ISSN: 0973-4929, Vol. 16, No. (3) 2021, Pg. 794-803

Current World Environment

www.cwejournal.org

Performance of Tree Species on Waterlogged Sites of Canal Command Area: A Case Study of Bargi Dam, Jabalpur (M.P.)

AVINASH JAIN*, DHEERAJ GUPTA, SAIKAT BANERJEE and RAMU NAIK

Forest Ecology and Climate Change Division, Tropical Forest Research Institute, P.O. – RFRC, Mandla Road, Jabalpur, M.P, India.

Abstract

Bio-drainage is removal of excess soil water through bio-energy of fast-growing tree species having higher transpiration rate. Seven tree species viz. *Albizia lebbek, Albizia procera, Acacia nilotica, Dalbergia sissoo, Eucalyptus tereticornis*, FRI-4 and FRI-5 clones of *Eucalyptus* hybrid, *Terminalia arjuna* and *Pongamia pinnata* were evaluated for their performance through growth characteristics and biomass studies by planting on waterlogged sites on the bank of Left Bank Canal (LBC) of Bargi command area, Jabalpur district of Madhya Pradesh state (India). *Eucalyptus* hybrid, followed by *Pongamia pinnata* exhibited maximum height and biomass accumulation and its allocation to leaves and branches after four years of plantation, attributing the most desirable species for reclaiming waterlogged sites along canal command areas with similar edaphic and climatic conditions.

Article History
Received: 11 July 2020
Accepted: 03 November 2021

Keywords
Bargi Dam;
Biodrainage;
Canal Command Area;
Tree Species;
Waterlogged.

Introduction

Agriculture sector in India contributes 17% in the Gross Domestic Product (GDP) engaging 54.6% of the population of the country. Out of total 328.7 million hectares geographical area of the country, net sown area is 140.10 million hectares while 198.40 million hectares is the gross cropped area with 142% cropping intensity. However, the irrigated area is 68.4 million hectares as per the land use statistics 2013-14.[1] Northern rivers owing to perennial in nature have enhanced water storage in the dams and provide irrigation facility as an important means of promising water supply through the network of canals in northern plains for the states of Punjab, Haryana, Uttar Pradesh, Rajasthan and Bihar. In spite of much higher initial cost, canal irrigation has its advantages of enhancing soil fertile by bringing down a huge amount of sediments from the rivers.[2] When the root zone of plant gets flooded with water and subsequent adverse effect on the crop productivity, the land is called to be waterlogged,[3] which is one of the drawbacks of canal irrigation. This

CONTACT Avinash Jain jainavi@yahoo.com Forest Ecology and Climate Change Division, Tropical Forest Research Institute, P.O. – RFRC, Mandla Road, Jabalpur, M.P, India.

Doi: http://dx.doi.org/10.12944/CWE.16.3.12

makes the high-water table in the agricultural land and affects more than 33 % of the World's irrigated land along with salinity.[4] However, in India itself, the extent of waterlogged area is 5.5-million-hectare in irrigated land out of total 8.4 million hectare affected area of soil alkalinity and salinity.[5,6]

Biodrainage is defined as the vertical drainage of waterlogged soils in irrigated canal commands by strategically planting tree vegetation which is increasingly catching the fancy of techno-scientific community of agricultural soil water management.[7,8,9,10,11] The consumptive use of water by trees and consequent lowering of water table of waterlogged soils through biodrainage is an established concept. There is paucity of information on the comparative biodrainage potential of different tree species and on their morpho-physiological traits. Recent perusal of literature evidences that majority of workers have raised biodrainage plantations using *Eucalyptus* trees only. The present study aims at evaluation of performance of seven tree species planted on the bank of Left Bank Canal of command area of Bargi dam in Somti, Jamuniya and Dabhola villages in Jabalpur district of M.P.

