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WATER CONSUMPTION BY EUCALYPTUS HYBRID

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Introduction

Of late, *Eucalyptus* has become a very controversial species for afforestation in India due to its reported high water consumption. Dabral (1970), for *Eucalyptus citriodora*, Chaturvedi (1983), and Chaturvedi, Sharma and Srivastava (1984) for *Eucalyptus hybrid* have reported higher water consumption in comparison to other species, but all the authors have reported least water consumed per unit weight of dry matter produced. Thomas *et al.* (1972) have reported the annual transpiration rate of *Eucalyptus globulus* in Nilgiris to be about 34.75 cm, Dabral and Raturi (1983), reported that water consumption in *Eucalyptus hybrid* at field capacity was nearly six times higher than at 1/3 field capacity. Whereas water consumption by *Eucalyptus hybrid* and *Eucalyptus camaldulensis* were nearly the same *Eucalyptus tereticornis* under water stress condition produced more biomass compared to other *Eucalyptus* species. Rawat *et al.* (1984), reported that in water stress conditions *Eucalyptus* cuts down its transpiration and that the dry matter production is not seriously affected. Mathur and Raj (1980), Raj Mathur and Raj Gopal (1984) and Mathur, Raj and Raj Gopal (1984) have reported that *Eucalyptus* *is a shallow rooted species, confined* to a depth of about 3 metres and no adverse effect on hydrological cycle due to planting of blue *gum was revealed,* nor there was evidence that local ground water and soil moisture regime and water quality have been upset adversely in Nilgiris. Kaul and Negi (1979), found *Eucalyptus tereticornis* and *Eucalyptus hybrid* having comparative lower transpiration rates compared to other four species, Ghosh *et al.* (1978), and Tiwari and Mathur (1983) have reviewed the subject and opined that *Eucalyptus* plantation in India have a big role to play in Indian Forestry.

Studies carried out in 3m X 3m X 3m R.C.C. lysimeters with *Eucalyptus hybrid* upto an age of three years at New Forest, Dehra Dun are reported in this paper.

Material and Methods

Four R.C.C. lysimeters, (3 m X 3 m X 3 m, each) with provision for collecting drainage at the bottom were constructed. The lysimeters all round were surrounded by trees. Adequate slope was provided in the floor of the lysimeters for quick drainage of water. The inner walls and floors of the lysimeters were cemented, plastered and painted with a thick layer of bitumen to prevent leakage of water. A 15 cm layer of gravel followed by a 15 cm layer of sand was spread on the floors of lysimeters and soil dug from a nearby chir-pine forest was filled, to the extent possible in its natural profile, leaving approximately 5 cm from the top, during the summer of 1978. Five six month old *Eucalyptus hybrid* seedlings were planted in each lysimeter during the ensuing rains. Some fresh soil had to be filled after the first showers to bring the soil to its original level in the lysimeters.

Soil moisture determinations were made within 5 cm at 30, 60, 120 and 200 cm of soil depths. This was done as during summer months it became practically impossible to extract the soil samples from surface up to 200 cm depth and recourse had to be taken to take the samples from the window constructed in the walls of the lysimeters. After taking the soil samples the windows were again sealed.

Rainfall was recorded by a raingauge installed nearby. Monthly rainfall has been calculated between the two dates of soil moisture sampling. Soil moisture sampling was usually done between 5th and 10th day of every month. For detertmination of soil moisture, 4 to 6 samples were drawn from each depth; values averaged between two consecutive soil depths gave the soil moisture content for the profile in question. Soil moisture for top layer (0-30 cm) was assumed on the basis of total rainfall received immediately before the soil moisture sampling as (1) rainy season or heavy rainfall immediately before soil moisture sampling 25% soil moisture (field capacity). (2) Semi dry period (winter and autumn) 18% soil moisture. (3) When the total rainfall was substantial but the days before actual soil sampling were dry - 12% soil moisture. (4) Dry periods or light rainfall many days before actual soil sampling - 8% soil moisture. (5) Very hot or dry season and rainfall very scanty- 6% soil moisture. Bulk density was determined at the close of the experiment for the natural hardiness to reappear and also not to disturb the soil mass during the experimental period. Potential evapotranspiration was calculated after Thornthwaite and Mathur (1955).

