-10	969	957	930
15 Apr-10	1003	994	952
1 May-10	1059	1094	1020
15 May-10	1115	1112	1090
1 Jun-10	1167	1155	1130
15 Jun-10	1102	1087	1050
1 Jul-10	454	454	443
15-Jul-10	421	421	412
1 Aug-10	404	402	396
15 Aug-10	386	382	378
1 Sep-10	371	367	364
15 Sep-10	377	373	370
1 Oct-10	600	577	560
15 Oct-10	597	567	572
1 Nov-10	779	772	752
15 Nov-10	864	813	790
1 Dec-10	839	831	796
15 Dec-10	842	835	810

Fig. 66: Monthly variation in water table in *P. pinnata* and *A. nilotica*

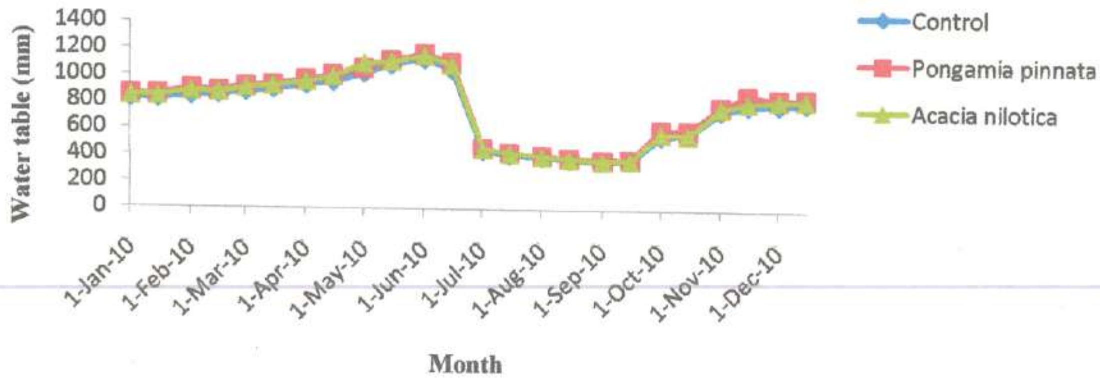


Table 19 : Monthly variation in water table in *D. sissoo, A. procera* and *A. lebbek* plantations.

Month	*Dalbergia sissoo*	*Albizia procera*	*Albizia lebbek*	Control
1 Jan-10	827	819	824	802
15 Jan-10	847	839	840	823
1 Feb-10	855	836	854	845
15 Feb-10	838	849	864	858
1 Mar-10	862	884	887	879
15 Mar-10	920	907	909	898
1 Apr-10	925	932	934	925
15 Apr-10	971	961	964	952
1 May-10	1019	1008	1009	993
15 May-10	1049	1037	1039	1015
1 Jun-10	1097	1091	1092	1070
15 Jun-10	1031	1027	1025	1010
1 Jul-10	524	512	522	517
15-Jul-10	491	491	496	491
1 Aug-10	406	407	404	406
15 Aug-10	380	379	380	379
1 Sep-10	370	370	370	370
15 Sep-10	362	362	362	362
1 Oct-10	507	507	509	497
15 Oct-10	541	538	540	528
1 Nov-10	616	618	624	599
15 Nov-10	675	681	683	662
1 Dec-10	764	765	763	749
15 Dec-10	813	809	806	796

Fig. 67: Monthly variation in water table in *D. sissoo, A. procera* and *A. lebbek*

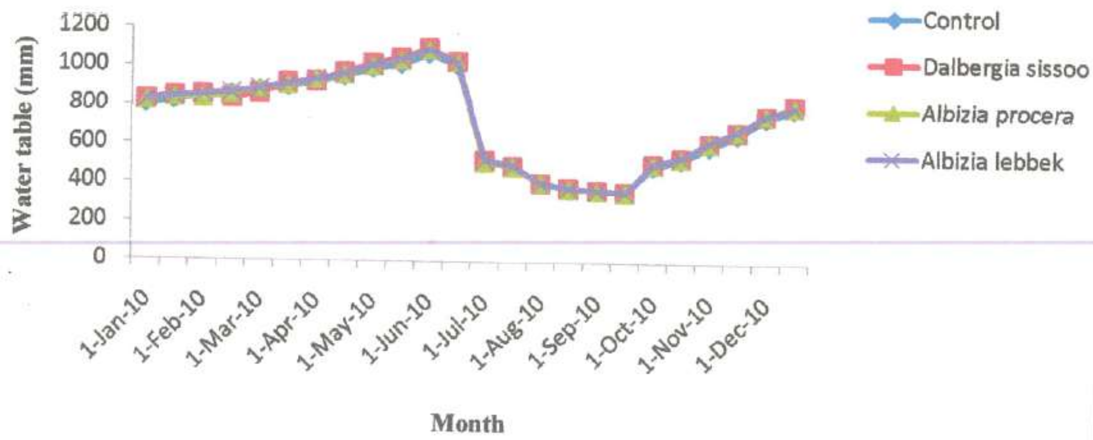
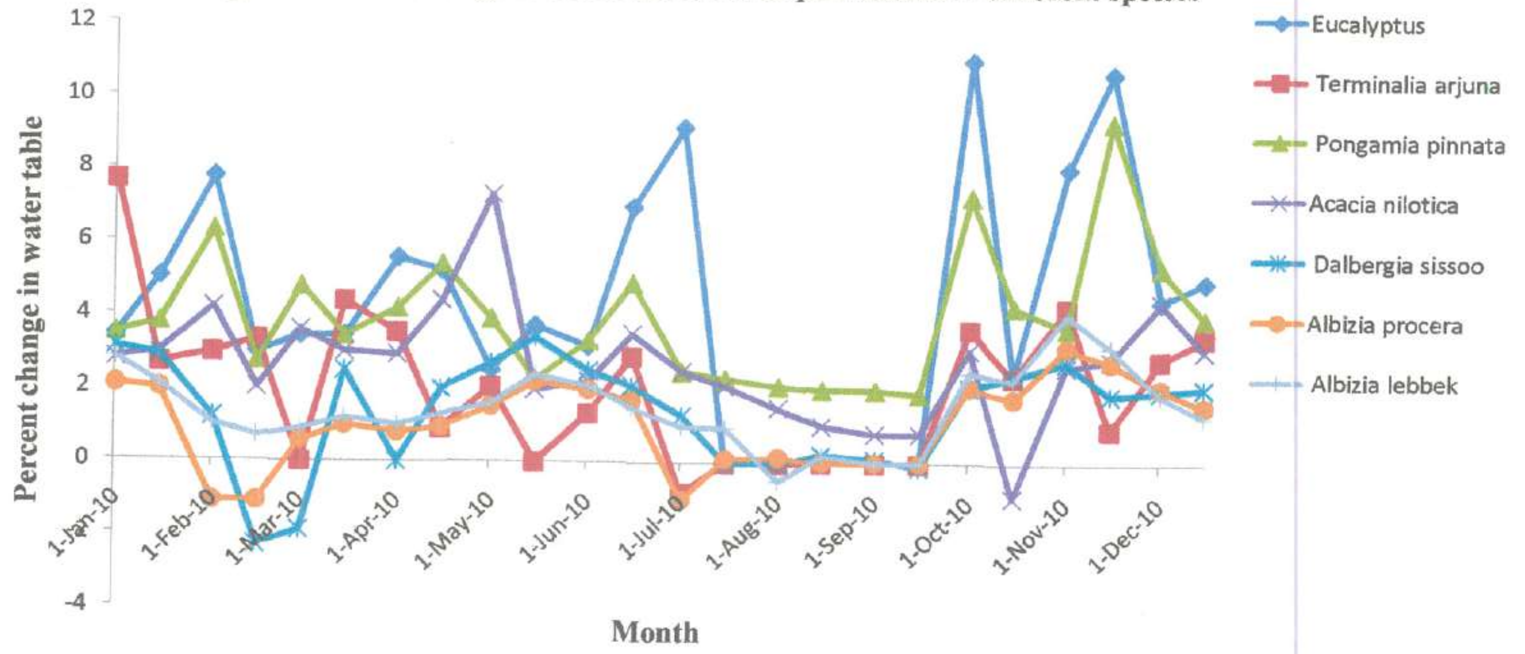


Table 20 : Percent change in water table due to plantations of different species.