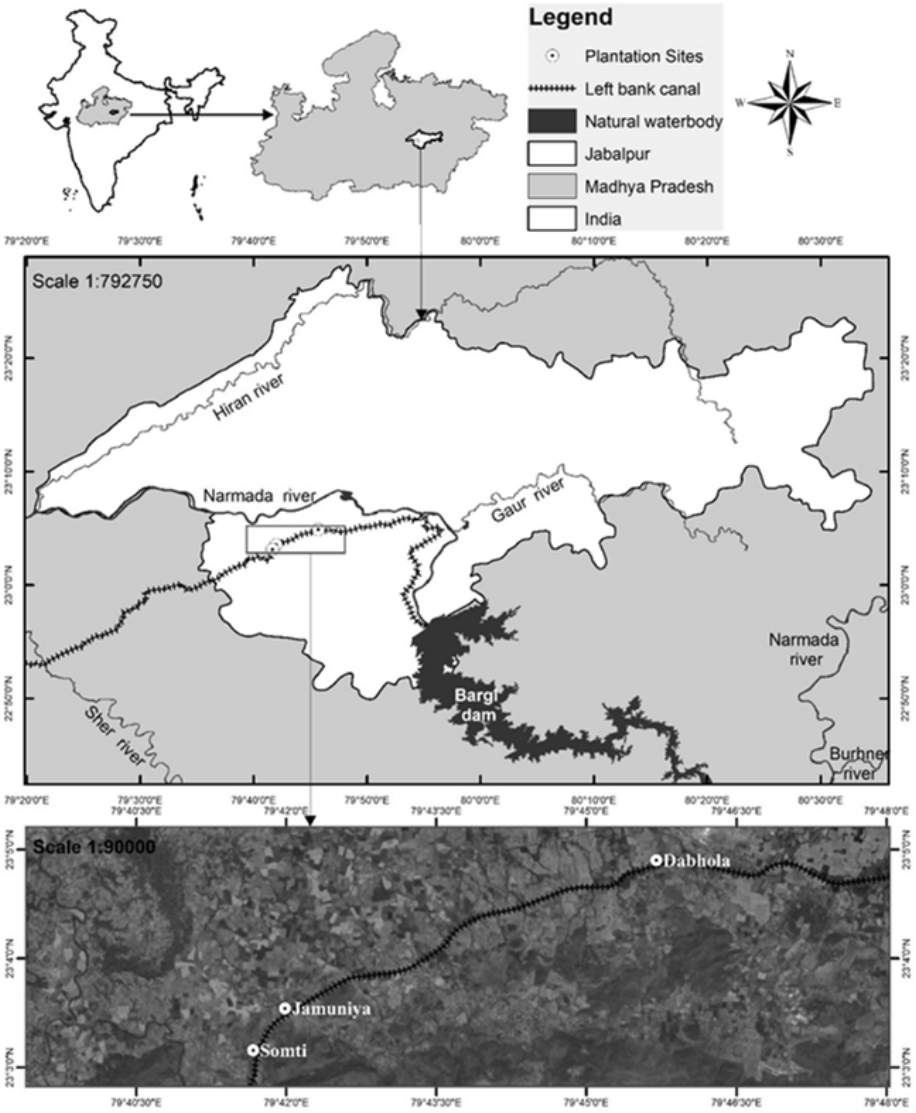


Fig. 1: Location map of study sites along left bank canal of Bargi command area

Materials and Methods

Selection of Sites

The study sites were selected along the left canal of Bargi dam for experimentation and plantation of forest tree species. Waterlogged sites were selected in 3 villages namely, Jamuniya (23°03'32.5"N; 79°41' 59.3"E), Somti (23°03'09.3"N; 79°41'40.1"E) and Dabhola (23°04'54.2"N; 79°45'42.0"E) with the total area of 10 ha (Fig. 1).

Collection and Analysis of Soil Samples

Three soil profiles were excavated and different soil horizons were studied in detail about 30 m away from the canal near Somti, Jamuniya and Dabhola villages. The soil samples from different horizons were collected, processed and subjected to physico-chemical analysis for the quantification of pH, electrical conductivity, salt concentration, CEC, organic carbon, available nutrients, exchangeable cations viz., Na, K, Ca and Mg, mechanical analysis including percent content of sand, silt and clay and texture of the soil samples.[12,13,14,15]

Raising Plantation of Tree Species

Seeds from phenotypically superior trees of *Albizia lebbek, Albizia procera, Acacia nilotica, Dalbergia sissoo, Eucalyptus tereticornis, Terminalia arjuna and Pongamia pinnata* were collected, while seeds of FRI-4 and FRI-5 clones of *Eucalyptus* were procured from Forest Research Institute, Dehradun (Uttarakhand). The seedlings of these species were raised in Modern Technical Nursery of Tropical Forest Research Institute, Jabalpur and maintained for about one year in polybags through regular watering, weeding, cleaning and shifting.