Soil moisture (%) was converted into mm of water using Bulk density as Soil Moisture (%) X Bulk density X 30.50 X 10/ 100.

The field capacity and the wilting point of the soil were 25% (24.75) and 9% (8.66). When the total soil moisture of the profile exceeded the field capacity i.e. 25% (677.3 mm), 677 mm of water was considered available for the plants, the excess being assumed as drainage. The year has been divided into three seasons; winter (15th Oct. to 14th Feb.), Summer (15th Feb. to 14th May) and Rains (15th May to 14th Oct.)

Evapotranspiration has been calculated as Evapotranspiration (E.T.) = (Rainfall + Soil moisture *in the preceeding month) - (Present* soil moisture + drainage + run off).

Run-off was assumed as 1/4 of rainfall during Sept. and Oct. 1978 due to inadequate height of wall above the soil surface to prevent water from over-flowing and 1/5 in the subsequent years when the walls were raised. Drainage was measured atleast twice a day, in the morning and evening in c.c. Under conditions when the soil moisture content exceeded that of the previous month, the data was skipped and bracketted *with that of the following month.* Such cases were very few and confined to within the prescribed season.

Results and Discussion

Water consumption from the lysimeters has been estimated at two soil depths (i) surface to 245 cm (0-245 cm) to account for the entire water loss from the trees (transpiration) and evaporation (E) losses from the soil, which gradually decreases with drying of soil, a stage being reached when evapotranspiration (ET), becomes equal to transpiration and (ii) 30-245 cm depth to cut off evaporation from the soil surface and assess the transpiration losses only from the trees as it is well known that evaporative factors do not work beyond 30 cm soil depth. However, this estimate will naturally by less, since rooting in *Eucalyptus* occurs within the first 30 cm soil depth also and water absorption by roots takes place from the zone it *is readily available. Thus an estimate* of soil moisture lost as assessed between these two soil profile depths may be the actual water consumption by *Eucalyptus* trees. Williams and Coventry (1979) have shown that the study of soil water regime will give a *good insight into the hydrology* of the area.

Water consumption in 0-245 cm soil depth were higher during winter (703 mm) and summer (495 mm) of 1978-79 compared to 1979-80 (656 and 248 mm respectively). This is because of the higher rainfall received during the winter of 78-79, thereby making more soil water available for evapotranspiration. Water consumption during rains of 1980 exceeded that of 1979, chiefly because of the higher rainfall and lower evaporation compared to the previous year. The ratio of the water consumption between these two depths ranged bytween 1.29 to 1.63 (maximum being 2.21 met in summer of 1980, due to higher evaporation rates) with an average value of 1.40. Water consumption ranged from 370 mm to 579 mm and 566 to 775 mm for 30-245 and surface to 245 cm soil depths respectively during winter. The corresponding figures for summer were from 37 to 384 mm and 173 to 527 mm and for rains from 761 to 1150 mm and 1041 to 1464 mm. However, water consumption for 12 months during 78-79 and 79-80 at both the depths showed marginal differences. Water consumption of 36 month old *Eucalyptus hybrid* during the last 27 months ranged from 5001 to 5081 mm and 3588 to 3640 mm for the soil depths 0-245 cm and 30-245 cm respectively, mean values being 5054 and 3621 mm (Table 1). It will be seen that the water consumption from 30 to 245 cm depth was sightly lesser than the rainfall received. However, water consumption from surface to 245 cm depth exceeded the rainfall at the expense of the previously stored soil moisture (Table 1)