Month	*E.* hybrid	*T. arjuna*	*P. pinnata*	*A. nilotica*	*D. sissoo*	*A. procera*	*A. lebbek*
1 Jan-10	3.45	7.66	3.50	2.80	3.10	2.10	2.80
15 Jan-10	5.03	2.68	3.80	3.00	2.90	2.00	2.10
1 Feb-10	7.77	2.96	6.32	4.21	1.20	-1.10	1.01
15 Feb-10	3.00	3.33	2.75	2.01	-2.30	-1.10	0.70
1 Mar-10	3.45	0	4.80	3.60	-1.90	0.60	0.90
15 Mar-10	3.45	4.39	3.45	3.01	2.50	1.00	1.20
1 Apr-10	5.57	3.54	4.20	2.92	0	0.80	1.00
15 Apr-10	5.23	0.90	5.40	4.40	2.00	0.95	1.30
1 May-10	2.51	2.05	3.90	7.30	2.69	1.52	1.60
15 May-10	3.73	0	2.25	1.98	3.40	2.20	2.40
1 Jun-10	3.17	1.33	3.31	2.20	2.50	2.00	2.10
15 Jun-10	6.99	2.89	4.91	3.52	2.10	1.70	1.5
1 Jul-10	9.17	-0.83	2.50	2.50	1.30	-1.00	1.00
15-Jul-10	0	0	2.30	2.10	0	0.10	0.95
1 Aug-10	0	0	2.10	1.50	0	0.15	-0.50
15 Aug-10	0	0	2.00	1.00	0.20	0	0.20
1 Sep-10	0	0	2.00	0.80	0.10	0	0
15 Sep-10	0	0	1.90	0.80	-0.10	0	0
1 Oct-10	11.03	3.68	7.30	3.10	2.10	2.10	2.50
15 Oct-10	2.37	2.37	4.31	-0.93	2.40	1.80	2.30
1 Nov-10	8.09	4.29	3.72	2.67	2.80	3.20	4.10
15 Nov-10	10.7	0.94	9.36	2.85	1.90	2.80	3.20
1 Dec-10	4.47	2.85	5.37	4.44	2.00	2.10	1.90
15 Dec-10	5.00	3.46	4.01	3.12	2.10	1.60	1.30

Fig. 68: Percent change in water table due to plantations of different species



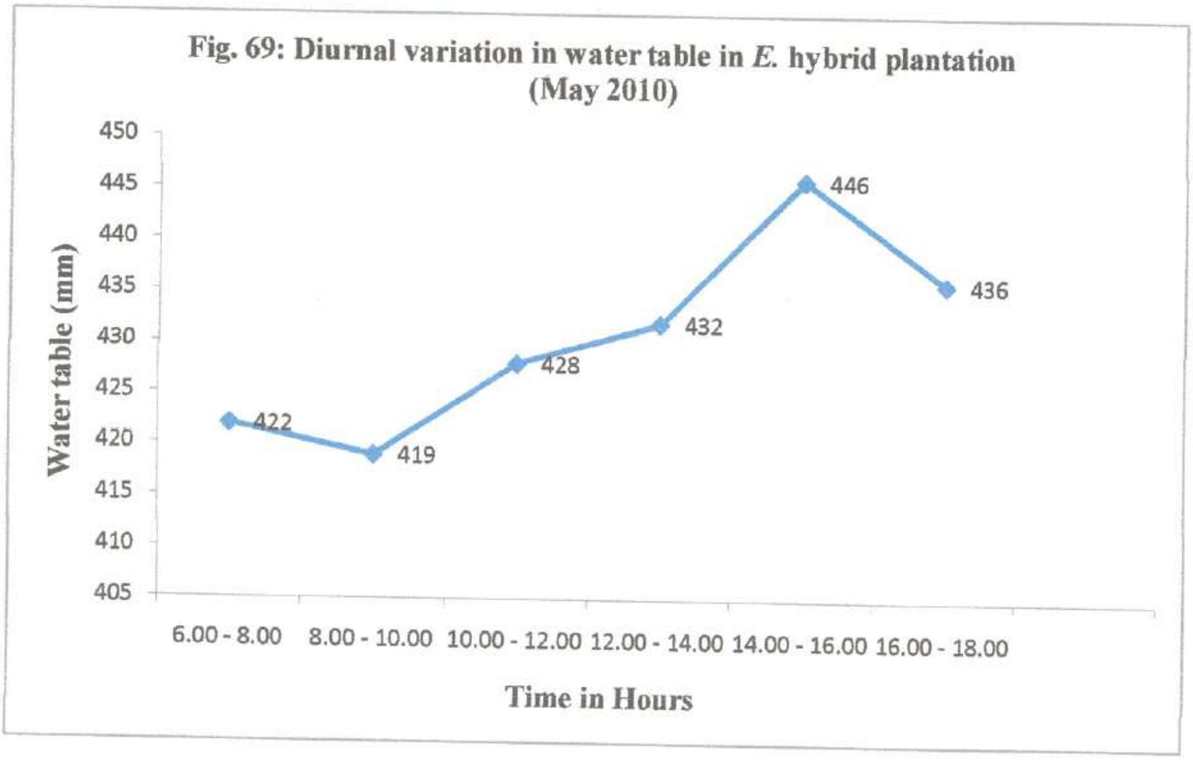


Fig. 69: Diurnal variation in water table in E. hybrid plantation
(May 2010)
Water table (mm)
450
445
440
435
430
425
420
415
410
405
422
419
428
432
446
436
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 14.00
14.00 - 16.00
16.00 - 18.00
Time in Hours

Visit of MP Forest Minister to Lysimetric tanks

Madhya Pradesh Forest Minister Shri Sartaj Singh, local MLA, senior forest officers of M.P. State Forest Department, officers and scientists of State Forest Research Institute and Tropical Forest Research Institute Jabalpur visited lysimetric tanks and discussed about the lysimetric experiments conducted under the INCID Project. The minister, MLA, scientists and officers appreciated the experiment and suggested to extend the results of this experiment to end users including farmers, tree growers and SFD officials.

Photo 14 : MP Forest Minister Shri Sartaj Singh and senior forest officers visiting lysimetric experiments conducted under the project

Photo 15 : MP Forest Minister and Director TFRI discussing on measurement of transpiration rate of tree species and its role in biodrainage

Conduct Training Programme

A training programme for farmers, tree growers and officials from state forest department was conducted at one of the plantation sites at village Dabhola of district Jabalpur on 20th February 2009. About 60 delegates attended the programme. The farmers, whose agriculture land is situated along the left bank canal and who face the problem of water logging, were preferred to attend the training. The scientists from Tropical Forest Research Institute and Jawahar Lal Nehru Krishi Vishwavidyalaya, Jabalpur delivered lectures on management of underground water table through plantation of suitable tree species, adoption of agroforestry systems in controlling water logging, biodrainage and soil management etc in local language and discussed in detail about the problems of the farmers. The scientists discussed with the farmers about the importance of biodrainage, its long term impact on the lands and how the water logged and saline lands can be managed for agricultural purposes. A training module in Hindi (next page) was prepared and provided to the farmers. In the last, the delegates visited the plantation sites and discussed their problems with the scientists.

Photos 16 : Scientists providing training to farmers

जैव–जलनिकास (BIO-DRAINAGE)

कृषकों एवं वृक्ष उत्पादकों के लिए

प्रशिक्षण पुस्तिका




डॉ. अविनाश जैन
वैज्ञानिक

वन पारिस्थितिकी एवं पुनर्वास प्रभाग
उष्ण कटिबंधीय वन अनुसंधान संस्थान
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9. Conclusions/Recommendations

The present study was proposed to identify suitable tree species to drain out excess water of the soil in waterlogged sites of canal command areas through biodrainage and to enhance the site productivity in Bargi command area (Jabalpur, M.P.). To achieve the objectives, two sets of experiments were conducted under the project. First set of experiments were conducted along left bank canal of Bargi command area, where a plantation of 10 ha area including 7 tropical forest tree species *viz. Acacia nilotica, Albizia lebbek, Albizia procera, Dalbergia sissoo, Eucalyptus* hybrid, *Pongamia pinnata* and *Terminalia arjuna* was raised. Strip plantations were raised along the canal and the effect of each tree species on underground water table was observed by installing 10 feet size observation wells in each plantation at different distances from the canal.

Out of the seven tropical forest tree species planted along left bank canal of Bargi command area, *E.* hybrid, followed by *P. pinnata* and *T. arjuna* was found to have significant effect on lowering down the water table in the canal command area, although average water use by *A. procera* and *A. lebbek* was found more than *T. arjuna* under lysimetric experiments. This could be attributed to slight variation in climatic conditions between lysimetric tanks (Tropical Forest Research Institute) and plantation sites (canal command areas) because monthly variation in water table due to tree plantations was found directly related to temperature, humidity and rainfall. Depth of water table in plantations of all the tree species gradually increased from January to mid June, with the increase in maximum and minimum temperature. After this period, water table suddenly increased due to decrease in temperature and onset of rainfall in the second half of June. In July, August and September the water table continued increasing in all the plantations due to high rainfall. Maximum decline in water table in *E.* hybrid plantation was observed at 14.00 – 16.00 hours in summer.

Maximum height was attained by *E.* hybrid, followed by *P. pinnata* and *A. nilotica*, while maximum girth was found in *D. sissoo*, followed by *P. pinnata* and *E.* hybrid in the plantations raised along left bank canal in June 2011. The results partially corroborate the growth characteristics of similar tree species planted in lysimetric tanks, where during this period maximum increase in height was found in *E.* hybrid, followed by *A. procera* and *A. nilotica* under 0 – 0.25 m water regime. Four and half years old trees of *E.* hybrid annually accumulated maximum biomass, which was followed by *P. pinnata* and *D. sissoo* planted along canal command sites.

In the experiments simulated in lysimeters, most of the selected species performed better under water logged conditions compared to control, which could be due to their high water requirement. *Eucalyptus* hybrid, *Pongamia pinnata, Albizia procera* and *Terminalia arjuna* exhibited their maximum growth values under 0-0.25 m water regime.

Maximum water use on per day basis was found in *Eucalyptus* hybrid, followed by *Pongamia pinnata* under different depths of water logging in lysimeters. Water use by the species decreased with increase in depth of water logging, which could be due to more surface area of roots in contact with soil water. Significant monthly variation in water use was observed in the species under test, which was directly related to the climatic conditions.

The transpiration rate was found maximum in *E. hybrid*, followed by *P. pinnata* and *T. arjuna* in control or non-waterlogged conditions, but under water table maintained at 0 - 0.25 m, 0.25 - 0.50 m and 0.50 - 0.75 m peak transpiration rate was observed in *P. pinnata, E. hybrid* and *D. sissoo* respectively. The results showed that with the increase in water logging, transpiration rate increased in all seven species. Peak transpiration was observed at 12 hour during the period for most of the species, but for some species the peak period shifted to 11 hour or 13 hour.