A plantation of the selected seven tree species covering 10 ha area was raised at Somti, Jamuniya and Dabhola villages along LBC and biofenced by Agave americana and Jatropha curcas. *Albizia lebbek*, *Albizia procera*, *Eucalyptus tereticornis*, *Eucalyptus* hybrid (FRI-4 and FRI-5), *Terminalia arjuna* and *Dalbergia sissoo* were planted at low lying areas of Somti with shallow soil, which remains waterlogged most of the times when the canal runs. The seedlings of *Pongamia pinnata* and *Acacia nilotica* were planted near Jamuniya village on the land with very shallow soil because the actual soil was used to construct the canal and unfertile land filled with boulders was left along the canal. *Eucalyptus tereticornis* and *Terminalia arjuna* seedlings were planted at Dabhola on the farmer's field which was again a low lying area. The spacing between the seedlings of all the planted tree species was maintained at 2m x 2m, while *Eucalyptus tereticornis* seedlings were planted at both 2m x 2m and 1m x 1m spacing.

Measuring Growth and Biomass of Seedlings

Growth characteristics of seedlings viz. height and girth were recorded using measuring tape on quarterly basis for 4 years or 16 quarters starting from September (Post-monsoon) of first year to June (Pre-monsoon) of fifth year. Biomass studies of the seedlings were conducted after 4 years by destructive method.[16] After completion of the experiment, seedlings were uprooted, washed, plant parts like stem, branches, leaves and roots were separated, dried in oven and weighed.

Statistical Analysis

The growth and biomass data were statistically analysed using SX software. Analysis of variance (ANOVA) was calculated and critical difference at 1% and 5% significant level was estimated. Standard error mean was also calculated.

Results and Discussion

The data on growth and dry biomass of four years old plants of the selected seven tree species planted at Somti, Jamuniya and Dabhola are given in Table 1, while percent increase in growth characteristics has been depicted in Fig. 2. Average height of *Eucalyptus* hybrid seedlings increased 3.31 times from 1.05m to 4.53m and girth increased 10.35 times from 1.98cm to 22.48cm during the study period of sixteen quarters. During last two decades, *Eucalyptus* has been planted on large scale in the country because this species is fast-growing and becomes the part of 'social forestry' programmes providing fuel and timber to the rural communities.[17] Eucalyptus plantations have always been debatable between environmentalists and foresters, wherein the later support it due to not able to meet the ever increasing demand of local communities and industries for wood from the natural forests, while environmentalists oppose its plantations due to its alleged ecological consequences on soil and ground water.[18] Along the canal, *Eucalyptus* planted with both spacing grew together initially 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.[16] The seedlings raised with the seeds collected from *Eucalyptus tereticornis* 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 *Eucalyptus tereticornis* 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.

Initially the growth of *Pongamia pinnata* and *Acacia nilotica* seedlings was slow, but after establishment of roots in the soil, the growth rapidly increased. At the time of plantation the average height and girth of *Pongamia pinnata* seedlings was 0.35m and 2.10cm, which increased to 4.22m and 25.15cm, respectively at the end of experiment. Similarly, height and girth of *Acacia nilotica* seedlings increased from 0.51m and 0.77cm to 3.45m and 15.86cm, respectively during this period. *Dalbergia sissoo* is a nitrogen fixing and highly preferred fodder tree species but its growth was found slower than *Eucalyptus* hybrid and Pongamia pinnata, which attained the average height and girth of 2.85m and 31.90cm respectively after 4 years of experimentation.