Water consumption was 56, 17 and 27 per cent of total water consumption for soil depth 0-245 cm and 60, 14 and 26 per cent for soil depth 30-245 cm during rains, summer and winter respectively (Table 2). It is thus seen that maximum water consumption took place during rains, followed by winter, chiefly because of the availability of soil water coupled with favourable conditions for evapotranspiration. However, it will be appreciated that mere favourable conditions for evapotranspiration without adequate soil water, kept the water consumption at the lowest as observed during summers. The data can be divided in two parts, one winters where high soil moisture content exists from a previous recharge or/rains where it is due to the current soil moisture recharge and the other during summers with scanty previous or current soil moisture recharge. The crop factor (ET/PE) ranged between 2.27 to 2.47 and 3.18 to 3.84, average values being 2.35 and 3.44 during winter, 0.32 to 1.20 and 0.71 to 1.70, average values being 0.72 and 1.16 during summer, 1.51 to 1.86 and 2.0 to 2.40, average values being 1.68 and 2.20 during rains for 30-245 and 0-245 cm soil depths respectively (Table 2). This shows the cutting down of transpiration by *Eucalyptus hybrid* during unfavourable periods, Such instances have been reported elsewhere also (Rawat *et al.*, 1984; Greenwood and Beresford, 1979). Riekerk (in press) has laid importance on crop factor (ET/PE), suggestive of the effects of available soil moisture on transpiration.

The Leaf Area Index (LAI) in this experiment was 3.7. A number of factors viz - Leaf Area Index (LAI), Boundary layer resistance (rb), stomatal resistance (rs), albedo are related towards transpiration losses (Dunin and Mackay, 1982). Greenwood and Beresford (1979) opined that in *Eucalyptus* total leaf area did not significantly affect transpiration per tree and that the average area of a leaf did not significantly influence transpiration per unit leaf area, nor was the boundary layer resistance a significant factor and that stomatal resistance may likely affect the transpiration behaviour. In eucalypt, minimal stomatal resistance ranged

Table 1

Seasonal, yearly and total evapotranspiration (mm) Eucalyptus hybrid

(Evapotranspiration (ET) values rounded to nearest whole number)

AGE - 3 years
LAI = 3.7

Lysimeter No.	Depth (cm)	WINTER			SUMMER		RAINS		EVAPOTRANSPIRATION (mm)			Total Evapotranspiration (mm)
		1978-79	1979-80	1980	1979	1980	1979	1980	78-79 (Oct-Sept)	79-80 (Oct-Sept)	1980 (Oct-Dec)	
1	30-245	467	579	442	350	134	761	907	1578	1620	422	3640
	0-245	739	775	541	494	270	1041	1221	2274	2266	541	5081
2	30-245	380	370	309	384	218	937	1032	1701	1620	309	3630
	0-245	652	566	407	527	353	1217	1345	2396	2264	407	5067
3	30-245	452	440	341	339	37	867	1150	1658	1627	341	3626
	0-245	724	636	440	482	173	1147	1464	3353	3273	440	5066
4	30-245	426	453	263	333	59	914	1140	1673	1652	263	3588
	0-245	698	649	361	477	194	1194	1428	2369	2271	361	5001
Mean	20-245	431	460	339	352	112	870	1057	1652	1630	339	3621
Mean	0-245	703	656	437	495	248	1150	1365	2348	2269	437	5054
Ratio	0-245 / 30-245	1.63	1.43	1.29	1.41	2.21	1.32	1.29	1.47	1.39	1.29	1.40
Rainfall (mm)		259.0	55.0	52.8	61.8	70.1	1361.6	1825.8	1662.4	1950.9	52.8	3666.1
Evaporation (mm)		283.2	355.0	186.1	474.6	616.4	478.9	342.0	1236.7	1313.4	136.1	2736.2