E. hybrid and *P. pinnata* showed the best performance regarding growth and biomass accumulation. Higher biomass in *E.* hybrid and *P. pinnata* and proportionately higher allocation to leaves and branches in *P. pinnata* might have resulted the higher transpiration rate by these species. Moreover, higher water use by these tree species support the fact that these species exhibited steady rate of transpiration throughout the year in comparison to other species. If rate of transpiration is the indicator of plant water use, it was found maximum for *E.* hybrid and *P. pinnata.*

Waterlogged areas in India cover about 2% of the irrigation command areas due to which land is degraded and growth of trees is adversely affected by deficiency of oxygen causing reduction in site productivity. Biodrainage is the vertical drainage of soil water through evapotranspiration by vegetation and is the eco-friendly approach to manage ground water table. In the present study, *E.* hybrid and *P. pinnata* were found to have steady rate of transpiration, more water use and higher biomass, hence these species have high potential to be used as efficient bio-drainage in Bargi command area and can be used for plantation purpose for reclaiming water logged areas. The strip plantation including these species can be done along the canal in rows and the number of rows can be decreased with increasing distance from the canal. The suitable gap between the group of rows can be maintained to facilitate the agricultural operations. This way, the waterlogged sites in canal command areas can be managed and site productivity can be enhanced to certain extent.

10. How do the conclusions/recommendations compare with current thinking

No published report on performance of the selected tree species in the reclamation of water logged canal command areas in central India is available. Similarly, the performance of *Eucalypts* in waterlogged areas is well known, but the use of *Pongamia pinnata* in reclaiming water logged sites is not known. The strip plantation including *E.* hybrid and *P.* pinnata can be raised on farmers' field facing the problem of severe to moderate water logging due to horizontal seepage from canals. Observations wells made with perforated pipes can be installed in the farmers' fields to regularly measure the under ground water table. Gap between rows of trees should be maintained in such a manner that movement of tractor and other agricultural operations can be performed smoothly.

11. Field tests conducted

The research findings are based on field experiments, which were conducted along left bank canal of Bargi command area and simulated in lysimeters.

12. Software generated, if any

No

13. Possibilities of any patents/copyrights. If so, then action taken in this regard

No

14. Suggestions for further work

The research results should be extended to the farmers, tree growers, state forest department and others who face the problem of water logging in the canal command areas. Although, one farmers' training was conducted at plantation site including all the stakeholders and the results are being disseminated through interactions to the farmers and forest officials from time to time.

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Appendix A

Table A1: Growth characteristics of seedlings planted in lysimetric tanks during September 2008.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	2.22	3.29	6	67
		0.25-0.50	1.84	2.98	4	62
		0.50-0.75	1.95	3.76	9	94
		Control	2.95	1.88	5	66
2.	*Pongamia pinnata*	0.00-0.25	0.64	2.82	1	30
		0.25-0.50	0.82	3.45	0	38
		0.50-0.75	0.65	2.66	2	8
		Control	0.79	3.92	8	34
3.	*Dalbergia sissoo*	0.00-0.25	1.52	2.35	3	39
		0.25-0.50	1.37	4.45	13	146
		0.50-0.75	1.33	2.66	9	51
		Control	1.31	2.66	4	53
4.	*Acacia nilotica*	0.00-0.25	0.99	1.88	9	131
		0.25-0.50	1.01	1.57	7	214
		0.50-0.75	0.90	1.72	9	237
		Control	1.07	2.04	9	212
5.	*Albizia procera*	0.00-0.25	0.88	2.19	4	13
		0.25-0.50	0.59	1.25	2	8
		0.50-0.75	0.68	1.72	4	12
		Control	0.97	2.51	3	5
6.	*Albizia lebbek*	0.00-0.25	1.46	2.98	5	29
		0.25-0.50	1.43	3.76	3	19
		0.50-0.75	1.15	3.14	3	22
		Control	1.16	3.45	3	15
7.	*Terminalia arjuna*	0.00-0.25	1.66	3.45	10	125
		0.25-0.50	1.49	3.92	7	127
		0.50-0.75	1.16	4.08	14	150
		Control	1.69	3.29	3	45

Table A2: Growth characteristics of seedlings planted in lysimetric tanks during January 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	2.28	4.23	6	238
		0.25-0.50	2.04	4.08	7	185
		0.50-0.75	2.46	5.02	9	195
		Control	3.02	5.02	8	153
2.	*Pongamia pinnata*	0.00-0.25	1.20	5.18	2	18
		0.25-0.50	1.22	5.65	0	21
		0.50-0.75	0.99	4.86	2	21
		Control	1.28	5.80	4	37
3.	*Dalbergia sissoo*	0.00-0.25	1.54	3.86	11	148
		0.25-0.50	1.50	6.59	8	560
		0.50-0.75	1.40	4.33	10	97
		Control	1.30	3.76	7	87
4.	*Acacia nilotica*	0.00-0.25	1.01	3.70	15	410
		0.25-0.50	1.05	2.82	14	615
		0.50-0.75	0.97	3.14	11	630
		Control	1.11	4.30	14	653
5.	*Albizia procera*	0.00-0.25	1.02	2.76	5	26
		0.25-0.50	0.16	1.57	1	7
		0.50-0.75	0.69	3.01	4	24
		Control	1.09	3.26	7	18
6.	*Albizia lebbek*	0.00-0.25	1.66	3.95	6	52
		0.25-0.50	1.47	3.92	1	8
		0.50-0.75	1.25	3.83	2	16
		Control	1.29	4.67	7	61
7.	*Terminalia arjuna*	0.00-0.25	1.73	6.12	11	113
		0.25-0.50	1.53	7.06	11	241
		0.50-0.75	1.63	8.47	18	319
		Control	1.76	6.06	3	148

Table A3: Growth characteristics of seedlings planted in lysimetric tanks during March 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	2.73	5.96	5	356
		0.25-0.50	2.10	5.65	4	517
		0.50-0.75	2.56	6.59	10	412
		Control	3.19	6.90	8	360
2.	*Pongamia pinnata*	0.00-0.25	1.22	6.90	2	13
		0.25-0.50	1.4	7.22	0	15
		0.50-0.75	1.15	6.75	4	37
		Control	1.36	7.22	8	65
3.	*Dalbergia sissoo*	0.00-0.25	1.55	5.65	8	246
		0.25-0.50	1.78	9.42	16	1090
		0.50-0.75	1.43	5.96	9	352
		Control	1.31	5.96	8	306
4.	*Acacia nilotica*	0.00-0.25	1.02	5.33	16	523
		0.25-0.50	1.08	5.65	21	638
		0.50-0.75	0.98	3.92	13	857
		Control	1.12	6.59	15	812
5.	*Albizia procera*	0.00-0.25	0.28	2.98	0	4
		0.25-0.50	0.32	4.71	1	16
		0.50-0.75	0.10	3.14	1	13
		Control	0.40	5.33	2	33
6.	*Albizia lebbek*	0.00-0.25	1.85	5.18	1	85
		0.25-0.50	1.57	5.65	2	56
		0.50-0.75	1.28	5.80	3	101
		Control	1.66	5.96	1	132
7.	*Terminalia arjuna*	0.00-0.25	1.79	8.47	4	289
		0.25-0.50	1.57	10.20	8	363
		0.50-0.75	1.65	1.90	14	689
		Control	1.88	7.85	3	154

Table A4: Growth characteristics of seedlings planted in lysimetric tanks during April 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	3.00	8.16	5	533
		0.25-0.50	2.12	7.85	4	602
		0.50-0.75	2.78	7.85	6	711
		Control	3.38	7.22	5	427
2.	*Pongamia pinnata*	0.00-0.25	1.25	7.37	5	57
		0.25-0.50	1.59	8.47	2	34
		0.50-0.75	1.50	8.16	3	147
		Control	1.46	8.16	9	121
3.	*Dalbergia sissoo*	0.00-0.25	1.58	5.96	5	318
		0.25-0.50	2.24	12.24	18	3110
		0.50-0.75	1.80	7.85	8	976
		Control	1.42	5.96	8	430
4.	*Acacia nilotica*	0.00-0.25	1.02	6.59	12	926
		0.25-0.50	1.09	6.90	21	1008
		0.50-0.75	0.99	5.65	13	955
		Control	1.12	7.22	15	1469
5.	*Albizia procera*	0.00-0.25	0.39	3.29	1	14
		0.25-0.50	0.53	4.71	1	13
		0.50-0.75	0.11	3.45	1	32
		Control	0.61	5.33	1	36
6.	*Albizia lebbek*	0.00-0.25	2.09	6.59	1	153
		0.25-0.50	1.72	5.65	2	280
		0.50-0.75	1.52	5.96	3	227
		Control	2.12	6.28	1	334
7.	*Terminalia arjuna*	0.00-0.25	1.80	9.26	4	654
		0.25-0.50	1.60	11.61	10	855
		0.50-0.75	1.82	13.18	12	701
		Control	1.92	9.73	4	102