Albizia procera and *Albizia lebbek* belonging to family Fabaceae are fast growing nitrogen fixing tree species. *A. procera,* is the preferred tree species in agroforestry systems and the plantations of this species are raised for wood, fodder and shade in tea plantations.[20] Distribution of this species in mixed deciduous forests exhibit its dominance, generally present either as scattered individuals or in small groups in the country.[21,22] *A. lebbek* is valued for shade, quality hardwood, fuel wood and forage, which prefers well drained soil and not adapted to heavy clay or water logged soils. At the time of plantation, average height of *Albizia procera* seedlings was 0.67m, which increased to 1.15m in the successive year, but due to die back new sprouting started from 0.55m height during rainy season, then attained the height of 2.35m at the end of experiment. Girth of *Albizia procera* seedlings increased from 0.62cm to 21.23cm during study period. Die back also occurred in *Albizia lebbek* seedlings in the next year of its plantation. Height and girth of seedlings of this species increased from 0.48m and 1.55cm to 1.96m and 18.98cm, respectively during the study period. Also, plants die-back during summers of first two years due to the absence of sufficient moisture content in the soil, however these plants again sprout in the next rainy season.[23]

Terminalia arjuna is a slow growing tree species and is commonly found along rivers, streams, nallahs throughout the country. The seedlings of this species were planted along the nallah crossing below the canal, because this tree species can survive under half submergence conditions for long periods.[24] The growth of this tree species was found slow reaching the height of 2.19m and attaining girth of 13.06cm after 4 years of plantation. Seedlings of this species survived even under submergence conditions especially during rainy season, when overflow in the nallah occurred.

Among the selected tree species, 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) at the end of experiment. 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) (Table 1).

Similarly, maximum dry biomass per tree was recorded in *E. hybrid* (50.91kg), followed by *P. pinnata* (20.24 kg) and *D. sissoo* (16.09 kg) (Table 3). Minimum dry biomass per tree 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 (Fig. 3). The biomass of *E. hybrid* was recorded about 4 times compared to *A. lebbek* and *A. nilotica*, while the biomass of *P. pinnata* was recorded to be 1.5 times as compared to these species. Biomass allocation to leaves + branches was maximum in *P. pinnata* (39.77%), followed by *T. arjuna* (39.50%) and *D. sissoo* (38.41%), while it was found minimum in *A. nilotica* (20.76%). Biomass allocation to stem compared to total biomass was recorded maximum in *E. hybrid* (58.59%), followed by *A. nilotica* (47.35%).

Table 1: Growth characteristics of the selected tree species for the study period

Year (Quarter)	*Eucalyptus spp.*		*P. pinnata*		*D. sissoo*		*A. nilotica*		*A. procera*		*A. lebbek*		*T. arjuna*	
	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth (cm)	Ht (m)	Basal girth(cm)
1 (3)	1.05	1.98	0.35	2.1	0.1	1.91	0.51	0.77	0.67	0.62	0.48	1.55	0.57	1.92
1 (4)	1.19	2.59	0.65	3.32	0.33	6.23	0.62	1.98	0.83	0.79	0.63	2.04	0.78	2.68
2 (1)	1.3	4.31	0.79	3.45	0.39	9.21	0.73	2.42	1.15	0.82	0.92	2.51	0.82	3.01
2 (2)	1.4	5.03	0.92	5.96	0.42	12.69	0.87	3.39	0.55	1.01	0.36	3.38	0.87	3.49
2 (3)	1.63	7.02	1.25	8.62	0.61	15.08	1.04	4.02	0.83	1.97	0.59	3.83	0.98	5.06
2 (4)	1.75	8.85	1.63	11.26	0.78	17.49	1.31	5.89	1.12	2.91	0.87	4.23	1.15	7.11
3 (1)	1.92	9.14	1.81	12.26	0.84	18.32	1.43	6.29	1.26	3.69	0.99	5.67	1.2	8.24
3 (2)	2.21	9.79	2.02	13.42	0.9	19.01	1.68	7.45	1.33	4.52	1.17	6.91	1.24	8.69
3 (3)	2.26	10.92	2.65	15.26	1.12	21.9	2.08	8.06	1.59	7.09	1.34	9.49	1.46	9.35
3 (4)	2.49	12.15	3.09	17.46	1.26	23.1	2.46	9.98	1.88	10.76	1.57	12.26	1.69	10.03
4 (1)	2.56	13.97	3.21	18.52	1.31	24.5	2.59	10.59	1.99	12.45	1.6	13.72	1.71	10.19
4 (2)	2.62	15.35	3.43	19.73	1.35	25.8	2.72	11.37	2.09	15.89	1.68	14.69	1.75	10.67
4 (3)	3.19	17.55	3.75	21.26	1.89	27.5	2.89	12.01	2.18	16.63	1.73	16.52	1.94	11.89
4 (4)	3.92	19.18	4.1	23.82	2.6	29.8	3.21	13.89	2.29	18.23	1.84	17.75	2.09	12.56
5 (1)	4.01	19.56	4.16	24.65	2.72	30.1	3.32	14.23	2.31	20.61	1.91	18.25	2.11	12.91
5 (2)	4.53	22.48	4.22	25.15	2.85	31.9	3.45	15.86	2.35	21.23	1.96	18.98	2.19	13.06

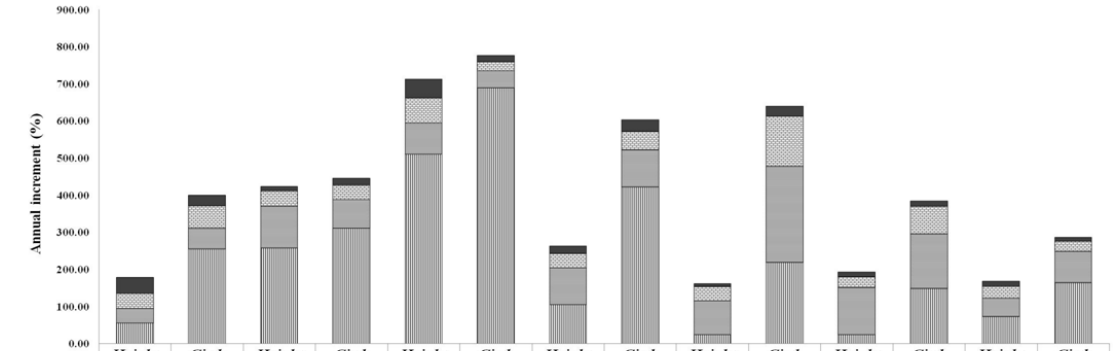
Table 2: Growth and dry biomass of four years old trees planted along LBC of Bargicommand area

Tree species	Growth data				Above ground biomass (kg)			Below ground biomass (kg)	Total biomass (kg)	Average annual biomass (t.ha-1)
	Height (m)	GBH (cm)	Basal girth (cm)	Root length (cm)	Stem	Branch	Leaves	Roots		
Eucalyptus spp.	7.51	40	52.2	136.1	29.83	6.31	7.75	7.02	50.91	28.28
P. pinnata	4.73	22.5	31.3	147	7.66	5.51	2.54	4.53	20.24	11.24
D. sissoo	2.95	35.6	39.1	96	6.4	4.95	1.23	3.51	16.09	8.94
A. nilotica	2.75	21.6	33.1	119.2	6.25	2.46	0.28	4.21	13.2	7.33
A. procera	2.51	24.8	32.3	88	6.2	3.81	1.01	3.6	14.62	8.12
A. lebbek	2.06	21.4	31.7	72	5.4	3.5	0.95	3.31	13.16	7.31
T. arjuna	2.33	15.8	20.2	66.4	5.9	3.73	2.12	3.06	14.81	8.23
CD0.05	0.3781	3.6614	2.3542	20.902	1.8461	0.1886	0.1333	0.3456		
CD0.01	0.5301	5.133	3.3005	29.304	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.**