Table A5: Growth characteristics of seedlings planted in lysimetric tanks during May 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	3.07	10.36	5	533
		0.25-0.50	2.16	8.47	4	906
		0.50-0.75	3.16	9.73	6	1045
		Control	3.42	8.47	5	753
2.	*Pongamia pinnata*	0.00-0.25	1.71	7.53	5	89
		0.25-0.50	1.61	8.79	2	81
		0.50-0.75	1.92	9.42	3	125
		Control	1.73	9.42	9	223
3.	*Dalbergia sissoo*	0.00-0.25	1.60	7.53	5	423
		0.25-0.50	2.56	13.81	19	4200
		0.50-0.75	2.32	12.78	10	1840
		Control	1.68	7.85	8	996
4.	*Acacia nilotica*	0.00-0.25	1.21	8.16	12	2163
		0.25-0.50	1.45	8.16	21	2110
		0.50-0.75	1.05	7.22	6	2217
		Control	1.60	9.10	15	2913
5.	*Albizia procera*	0.00-0.25	0.54	4.08	1	36
		0.25-0.50	1.00	6.28	1	27
		0.50-0.75	0.52	5.65	1	68
		Control	1.27	7.22	1	198
6.	*Albizia lebbek*	0.00-0.25	2.30	7.53	1	175
		0.25-0.50	2.12	7.06	3	528
		0.50-0.75	2.20	9.10	2	543
		Control	2.95	10.36	1	528
7.	*Terminalia arjuna*	0.00-0.25	1.82	10.04	4	741
		0.25-0.50	1.63	13.50	10	1320
		0.50-0.75	2.19	16.01	14	1105
		Control	1.94	11.30	5	390

Table A6: Growth characteristics of seedlings planted in lysimetric tanks during June 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	No. of Branches	No. of Leaves
1.	*Eucalyptus hybrid*	0.00-0.25	3.46	11.30	6	635
		0.25-0.50	2.40	9.42	5	1310
		0.50-0.75	3.28	10.67	7	1210
		Control	3.58	10.20	6	842
2.	*Pongamia pinnata*	0.00-0.25	2.15	8.47	5	128
		0.25-0.50	2.24	9.73	3	207
		0.50-0.75	2.56	11.30	4	210
		Control	2.26	12.08	10	380
3.	*Dalbergia sissoo*	0.00-0.25	1.92	10.67	6	883
		0.25-0.50	3.09	17.27	-	-
		0.50-0.75	3.10	15.07	11	3610
		Control	2.53	12.24	9	1246
4.	*Acacia nilotica*	0.00-0.25	1.73	10.36	12	2410
		0.25-0.50	1.98	10.04	22	2800
		0.50-0.75	1.52	9.73	5	2613
		Control	2.18	12.56	16	1900
5.	*Albizia procera*	0.00-0.25	0.98	6.28	1	78
		0.25-0.50	1.45	9.10	1	115
		0.50-0.75	1.12	6.28	1	15
		Control	2.22	12.87	1	678
6.	*Albizia lebbek*	0.00-0.25	3.46	9.10	1	224
		0.25-0.50	3.20	9.73	3	680
		0.50-0.75	3.40	12.87	2	740
		Control	4.05	13.50	1	678
7.	*Terminalia arjuna*	0.00-0.25	2.11	12.87	5	833
		0.25-0.50	2.18	16.64	11	1570
		0.50-0.75	2.58	18.21	14	1285
		Control	2.24	13.18	7	428

Table A7: Growth characteristics of seedlings planted in lysimetric tanks during July 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	2.87	12.24
		0.25-0.50	3.01	10.83
		0.50-0.75	3.60	12.56
		Control	3.82	10.36
2.	*Pongamia pinnata*	0.00-0.25	2.28	9.42
		0.25-0.50	2.71	11.30
		0.50-0.75	2.91	11.93
		Control	2.58	12.56
3.	*Dalbergia sissoo*	0.00-0.25	2.45	12.56
		0.25-0.50	3.77	21.66
		0.50-0.75	3.49	18.52
		Control	3.01	14.44
4.	*Acacia nilotica*	0.00-0.25	2.11	11.93
		0.25-0.50	2.37	13.50
		0.50-0.75	1.81	9.73
		Control	2.66	14.44
5.	*Albizia procera*	0.00-0.25	1.12	7.22
		0.25-0.50	2.30	9.42
		0.50-0.75	1.68	7.22
		Control	2.88	14.75
6.	*Albizia lebbek*	0.00-0.25	4.01	10.99
		0.25-0.50	3.51	13.18
		0.50-0.75	4.01	16.32
		Control	4.48	16.32
7.	*Terminalia arjuna*	0.00-0.25	2.30	15.07
		0.25-0.50	2.41	19.46
		0.50-0.75	2.78	18.84
		Control	2.47	14.75

Table A8: Growth characteristics of seedlings planted in lysimetric tanks during August 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.25	13.50
		0.25-0.50	3.78	12.56
		0.50-0.75	4.07	14.13
		Control	4.16	10.67
2.	*Pongamia pinnata*	0.00-0.25	2.40	10.67
		0.25-0.50	3.17	13.18
		0.50-0.75	3.44	12.87
		Control	2.76	12.56
3.	*Dalbergia sissoo*	0.00-0.25	2.68	14.44
		0.25-0.50	4.27	22.92
		0.50-0.75	3.97	23.55
		Control	3.51	16.64
4.	*Acacia nilotica*	0.00-0.25	2.38	13.81
		0.25-0.50	2.62	16.01
		0.50-0.75	2.20	12.24
		Control	3.12	16.95
5.	*Albizia procera*	0.00-0.25	1.25	8.16
		0.25-0.50	3.04	12.87
		0.50-0.75	2.10	8.79
		Control	3.54	16.32
6.	*Albizia lebbek*	0.00-0.25	4.68	12.87
		0.25-0.50	3.96	16.95
		0.50-0.75	4.39	19.78
		Control	5.05	19.15
7.	*Terminalia arjuna*	0.00-0.25	2.48	16.95
		0.25-0.50	2.88	22.60
		0.50-0.75	3.06	19.46
		Control	2.85	16.95

Table A9: Growth characteristics of seedlings planted in lysimetric tanks during September 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.59	14.75
		0.25-0.50	4.07	13.18
		0.50-0.75	4.32	15.38
		Control	4.36	10.86
2.	*Pongamia pinnata*	0.00-0.25	2.55	11.93
		0.25-0.50	3.50	14.13
		0.50-0.75	3.65	14.13
		Control	2.82	13.81
3.	*Dalbergia sissoo*	0.00-0.25	3.01	16.64
		0.25-0.50	4.52	23.55
		0.50-0.75	4.40	26.37
		Control	3.67	17.89
4.	*Acacia nilotica*	0.00-0.25	2.76	11.30
		0.25-0.50	2.88	17.58
		0.50-0.75	2.62	16.32
		Control	3.37	18.52
5.	*Albizia procera*	0.00-0.25	1.49	9.10
		0.25-0.50	3.53	15.07
		0.50-0.75	2.28	9.73
		Control	3.71	17.58
6.	*Albizia lebbek*	0.00-0.25	5.35	15.70
		0.25-0.50	4.11	18.52
		0.50-0.75	4.52	21.66
		Control	5.35	21.66
7.	*Terminalia arjuna*	0.00-0.25	2.71	19.15
		0.25-0.50	3.10	24.80
		0.50-0.75	3.22	21.66
		Control	2.98	19.15

Table A10: Growth characteristics of seedlings planted in lysimetric tanks during October 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.80	15.38	--
		0.25-0.50	4.29	13.50	--
		0.50-0.75	4.50	17.58	--
		Control	4.60	10.99	--
2.	*Pongamia pinnata*	0.00-0.25	270	12.56	--
		0.25-0.50	3.77	15.07	--
		0.50-0.75	3.88	15.38	--
		Control	2.95	14.75	6.59
3.	*Dalbergia sissoo*	0.00-0.25	3.26	18.52	--
		0.25-0.50	4.75	24.17	16.96
		0.50-0.75	4.67	28.88	--
		Control	3.80	19.15	--
4.	*Acacia nilotica*	0.00-0.25	2.96	20.09	--
		0.25-0.50	3.06	18.52	--
		0.50-0.75	2.97	16.64	--
		Control	3.50	20.09	--
5.	*Albizia procera*	0.00-0.25	1.65	10.04	--
		0.25-0.50	3.71	16.64	--
		0.50-0.75	2.40	11.30	--
		Control	3.85	18.84	--
6.	*Albizia lebbek*	0.00-0.25	5.90	16.95	--
		0.25-0.50	4.32	19.78	--
		0.50-0.75	4.93	22.92	--
		Control	5.60	23.86	--
7.	*Terminalia arjuna*	0.00-0.25	2.85	21.03	--
		0.25-0.50	3.30	26.37	--
		0.50-0.75	3.35	23.86	--
		Control	3.11	21.03	--

Table A11: Growth characteristics of seedlings planted in lysimetric tanks during November 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	5.40	16.95	13.19
		0.25-0.50	4.45	15.70	14.13
		0.50-0.75	4.80	18.21	13.50
		Control	5.03	12.87	12.25
2.	*Pongamia pinnata*	0.00-0.25	2.85	13.50	7.54
		0.25-0.50	3.90	16.64	6.59
		0.50-0.75	3.99	16.32	7.54
		Control	3.15	15.70	7.22
3.	*Dalbergia sissoo*	0.00-0.25	3.60	19.51	10.05
		0.25-0.50	4.88	24.49	17.58
		0.50-0.75	4.75	28.88	16.64
		Control	4.00	19.31	8.16
4.	*Acacia nilotica*	0.00-0.25	3.07	20.09	12.87
		0.25-0.50	3.22	16.32	8.16
		0.50-0.75	3.07	16.95	7.54
		Control	3.60	20.41	8.16
5.	*Albizia procera*	0.00-0.25	1.85	10.67	N.A.
		0.25-0.50	3.85	19.46	10.68
		0.50-0.75	2.48	13.50	6.59
		Control	3.93	20.41	12.56
6.	*Albizia lebbek*	0.00-0.25	6.15	17.11	11.30
		0.25-0.50	4.40	20.41	9.73
		0.50-0.75	4.30	23.55	13.50
		Control	5.90	24.17	14.13
7.	*Terminalia arjuna*	0.00-0.25	3.90	21.98	7.85
		0.25-0.50	3.40	26.37	11.62
		0.50-0.75	3.42	24.08	13.50
		Control	3.20	21.35	10.36