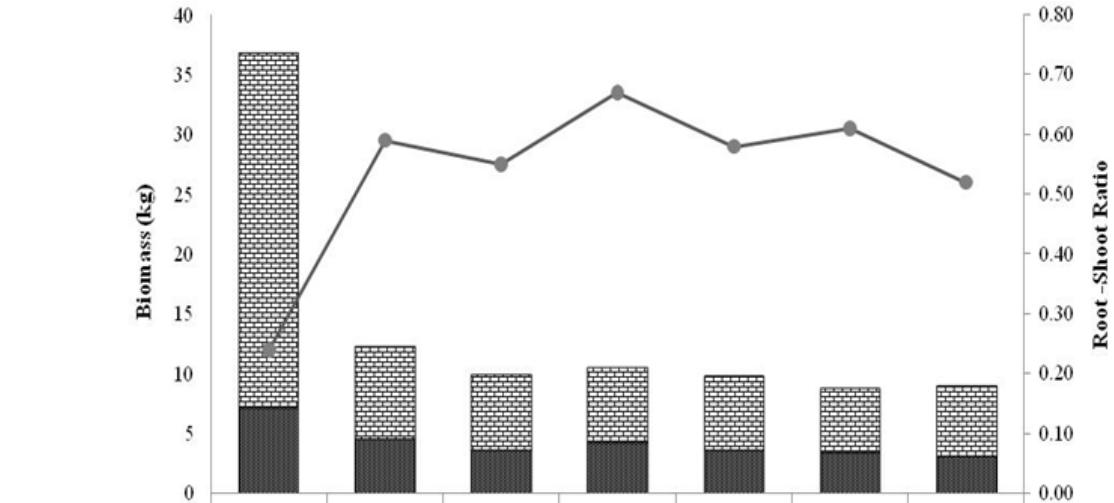
Table 3 : Physicochemical characteristics of soil in different horizons of Somti, Jamuniya and Dabhola sites

Site	Depth (cm)	Horizon	pH	EC (dSm^{-1})	Salt conc. (ppt)	Mechanical composition (%)			Soil texture	Organic carbon (%)	Available nutrients ($kg.ha^{-1}$)				Exchangeable cations ($m\ eq.100g^{-1}$)			CEC ($m\ eq.100g^{-1}$)
						Sand	Silt	Clay			N	P_2O_5	K_2O	Ca	Mg	Na	K	
Somti	10-13	A	8.7	0.253	0.2	61	26	22	SCL	0.31	156.80	33.11	132.00	23.60	3.20	3.43	0.44	31.80
	13-19	B1	8.5	0.158	0.2	34	34	32	CL	0.25	62.72	39.13	130.50	17.80	5.20	3.66	0.29	28.00
	19-22	B2	7.9	0.085	0.1	32	38	30	CL	0.22	47.04	48.18	121.50	13.40	2.40	1.51	0.07	18.80
	22-42	B2 Ca1	8.0	0.105	0.1	68	24	8	SL	0.15	94.08	54.20	115.50	16.20	2.40	1.53	0.09	22.00
	42-69	B2 Ca2	8.1	0.075	0.1	66	26	8	SL	0.10	62.72	60.22	132.00	10.20	3.60	1.50	0.07	17.20
Jamuniya	0 -16	A	7.9	0.140	0.2	34	46	20	L	0.84	94.08	129.47	189.00	24.60	2.80	1.79	0.32	30.60
	16 -36	B	7.8	0.077	0.2	62	14	24	SCL	0.41	78.40	159.59	127.50	21.80	2.00	1.23	0.27	28.80
Dabhola	0 -17	A	7.3	0.069	0.1	28	36	36	CL	0.26	78.40	168.63	172.50	9.40	2.00	1.07	0.36	14.80
	17-32	B1	7.8	0.106	0.1	30	64	6	SL	0.40	125.44	177.65	130.50	10.20	2.00	0.95	0.19	14.40
	32-49	B2 Ca1	8.0	0.286	0.3	10	84	42	SI	0.28	94.08	168.63	136.50	9.98	2.40	1.08	0.28	15.50
	49+	B2 Ca2	8.2	0.163	0.1	16	30	54	C	0.25	47.04	156.59	130.50	11.98	2.40	1.18	0.25	17.00



	Eucalyptus spp.		Pongamia pinnata		Dalbergia sissoo		Acacia nilotica		Albizia procera		Albizia lebbek		Terminalia arjuna	
	Height	Girth	Height	Girth	Height	Girth	Height	Girth	Height	Girth	Height	Girth	Height	Girth
Year (4-5)	42.01	28.09	12.53	18.30	50.79	16.00	19.38	32.06	7.80	27.66	13.29	14.89	12.89	9.84
Year (3-4)	41.15	60.71	41.51	39.32	68.75	25.57	38.94	49.01	37.11	134.56	29.10	74.08	32.88	27.17
Year (2-3)	38.65	55.56	112.00	77.03	83.61	45.23	100.00	100.50	91.57	259.90	127.12	147.78	48.98	84.78
Year (1-2)	55.24	254.55	257.14	310.48	510.00	689.53	103.92	422.08	23.88	217.74	22.92	147.10	71.93	163.54

Fig. 2: Annual increment (%) in height and basal girth of planted tree species along left bank canal, Bargi command area



	E. hybrid	P. pinnata	D. sissoo	A. nilotica	A. procera	A. lebbek	T. arjuna
Shoot	29.83	7.66	6.40	6.25	6.20	5.40	5.90
Root	7.02	4.53	3.51	4.21	3.60	3.31	3.06
Root-Shoot Ratio	0.24	0.59	0.55	0.67	0.58	0.61	0.52

Fig. 3: Root-shoot dry biomass ratio of trees planted along left bank canal, Bargi command area

Annual biomass produced by four years old trees of different species considering 2m x 2m distance between trees and accommodating 2500 trees per hectare was quantified. *Eucalyptus* spp. accumulated 28.28 t/ha biomass annually, which was the maximum 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). Above ground biomass in high density plantations of *Eucalyptus tereticornis*, irrigated with secondary treated sewage water has been estimated to be 24.1 t/ha, followed by A. excelsa (21.8 t/ha) and Melia azedarach (12.6 t/ha).[25]

The profile soil of Somti varies from strongly alkaline to moderately alkaline, however in Jamunia site

where soil depth is 36 cm only, soil is mildly alkaline. But at Dabhola site soil range from mildly alkaline to moderately alkaline with depth of the soil. Electrical conductivity of the soil in the selected sites is comparatively low resulting low base saturation. Mechanical composition of the 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, the texture of the soil has been found as sandy clay loam to clay loam, which changes to sandy loam in the deeper layers of soil. 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 where soil depth is very shallow, loam to sandy clay loam textured soil is found. But at Dabhola site mechanical composition of the soil is little different, where texture of the soil on the surface and lower layers become heavier where as in the middle layer it shows loose texture.

Soil organic carbon is less because of the low crop density in the study sites.[26] However, it is comparatively higher in surface layer of Somti and Jamunia which further 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. The concentration of available nitrogen is low in all three profile sites due to low crop density and less amount of litter present on the floor. Available phosphorous content is very high in all three studied profile sites because parent rock contains high amount of total phosphorous (Granite). The concentration of available potassium is in medium range (120-280 kg/ha) in all the three studied profile sites. In Somti and Jamunia site exchangeable cations are comparatively higher in the surface layer, which 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. The Cation Exchange Capacity (CEC) is positively correlated with the type and amount of clay minerals and organic carbon and also indicates 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 CEC indicates that soil might have contained kaolinite, illite and muscovite type of mixed clay minerals present in all the soil profiles.

Higher growth characteristics and biomass accumulation in *E. hybrid* and *P. pinnata* and proportionately higher biomass allocation to leaves and branches attribute these tree species the most desirable for reclaiming waterlogged sites along canal command areas with similar edaphic and climatic conditions.

Conclusion

Tree plantations with comparatively deep rooting system consume more water than shorter vegetation by extracting water from several meters down the earth's surface. The trees having higher growth and transpiration rates can be used for reclaiming waterlogged sites through transforming their nutrient energy into wood biomass. In the present study, *Eucalyptus* hybrid and *Pongamia pinnata* plantations performed better than other tree species coinciding water consumption with their growth and biomass accumulation. Hence, the plantations of these species can be raised along the canal with proper spacing between the trees and rows and required amendments to manage the ground water table through the process of biodrainage and to enhance the production of agricultural crops.