Table A12: Growth characteristics of seedlings planted in lysimetric tanks during December 2009.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	5.75	18.21	13.82
		0.25-0.50	4.67	17.58	15.39
		0.50-0.75	5.00	18.52	14.13
		Control	5.56	14.44	13.19
2.	*Pongamia pinnata*	0.00-0.25	3.00	14.13	8.16
		0.25-0.50	3.97	17.89	8.16
		0.50-0.75	4.08	16.95	8.16
		Control	3.35	16.64	7.85
3.	*Dalbergia sissoo*	0.00-0.25	3.90	19.78	10.68
		0.25-0.50	5.00	24.80	17.90
		0.50-0.75	4.98	29.04	16.96
		Control	4.35	19.62	8.95
4.	*Acacia nilotica*	0.00-0.25	2.16	20.41	13.19
		0.25-0.50	3.33	16.95	8.79
		0.50-0.75	3.14	17.27	7.85
		Control	3.72	21.08	8.48
5.	*Albizia procera*	0.00-0.25	2.00	11.30	N.A.
		0.25-0.50	3.99	20.74	12.87
		0.50-0.75	2.59	14.13	6.91
		Control	4.03	21.66	13.50
6.	*Albizia lebbek*	0.00-0.25	6.30	17.27	11.62
		0.25-0.50	4.53	21.35	10.36
		0.50-0.75	4.70	24.80	13.82
		Control	6.25	24.49	14.44
7.	*Terminalia arjuna*	0.00-0.25	3.01	22.60	8.16
		0.25-0.50	3.50	26.53	11.93
		0.50-0.75	3.53	25.74	13.82
		Control	3.24	21.50	10.68

Table A13: Growth characteristics of seedlings planted in lysimetric tanks during January 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.10	20.09	14.44
		0.25-0.50	4.95	19.15	16.33
		0.50-0.75	5.30	19.15	14.44
		Control	6.00	15.38	13.82
2.	*Pongamia pinnata*	0.00-0.25	3.15	14.75	8.48
		0.25-0.50	4.20	18.84	9.42
		0.50-0.75	4.20	17.58	8.79
		Control	3.35	16.64	7.85
3.	*Dalbergia sissoo*	0.00-0.25	4.05	20.41	11.30
		0.25-0.50	5.11	24.96	18.06
		0.50-0.75	5.10	29.20	17.27
		Control	4.35	19.62	8.95
4.	*Acacia nilotica*	0.00-0.25	3.29	20.41	13.50
		0.25-0.50	3.40	20.41	9.42
		0.50-0.75	3.20	17.58	8.16
		Control	3.80	21.66	8.79
5.	*Albizia procera*	0.00-0.25	2.10	12.24	N.A.
		0.25-0.50	4.10	22.29	14.13
		0.50-0.75	2.65	14.44	7.22
		Control	4.10	23.23	14.44
6.	*Albizia lebbek*	0.00-0.25	6.55	17.58	11.93
		0.25-0.50	4.60	21.98	10.68
		0.50-0.75	5.00	24.80	14.13
		Control	6.60	24.80	14.76
7.	*Terminalia arjuna*	0.00-0.25	3.10	23.23	8.48
		0.25-0.50	3.60	26.69	12.25
		0.50-0.75	3.60	27.00	14.13
		Control	3.30	21.66	10.99

Table A14: Growth characteristics of seedlings planted in lysimetric tanks during February 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.15	20.41	14.60
		0.25-0.50	5.00	19.78	16.49
		0.50-0.75	5.34	19.78	14.76
		Control	6.15	16.01	13.82
2.	*Pongamia pinnata*	0.00-0.25	3.20	15.07	8.79
		0.25-0.50	4.23	19.15	9.73
		0.50-0.75	4.25	17.89	9.11
		Control	3.75	17.42	8.95
3.	*Dalbergia sissoo*	0.00-0.25	4.10	20.72	11.62
		0.25-0.50	5.17	24.96	18.06
		0.50-0.75	5.15	29.35	17.43
		Control	4.65	19.87	9.42
4.	*Acacia nilotica*	0.00-0.25	3.33	20.41	13.50
		0.25-0.50	3.42	21.03	10.36
		0.50-0.75	3.28	18.21	8.48
		Control	3.85	21.82	8.79
5.	*Albizia procera*	0.00-0.25	2.15	12.24	N.A.
		0.25-0.50	4.15	22.45	14.44
		0.50-0.75	2.70	14.75	7.54
		Control	4.15	23.39	14.60
6.	*Albizia lebbek*	0.00-0.25	6.60	17.89	10.99
		0.25-0.50	4.67	22.29	10.68
		0.50-0.75	5.20	25.12	14.44
		Control	6.65	24.96	14.92
7.	*Terminalia arjuna*	0.00-0.25	3.15	23.55	8.79
		0.25-0.50	3.64	27.00	12.40
		0.50-0.75	3.64	27.00	14.13
		Control	3.35	21.82	11.15

Table A15 : Growth characteristics of seedlings planted in lysimetric tanks during March 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.18	20.41	14.60
		0.25-0.50	5.03	19.78	16.49
		0.50-0.75	5.37	19.78	14.76
		Control	6.17	16.17	13.82
2.	*Pongamia pinnata*	0.00-0.25	3.22	15.07	8.79
		0.25-0.50	4.24	19.24	9.83
		0.50-0.75	4.28	18.05	9.11
		Control	3.76	17.36	8.95
3.	*Dalbergia sissoo*	0.00-0.25	4.13	20.72	11.62
		0.25-0.50	5.19	25.12	18.21
		0.50-0.75	5.18	29.51	17.58
		Control	4.67	19.93	9.42
4.	*Acacia nilotica*	0.00-0.25	3.36	20.72	13.66
		0.25-0.50	3.48	21.03	10.36
		0.50-0.75	3.31	18.36	8.64
		Control	3.87	21.82	8.79
5.	*Albizia procera*	0.00-0.25	2.17	12.04	3.45
		0.25-0.50	4.17	22.45	14.60
		0.50-0.75	2.73	14.75	7.54
		Control	4.17	23.39	14.60
6.	*Albizia lebbek*	0.00-0.25	6.62	18.05	11.93
		0.25-0.50	4.68	22.29	10.83
		0.50-0.75	5.22	25.27	14.44
		Control	6.68	24.96	14.92
7.	*Terminalia arjuna*	0.00-0.25	3.18	23.55	8.95
		0.25-0.50	3.67	27.00	12.56
		0.50-0.75	3.67	27.00	14.13
		Control	3.38	21.82	11.15

Table A16: Growth characteristics of seedlings planted in lysimetric tanks during April 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.22	20.56	14.76
		0.25-0.50	5.07	19.93	16.64
		0.50-0.75	5.39	19.87	14.76
		Control	6.20	16.32	13.97
2.	*Pongamia pinnata*	0.00-0.25	3.24	15.22	8.95
		0.25-0.50	4.28	19.24	9.89
		0.50-0.75	4.32	18.21	9.26
		Control	3.78	17.58	9.11
3.	*Dalbergia sissoo*	0.00-0.25	4.15	20.88	11.62
		0.25-0.50	5.31	25.43	18.53
		0.50-0.75	5.21	29.67	17.58
		Control	4.69	20.09	9.58
4.	*Acacia nilotica*	0.00-0.25	3.38	20.72	13.66
		0.25-0.50	3.50	21.19	10.52
		0.50-0.75	3.34	18.52	8.64
		Control	3.9	21.98	8.95
5.	*Albizia procera*	0.00-0.25	2.18	12.40	3.61
		0.25-0.50	4.19	22.60	14.60
		0.50-0.75	2.78	14.91	7.69
		Control	4.19	23.55	14.76
6.	*Albizia lebbek*	0.00-0.25	6.66	18.05	12.09
		0.25-0.50	4.10	22.45	10.83
		0.50-0.75	5.26	25.43	14.60
		Control	6.70	25.12	15.07
7.	*Terminalia arjuna*	0.00-0.25	3.20	23.70	8.95
		0.25-0.50	3.71	27.16	12.56
		0.50-0.75	3.70	27.16	14.13
		Control	3.40	21.98	11.30

Table A17: Growth characteristics of seedlings planted in lysimetric tanks during May 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.25	21.03	15.07
		0.25-0.50	5.28	20.09	16.80
		0.50-0.75	5.45	20.09	15.07
		Control	6.22	16.64	14.44
2.	*Pongamia pinnata*	0.00-0.25	3.49	15.54	9.26
		0.25-0.50	4.29	19.46	10.05
		0.50-0.75	4.35	18.21	9.73
		Control	3.80	17.89	9.26
3.	*Dalbergia sissoo*	0.00-0.25	4.27	21.35	11.93
		0.25-0.50	5.43	25.74	18.84
		0.50-0.75	5.27	30.14	17.90
		Control	4.70	20.09	9.73
4.	*Acacia nilotica*	0.00-0.25	3.52	21.35	13.82
		0.25-0.50	3.63	21.35	10.68
		0.50-0.75	3.48	19.15	9.11
		Control	3.91	22.29	9.11
5.	*Albizia procera*	0.00-0.25	2.19	12.56	3.77
		0.25-0.50	4.21	23.23	15.07
		0.50-0.75	2.80	14.91	7.85
		Control	4.21	23.86	14.76
6.	*Albizia lebbek*	0.00-0.25	6.72	18.52	12.56
		0.25-0.50	4.89	22.92	10.99
		0.50-0.75	5.38	25.74	14.76
		Control	6.71	25.43	15.07
7.	*Terminalia arjuna*	0.00-0.25	3.21	24.17	9.42
		0.25-0.50	3.77	27.31	12.87
		0.50-0.75	3.71	27.31	14.44
		Control	3.41	22.29	11.62