Acknowledgements

The authors are thankful to Indian National Committee on Irrigation and Drainage (INCID), Ministry of Water Resources, New Delhi for providing financial assistance to conduct the study. Authors also thank the officers and engineers of Rani Avanti Bai Lodhi Sagar Pariyojana, Jabalpur and M.P. state forest department for providing 10 hectare land for raising plantation of tree species along LBC. Authors are grateful to Director and Group Coordinator Research of Tropical Forest Research Institute, Jabalpur for imparting continuous guidance and support during the execution of research project. Finally, thanks are also due to technical officers and staff of Forest Ecology and Climate Change Division for raising plantation and analysing soil samples in laboratory.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest
The authors do not have any conflict of interest.

Obituary
It is with the profoundest regret that we must report the passing of Prof Shri Ramu Naik Orcid Id: 0000-0003-3650-9469. We express our most sincere condolences to his family, colleagues and friends.

References

1. Department of Agriculture. Annual Report 2016-17. Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare: Government of India; 2017.
2. Goyal V.C, Jain S.K, Pareek N. Water logging and drainage assessment in Ravi-Tawi irrigation command (J&K) using remote sensing approach. *Indian Soc Remote Sens.* 2005; 33(7). https://doi.org/10.1007/BF02989986.
3. Pandey A. Environmental impacts of canal irrigation in India. *Mediterr J Soc Sci*. 2013; 4(11): 138-143.
4. Denecke H. W. Concept note on biodrainage and bio-disposal system. Food and Agriculture Organization. http://www.fao.org/iptrid/drainage/bio_drainage/concept_note_bio_drainage.htm. 2000.
5. Ram J, Dalal S.K, Meena K.C, Garg V. Biodrainage for salt-affected waterlogged soils. Paper presented at: Seminar on Biodrainage, 7 November 2002. Forest Department Haryana and Command Area Development Authority, Rohtak.
6. Ram J, Garg V.K, Toky O.P, Minhas P.S, Tomar O.S, Dagar J.C, Kamra S.K. Biodrainage potential of *Eucalyptus tereticornis* for reclamation of shallow water table areas in north-west India. *Agrofor Syst.* 2007; 69 147-165.
7. Kapoor A.S. Biodrainage – A biological option for controlling waterlogging and salinity. New Delhi: Tata McGraw Hill; 2001.
8. Angrish R, Toky O.P, Datta K.S. Biological management of water: *biodrainage. Curr Sci.* 2006; 90(7): 897.
9. Angrish R, Toky O.P, Patel R.K. Biodrainage: potential and practice. Hisar: Ministry of Water Resources; 2008.1-99.
10. Jackson M.L. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd; 1973.
11. Black C.A. Methods of soil analysis. USA: American Society of Agronomy; 1965.
12. Chopra S.L, Kanwar J.S. Analytical Chemistry. Ludhiana: Kalyani Publishers; 1976.
13. Piper C.S. Soil and plant analysis. Australia: University of Adelaide; 1950.
14. Shyam Sunder S. Parameswarappa S. Social forestry and *Eucalyptus*. *Econ Polit Wkly.* 1989; 24(1): 51-52.
15. Benthall A.P. Calcutta, India: The trees of Calcutta and its neighborhood. Thacker Spink and Co.; 1933.
16. Bor N.L. Manual of Indian forest botany. London, UK: Oxford University Press; 1953.
17. Ciesla W.M. Donaubauer E. 1994. Decline and dieback of trees and forests: A global overview. FAO Forestry Paper. 120. Rome: Food and Agriculture Organization of the United Nations; 1994.
18. Biswas M, Biswas K, Karan T.K, Bhattacharya S, Ghosh A.K, Haldar P.K. Evaluation of analgesic and anti-inflammatory activities of *Terminalia arjuna* leaf. *J Phytol.* 2011; 3(1): 33-38.
19. Toky O.P, Vasudevan P, Black D.R, Harris P.J.C. Davies P.A. Biomass production in short rotation effluent-irrigated plantations in north-west India. *J Sci Ind Res.* 2011; 70(8): 601-609.