Table A18: Growth characteristics of seedlings planted in lysimetric tanks during June 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	6.32	21.35	15.39
		0.25-0.50	5.41	20.52	16.96
		0.50-0.75	5.62	20.09	15.23
		Control	6.27	16.95	14.76
2.	*Pongamia pinnata*	0.00-0.25	3.70	16.01	9.73
		0.25-0.50	4.30	19.78	10.21
		0.50-0.75	4.41	19.15	10.05
		Control	3.85	18.21	9.42
3.	*Dalbergia sissoo*	0.00-0.25	4.41	21.66	12.25
		0.25-0.50	5.50	26.37	20.10
		0.50-0.75	3.39	30.45	18.21
		Control	4.73	20.52	10.05
4.	*Acacia nilotica*	0.00-0.25	3.70	21.82	13.97
		0.25-0.50	3.75	21.66	10.36
		0.50-0.75	3.54	19.78	9.73
		Control	3.93	22.60	9.26
5.	*Albizia procera*	0.00-0.25	2.21	12.56	4.08
		0.25-0.50	4.24	23.86	15.70
		0.50-0.75	2.83	15.07	8.01
		Control	4.24	23.86	14.92
6.	*Albizia lebbek*	0.00-0.25	6.75	20.72	13.82
		0.25-0.50	4.89	23.23	11.30
		0.50-0.75	5.60	26.06	14.92
		Control	6.73	25.59	15.23
7.	*Terminalia arjuna*	0.00-0.25	3.22	24.49	9.73
		0.25-0.50	3.83	27.63	13.19
		0.50-0.75	3.72	27.31	14.76
		Control	3.44	22.60	11.93

Table A19: Growth characteristics of seedlings planted in lysimetric tanks during July 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	3.35	22.29	16.33
		0.25-0.50	5.85	21.35	17.58
		0.50-0.75	5.90	21.03	15.70
		Control	6.36	17.89	15.07
2.	*Pongamia pinnata*	0.00-0.25	3.95	20.09	11.93
		0.25-0.50	4.40	21.03	10.99
		0.50-0.75	4.50	21.35	10.68
		Control	3.88	19.46	9.42
3.	*Dalbergia sissoo*	0.00-0.25	4.60	22.92	12.87
		0.25-0.50	5.56	29.80	24.60
		0.50-0.75	5.40	30.77	19.47
		Control	4.75	21.35	11.30
4.	*Acacia nilotica*	0.00-0.25	3.80	22.29	14.13
		0.25-0.50	3.90	22.29	12.87
		0.50-0.75	3.80	21.66	10.36
		Control	4.09	23.55	9.42
5.	*Albizia procera*	0.00-0.25	2.28	12.87	4.08
		0.25-0.50	4.61	24.17	16.96
		0.50-0.75	3.10	15.70	9.73
		Control	4.30	24.10	15.07
6.	*Albizia lebbek*	0.00-0.25	6.78	21.66	14.76
		0.25-0.50	5.10	23.86	12.56
		0.50-0.75	5.90	26.96	15.70
		Control	6.78	26.06	15.70
7.	*Terminalia arjuna*	0.00-0.25	3.55	26.69	10.36
		0.25-0.50	3.90	28.88	14.76
		0.50-0.75	3.90	28.57	16.33
		Control	3.48	23.55	12.56

Table A20: Growth characteristics of seedlings planted in lysimetric tanks during August 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	3.77	22.0	17.0
		0.25-0.50	6.02	24.0	20.0
		0.50-0.75	5.98	24.0	20.0
		Control	6.38	22.0	16.0
2.	*Pongamia pinnata*	0.00-0.25	4.41	25.0	16.0
		0.25-0.50	4.62	31.0	15.0
		0.50-0.75	4.55	26.0	13.0
		Control	3.96	24.0	12.0
3.	*Dalbergia sissoo*	0.00-0.25	4.38	36.0	29.0
		0.25-0.50	5.60	36.0	28.0
		0.50-0.75	5.57	36.0	28.0
		Control	4.80	28.0	14.0
4.	*Acacia nilotica*	0.00-0.25	4.15	24.0	17.0
		0.25-0.50	4.41	26.0	13.0
		0.50-0.75	4.30	28.0	8.50
		Control	4.18	26.0	14.0
5.	*Albizia procera*	0.00-0.25	2.68	18.0	8.0
		0.25-0.50	5.11	30.0	24.0
		0.50-0.75	3.60	22.0	16.0
		Control	4.45	30.0	24.0
6.	*Albizia lebbek*	0.00-0.25	7.04	29.0	21.0
		0.25-0.50	5.43	30.0	17.0
		0.50-0.75	6.01	33.0	24.0
		Control	6.84	33.0	22.0
7.	*Terminalia arjuna*	0.00-0.25	3.67	34.0	12.0
		0.25-0.50	4.38	37.0	23.0
		0.50-0.75	4.12	32.0	21.0
		Control	3.49	32.0	20.0

Table A21: Growth characteristics of seedlings planted in lysimetric tanks during September 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.30	24.0	18.0
		0.25-0.50	6.25	27.0	21.0
		0.50-0.75	6.10	26.0	21.0
		Control	6.40	23.0	17.0
2.	*Pongamia pinnata*	0.00-0.25	4.80	27.0	17.0
		0.25-0.50	4.80	34.0	16.0
		0.50-0.75	4.60	29.0	14.0
		Control	4.09	26.0	13.0
3.	*Dalbergia sissoo*	0.00-0.25	5.00	38.0	30.0
		0.25-0.50	5.66	36.0	28.0
		0.50-0.75	5.70	40.0	30.0
		Control	4.85	30.0	15.0
4.	*Acacia nilotica*	0.00-0.25	4.60	26.0	18.0
		0.25-0.50	4.70	29.0	14.0
		0.50-0.75	4.50	29.0	9.0
		Control	4.30	28.0	15.0
5.	*Albizia procera*	0.00-0.25	3.00	20.0	9.0
		0.25-0.50	5.80	33.0	25.0
		0.50-0.75	4.10	24.0	17.0
		Control	4.60	33.0	26.0
6.	*Albizia lebbek*	0.00-0.25	7.30	31.0	22.0
		0.25-0.50	5.80	33.0	19.0
		0.50-0.75	6.10	36.0	25.0
		Control	6.95	36.0	24.0
7.	*Terminalia arjuna*	0.00-0.25	4.00	38.0	13.0
		0.25-0.50	4.80	40.0	24.0
		0.50-0.75	4.40	35.0	22.0
		Control	3.50	35.0	21.0

Table A22: Growth characteristics of seedlings planted in lysimetric tanks during October 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.3	24.0	18.0
		0.25-0.50	6.3	27.5	21.4
		0.50-0.75	6.3	27.0	21.0
		Control	6.4	23.0	17.0
2.	*Pongamia pinnata*	0.00-0.25	4.8	27.0	17.0
		0.25-0.50	4.8	35.0	16.5
		0.50-0.75	4.6	29.0	15.0
		Control	4.1	26.0	14.0
3.	*Dalbergia sissoo*	0.00-0.25	5.1	38.0	30.0
		0.25-0.50	5.6	36.6	28.2
		0.50-0.75	5.7	40.0	30.0
		Control	4.8	30.5	15.0
4.	*Acacia nilotica*	0.00-0.25	4.6	26.0	18.0
		0.25-0.50	4.7	29.2	14.9
		0.50-0.75	4.5	29.2	9.5
		Control	4.4	29.0	17.0
5.	*Albizia procera*	0.00-0.25	3.0	20.0	9.0
		0.25-0.50	5.9	34.0	26.0
		0.50-0.75	4.6	25.0	18.0
		Control	4.7	34.0	26.0
6.	*Albizia lebbek*	0.00-0.25	7.3	31.0	22.0
		0.25-0.50	5.8	33.8	19.1
		0.50-0.75	6.1	37.0	25.5
		Control	6.9	36.5	24.0
7.	*Terminalia arjuna*	0.00-0.25	4.0	38.0	13.0
		0.25-0.50	4.8	40.0	29.0
		0.50-0.75	4.4	36.0	22.0
		Control	3.5	35.0	21.5

Table A23: Growth characteristics of seedlings planted in lysimetric tanks during November 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.5	25.0	18.0
		0.25-0.50	6.5	28.0	21.6
		0.50-0.75	6.5	28.0	21.0
		Control	6.5	24.0	17.0
2.	*Pongamia pinnata*	0.00-0.25	4.8	28.0	18.0
		0.25-0.50	4.8	36.0	17.0
		0.50-0.75	4.7	30.0	17.0
		Control	4.1	26.5	15.0
3.	*Dalbergia sissoo*	0.00-0.25	5.1	39.0	30.0
		0.25-0.50	5.8	36.8	28.4
		0.50-0.75	5.7	41.0	31.0
		Control	4.9	30.5	15.0
4.	*Acacia nilotica*	0.00-0.25	4.6	27.0	18.0
		0.25-0.50	4.7	29.6	15.9
		0.50-0.75	4.6	29.4	9.8
		Control	4.5	29.5	18.0
5.	*Albizia procera*	0.00-0.25	3.1	20.0	9.0
		0.25-0.50	5.9	36.0	27.0
		0.50-0.75	5.1	27.0	19.0
		Control	4.8	35.0	26.5
6.	*Albizia lebbek*	0.00-0.25	7.3	31.0	22.0
		0.25-0.50	5.8	34.0	19.8
		0.50-0.75	6.1	38.0	26.0
		Control	6.9	37.0	25.0
7.	*Terminalia arjuna*	0.00-0.25	4.1	38.0	13.0
		0.25-0.50	4.8	40.6	25.0
		0.50-0.75	4.4	37.0	22.0
		Control	3.5	35.0	21.5

Table A24 : Growth characteristics of seedlings planted in lysimetric tanks during December 2010.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.7	26.0	19.0
		0.25-0.50	6.5	29.0	22.0
		0.50-0.75	6.7	28.0	21.0
		Control	6.5	25.0	broken
2.	*Pongamia pinnata*	0.00-0.25	4.8	29.0	19.0
		0.25-0.50	4.8	36.5	17.6
		0.50-0.75	4.9	30.0	18.0
		Control	4.4	27.0	15.0
3.	*Dalbergia sissoo*	0.00-0.25	5.1	40.0	30.5
		0.25-0.50	5.8	37.0	28.5
		0.50-0.75	5.8	41.0	31.0
		Control	4.9	30.5	15.0
4.	*Acacia nilotica*	0.00-0.25	4.7	28.0	19.0
		0.25-0.50	4.7	29.9	17.1
		0.50-0.75	4.8	30.0	11.0
		Control	4.6	30.0	21.0
5.	*Albizia procera*	0.00-0.25	3.1	20.0	10.0
		0.25-0.50	5.9	37.0	27.5
		0.50-0.75	5.6	29.0	21.0
		Control	4.8	35.5	27.0
6.	*Albizia lebbek*	0.00-0.25	7.3	31.0	22.0
		0.25-0.50	5.8	34.0	19.9
		0.50-0.75	6.2	40.0	27.0
		Control	6.9	37.0	25.0
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.0	14.0
		0.25-0.50	4.8	40.8	25.8
		0.50-0.75	4.5	39.0	22.8
		Control	3.5	36.0	21.9

Table A25: Growth characteristics of seedlings planted in lysimetric tanks during January 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	27.0	19.0
		0.25-0.50	6.6	30.0	22.0
		0.50-0.75	6.8	29.0	21.0
		Control	6.5	26.0	14.0
2.	*Pongamia pinnata*	0.00-0.25	4.9	30.0	20.0
		0.25-0.50	4.9	37.0	18.0
		0.50-0.75	4.8	31.0	19.0
		Control	4.2	28.0	16.0
3.	*Dalbergia sissoo*	0.00-0.25	5.2	41.0	31.2
		0.25-0.50	3.8	37.0	28.9
		0.50-0.75	5.8	42.0	32.0
		Control	4.9	30.5	15.0
4.	*Acacia nilotica*	0.00-0.25	4.7	29.0	19.0
		0.25-0.50	4.7	29.9	17.1
		0.50-0.75	4.8	30.0	13.0
		Control	4.6	31.0	23.0
5.	*Albizia procera*	0.00-0.25	3.1	20.1	10.0
		0.25-0.50	5.9	37.0	27.5
		0.50-0.75	6.1	30.0	22.0
		Control	4.9	36.0	27.0
6.	*Albizia lebbek*	0.00-0.25	7.4	31.5	22.5
		0.25-0.50	5.8	35.0	20.0
		0.50-0.75	6.2	41.0	28.0
		Control	6.9	38.0	26.0
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.0	14.0
		0.25-0.50	4.9	41.0	26.0
		0.50-0.75	4.5	40.0	22.0
		Control	3.5	36.0	22.0

Table A26: Growth characteristics of seedlings planted in lysimetric tanks during February 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	27.0	19.0
		0.25-0.50	6.6	30.5	22.6
		0.50-0.75	6.8	29.0	21.2
		Control	2.1	26.0	15.0
2.	*Pongamia pinnata*	0.00-0.25	4.8	30.5	20.5
		0.25-0.50	4.9	37.3	18.2
		0.50-0.75	4.8	31.0	19.2
		Control	4.2	29.0	16.0
3.	*Dalbergia sissoo*	0.00-0.25	5.2	41.5	31.8
		0.25-0.50	5.9	37.5	28.9
		0.50-0.75	5.8	42.0	32.1
		Control	4.9	30.5	16.0
4.	*Acacia nilotica*	0.00-0.25	4.7	29.0	19.0
		0.25-0.50	4.8	30.5	19.0
		0.50-0.75	4.8	30.0	13.0
		Control	4.6	31.0	23.0
5.	*Albizia procera*	0.00-0.25	3.1	20.8	11.0
		0.25-0.50	6.1	38.2	28.1
		0.50-0.75	6.1	30.0	22.0
		Control	4.9	36.0	27.0
6.	*Albizia lebbek*	0.00-0.25	7.3	31.6	22.6
		0.25-0.50	5.8	35.0	20.4
		0.50-0.75	6.2	41.0	28.0
		Control	6.9	38.0	26.0
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.0	14.0
		0.25-0.50	4.9	44.0	26.0
		0.50-0.75	4.5	4.0	22.0
		Control	3.5	36.5	22.1

Table A27: Growth characteristics of seedlings planted in lysimetric tanks during March 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	28.0	21.0
		0.25-0.50	6.6	31.0	23.0
		0.50-0.75	6.8	29.0	22.0
		Control	2.0	26.0	15.0
2.	*Pongamia pinnata*	0.00-0.25	4.9	31.0	21.0
		0.25-0.50	4.9	38.0	18.5
		0.50-0.75	4.8	31.5	19.5
		Control	4.2	29.0	16.0
3.	*Dalbergia sissoo*	0.00-0.25	5.2	42.0	31.0
		0.25-0.50	5.9	37.5	28.9
		0.50-0.75	5.7	43.0	33.0
		Control	4.9	31.0	17.0
4.	*Acacia nilotica*	0.00-0.25	4.7	29.1	19.2
		0.25-0.50	4.8	31.5	20.5
		0.50-0.75	4.8	30.0	14.0
		Control	4.6	31.0	23.0
5.	*Albizia procera*	0.00-0.25	3.1	21.0	12.0
		0.25-0.50	6.1	40.0	30.5
		0.50-0.75	6.1	31.0	22.0
		Control	4.9	37.0	30.0
6.	*Albizia lebbek*	0.00-0.25	7.4	32.0	23.0
		0.25-0.50	5.8	36.0	22.0
		0.50-0.75	6.2	41.0	28.0
		Control	6.9	38.0	26.0
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.0	15.0
		0.25-0.50	4.9	46.0	26.0
		0.50-0.75	4.5	40.0	23.0
		Control	3.5	36.5	22.1

Table A28: Growth characteristics of seedlings planted in lysimetric tanks during April 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	28.2	21.4
		0.25-0.50	6.6	31.0	23.4
		0.50-0.75	6.8	29.1	22.4
		Control	2.1	26.5	16.0
2.	*Pongamia pinnata*	0.00-0.25	4.9	31.3	21.2
		0.25-0.50	4.9	38.0	18.9
		0.50-0.75	4.8	31.6	19.6
		Control	4.2	29.5	16.5
3.	*Dalbergia sissoo*	0.00-0.25	5.7	42.2	31.2
		0.25-0.50	5.9	37.6	29.0
		0.50-0.75	5.8	43.6	33.4
		Control	4.9	31.5	17.5
4.	*Acacia nilotica*	0.00-0.25	4.7	29.4	19.6
		0.25-0.50	4.8	31.6	20.8
		0.50-0.75	4.8	30.5	15.6
		Control	4.6	31.0	23.5
5.	*Albizia procera*	0.00-0.25	3.1	21.3	12.2
		0.25-0.50	6.2	40.0	30.8
		0.50-0.75	6.1	31.4	22.4
		Control	4.9	37.5	30.5
6.	*Albizia lebbek*	0.00-0.25	7.4	32.2	23.4
		0.25-0.50	5.9	36.0	22.5
		0.50-0.75	6.2	41.5	28.2
		Control	7.0	38.0	26.5
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.2	15.1
		0.25-0.50	4.9	46.2	26.5
		0.50-0.75	4.5	40.5	23.6
		Control	3.5	37.0	22.5

Table A29: Growth characteristics of seedlings planted in lysimetric tanks during May 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	28.3	21.5
		0.25-0.50	6.6	31.0	23.4
		0.50-0.75	6.8	29.4	22.7
		Control	2.1	26.5	16.2
2.	*Pongamia pinnata*	0.00-0.25	4.9	31.3	21.2
		0.25-0.50	5.0	38.0	19.0
		0.50-0.75	4.8	31.6	19.7
		Control	4.9	29.5	16.5
3.	*Dalbergia sissoo*	0.00-0.25	5.2	42.2	31.4
		0.25-0.50	5.9	37.7	29.0
		0.50-0.75	5.8	43.6	33.4
		Control	4.9	31.5	17.5
4.	*Acacia nilotica*	0.00-0.25	4.7	29.4	19.6
		0.25-0.50	4.8	31.9	20.9
		0.50-0.75	4.8	30.5	16.0
		Control	4.6	31.2	23.8
5.	*Albizia procera*	0.00-0.25	3.1	21.4	12.2
		0.25-0.50	6.2	40.0	30.9
		0.50-0.75	6.1	31.6	22.7
		Control	4.9	37.5	30.5
6.	*Albizia lebbek*	0.00-0.25	7.3	32.2	23.4
		0.25-0.50	5.9	36.0	22.6
		0.50-0.75	6.2	41.6	28.3
		Control	7.0	38.6	26.7
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.5	15.2
		0.25-0.50	4.9	46.2	26.5
		0.50-0.75	4.5	40.7	23.8
		Control	3.5	37.2	22.5

Table A30 : Growth characteristics of seedlings planted in lysimetric tanks during June 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	4.8	28.3	21.5
		0.25-0.50	6.6	31.2	23.6
		0.50-0.75	6.9	29.4	22.7
		Control	2.5	27.0	16.5
2.	*Pongamia pinnata*	0.00-0.25	4.9	31.5	21.3
		0.25-0.50	5.2	38.2	19.3
		0.50-0.75	4.8	31.7	19.8
		Control	4.2	29.7	16.7
3.	*Dalbergia sissoo*	0.00-0.25	5.2	42.3	31.6
		0.25-0.50	5.9	37.8	29.2
		0.50-0.75	5.9	43.7	33.5
		Control	4.9	31.7	17.6
4.	*Acacia nilotica*	0.00-0.25	4.7	29.5	19.7
		0.25-0.50	4.8	31.9	20.9
		0.50-0.75	4.9	30.7	16.2
		Control	4.8	31.5	23.9
5.	*Albizia procera*	0.00-0.25	3.1	21.4	12.3
		0.25-0.50	6.2	40.2	31.0
		0.50-0.75	6.1	31.7	22.8
		Control	5.1	37.8	30.7
6.	*Albizia lebbek*	0.00-0.25	7.4	32.3	23.5
		0.25-0.50	5.9	36.2	22.8
		0.50-0.75	6.3	41.7	28.6
		Control	7.0	38.1	26.7
7.	*Terminalia arjuna*	0.00-0.25	4.1	39.3	16.3
		0.25-0.50	4.9	46.3	26.6
		0.50-0.75	4.5	40.7	23.8
		Control	3.6	37.6	22.8

Table A31: Growth characteristics of seedlings planted in lysimetric tanks during July 2011.

S. No.	Species Name	Water Level (m)	Height (m)	Basal Girth (cm)	GBH (cm)
1.	*Eucalyptus hybrid*	0.00-0.25	5.8	28.5	23.1
		0.25-0.50	7.1	31.2	23.6
		0.50-0.75	6.9	31.2	24.1
		Control	2.7	27.0	16.5
2.	*Pongamia pinnata*	0.00-0.25	4.9	31.5	21.5
		0.25-0.50	6.1	43.7	24.9
		0.50-0.75	4.9	35.2	20.2
		Control	4.2	29.8	16.8
3.	*Dalbergia sissoo*	0.00-0.25	5.9	43.6	31.6
		0.25-0.50	6.2	39.0	31.4
		0.50-0.75	6.5	45.8	34.2
		Control	5.0	32.0	18.3
4.	*Acacia nilotica*	0.00-0.25	5.2	29.5	20.1
		0.25-0.50	4.8	31.9	20.9
		0.50-0.75	5.5	30.7	17.2
		Control	4.9	31.6	24.0
5.	*Albizia procera*	0.00-0.25	3.6	24.1	12.9
		0.25-0.50	8.0	40.0	31.1
		0.50-0.75	6.5	34.0	25.7
		Control	6.5	37.8	32.4
6.	*Albizia lebbek*	0.00-0.25	7.4	34.0	24.2
		0.25-0.50	5.9	36.5	22.8
		0.50-0.75	7.0	44.0	28.5
		Control	7.1	38.2	26.8
7.	*Terminalia arjuna*	0.00-0.25	4.2	41.1	17.2
		0.25-0.50	5.5	46.4	27.8
		0.50-0.75	4.5	40.7	24.2
		Control	3.6	37.6	22.8

Appendix B

Table B1: Mean monthly meteorological data of Jabalpur during 2005 -2010.

Month	Mean monthly temperature (^{0}C.)		Mean monthly relative humidity (%)		Mean monthly rainfall (mm)	Mean monthly sunshine hours	Mean monthly wind velocity (km/hr.)
	Max.	Min.	Max.	Min.			
2005							
January	23.8	10.0	93	46	81	6.7	2.5
February	27.0	12.4	85	37	4.5	8.5	3.0
March	33.2	17.0	72	27	31.1	8.3	3.5
April	37.4	19.1	54	15	5.2	8.5	3.4
May	40.8	24.6	37	13	9.2	9.1	4.6
June	39.8	27.6	50	31	138.0	5.5	5.3
July	29.8	24.3	90	77	858.6	4.0	6.4
August	29.4	24.2	90	74	323.6	6.1	5.6
September	30.8	23.8	90	71	390.0	5.7	4.4
October	30.2	18.8	90	48	5.2	7.5	2.2
November	28.6	10.6	91	25	0	8.5	1.5
December	24.4	7.3	93	33	7.2	7.6	1.6
2006							
January	25.1	8.0	90	33	0.0	8.9	1.8
February	31.2	12.4	83	5.0	0.0	9.3	1.7
March	30.2	15.7	79	38	77.2	7.8	2.9
April	38.0	20.9	47	17	1.6	8.8	4.4
May	40.3	26.2	52	23	49.5	8.0	6.1
June	38.2	27.5	57	34	91.8	6.3	6.7
July	29.2	24.4	89	77	350.7	3.2	7.4
August	29.2	23.9	91	77	358.6	4.0	6.3
September	31.1	23.6	89	63	85.5	7.0	3.4
October	32.2	20.0	83	43	3.0	8.2	2.6
November	28.8	14.2	88	39	19.8	7.3	1.4
December	26.1	10.6	91	37	0.3	7.6	1.6

Month	Mean monthly temperature (⁰C.)		Mean monthly relative humidity (%)		Mean monthly rainfall (mm)	Mean monthly sunshine hours	Mean monthly wind velocity (km/hr.)
	Max.	Min.	Max.	Min.			
				2007			
January	25.3	8.5	89	32	0.0	8.1	1.8
February	27.5	12.4	90	37	83.4	8.5	2.3
March	31.6	14.8	77	27	47.6	8.8	2.6
April	38.8	21.4	54	15	1.7	9.4	3.8
May	40.7	25.6	47	18	1.6	8.5	5.5
June	38.2	27.6	65	40	88.6	6.5	6.5
July	30.6	24.4	89	70	388.9	4.1	5.2
August	29.8	24.1	91	74	357.1	4.2	3.3
September	31.2	23.8	91	69	213.6	5.7	2.3
October	31.3	16.4	88	36	0.0	8.5	1.5
November	29.0	11.1	92	29	0.0	7.8	1.5
December	25.3	8.6	93	41	6	7.1	2.0
				2008			
January	24.1	7.8	89	39	2.6	7.8	2.4
February	25.7	6.9	84	29	4.4	9.1	3.0
March	34.3	15.6	72	23	1.4	8.2	4.1
April	38.5	18.6	52	13	0.0	9.6	4.4
May	40.7	24.8	42	17	10.4	9.1	7.1
June	34.1	23.8	82	58	496.5	5.6	7.6
July	31.0	24.0	89	72	325.5	3.3	7.6
August	30.9	22.2	93	73	453.7	3.9	6.0
September	32..2	21.4	89.5	62.3	90.8	6.7	4.6
October	32.7	16.0	86.5	39.5	13.4	8.4	2.2
November	30.2	11.2	86.5	31.8	0.0	7.0	1.8
December	27.5	8.2	90.6	34.4	0.0	7.2	1.5

Month	Mean monthly temperature (^0C.)		Mean monthly relative humidity (%)		Mean monthly rainfall (mm)	Mean monthly sunshine hours	Mean monthly wind velocity (km/hr.)
	Max.	Min.	Max.	Min.			
2009							
January	25.6	10.6	92.3	49.28	37.8	7.1	2.1
February	29.0	10.2	85.7	29.50	0	9.5	2.1
March	34.4	13.8	70.6	19.40	2.0	8.1	2.9
April	38.8	17.5	51.2	13.30	0	9.7	4.2
May	42.1	25.1	44.2	16.80	14.6	8.8	6.5
June	41.6	27.3	50.5	22.00	64.4	7.3	7.9
July	31.5	24.0	89.2	70.00	506.5	3.1	7.1
August	31.6	23.3	90.0	68.80	348.2	5.0	7.9
September	32.3	22.5	87.7	60.75	441.8	8.2	5.6
October	32.2	17.4	87.4	39.14	42.8	8.3	3.3
November	28.4	12.2	90.0	39.80	55.7	7.5	2.3
December	26.3	10.0	92.5	46.00	25.4	7.5	1.9
2010							
January	23.3	7.9	93.0	42.0	12.4	8.0	1.7
February	30.2	11.6	85.0	28.7	0	7.8	2.3
March	36.3	17.1	67.5	19.5	2.8	9.1	3.4
April	41.0	22.1	38.5	10.0	0	9.7	4.8
May	41.4	26.8	37.6	16.0	0	5.6	7.4
June	40.0	26.1	60.7	33.5	107.3	6.3	8.0
July	32.2	24.6	88.0	71.0	441.9	3.3	5.9
August	32.6	23.4	86.2	69.0	471.5	3.9	5.3
September	31.8	22.5	91.0	63.7	511.2	5.1	4.2
October	31.4	18.7	90.4	48.0	79.8	8.6	3.1
November	30.1	16.6	91.0	49.7	1.4	6.4	2.8
December	25.0	8.5	87.5	34.7	7.6	8.1	3.0