Table 2

Evapotranspiration (ET), Potential evapotranspiration (PF) and ET/PE

Year	Depth (cm)	WINTER (Oct. to Feb.) ET	PE	Rain fall (mm)	ET/PE	SUMMER (Mar. to May) ET	PE	Rain fall (mm)	ET/PE	RAINS (Jun. to Sept.) ET	PE	Rain fall (mm)	ET/PE	TOTAL ET	PE	RATIO ET/PE
1978-79	30-245	431			2.35	352			1.20	870			1.51	1652		1.57
			183	239.0			291	61.8			575	1361.6			1049	
	0-245	703			3.84	495			1.70	1150			2.00	2348		2.23
1979-80	30-245	460			2.27	112			0.32	1057			1.86	1630		1.46
			202	55.0			346	70.1			567	1825.8			1115	
	0-245	656			3.24	248			0.71	1365			2.40	2269		2.03
1980	30-245	339			2.47	-			-	-			-	339		2.47
			137	52.8											137	
	0-245	437			3.18	-			-	-			-	437		3.18
Total	30-245	1230				464				1927						
			522	346.8			637	131.9			1142	3187.4				
	0-245	1796				743				2515						
Mean	30-245	410 (26%)	174		2.35	232 (14%)	319		0.72	964 (60%)	571		1.68			
	0-245	599 (27%)			3.44	372 (17%)			1.16	1258 (56%)			2.20			

between 100 to 200 sm^{-1} compared to conifers where it ranged from 200 to 300 sm^{-1} (Connor *et al.*, 1977 and Sinclair, 1980) cited by Dunin and Mackay (1982). The values of albedo were between 0.10 to 0.20 for conifers and 0.15 to 0.19 for broad-leaved forests (Rutter, 1968). It can be reasonably said that with high soil water and a well developed canopy, the transpiration rates will be directly related to net radiation received. In a model study at Lidsdale (Dunin and Mackay, 1982) eucalypt vapour loss between 20 Feb. 1969 and 19 Feb. 1971 was 1346 mm.

The higher values of ET/PE in winter may be explained due to greater availability of soil moisture from the preceeding rains and the lower evaporation rates. Although soil moisture recharge is maximum during rains, ET/PE ratio are of a lower order mainly because of the high evaporation rates. During summer ET/PE ratios are minimum because of lower availability of soil moisture and high evaporation rates.

Thus water consumption during rains, summer and winter by *Eucalyptus* may reflect upon its consumptive behaviour in hot humid, hot dry and cool humid climates. In summer, soil evaporation is practically negligible due to quick heavy depletion of soil moisture from the top layers, evapotranspiration may be practically the same as water lost by transpiration. Considering only 3 months (March to May) of summer, the cumulative amount of water consumption was 14% of the total water lost as against 60% during rains and 26% during winter (Table 2)

It will be seen that whereas the evapotranspiration values (% of total water consumed) were practically the same, 26 and 27%, during winter, it was 14 and 17% during summer and 60 and 56% during rains for the two said soil depths respectively. The lower percentage (56%) in 0-245 cm soil depth against 60% in 30-245 cm soil depth may be due to higher soil moisture in the lower layers of soil mass due to hydraulic conductivity and the occasional drying of moisture in the top soil layers due to bright sun-shine in between rains. A higher percentage (17%) of soil moisture depletion from 0-245 cm depth against 14% from 30 to 245 cm soil depth in summer may be due to continuous depletion of soil moisture at slower rates from the surface layers to below wilting point moisture content (Stibbe, 1975).

Soil moisture during rains and winter is readily available for consumption. But the potential evapotranspiration (PE) during rains is of a much higher order than in winter. This is reflected in more consistent values of ET/PE during winter than in rains (Table 2). Rutter (1968) citing Denmead *et al.* (1962) and others has suggested that a reduction in soil moisture reduces transpiration and that the actual to potential transpiration ratios remain constant over a wider range of available soil water when the potential transpiration rate is low than when it is high.

The analysis of variance shows a very high correlation between seasons and water consumption by *Eucalyptus hybrid* (Table 3).

Growth behaviour

The growth behaviour was measured by two parameters, monthly linear and radial increments upto February 1980. The observations had to be stopped after February 1980, as the height of the trees could not be measured accurately due to their lodging. Monthly increments of dry weight were not recorded due to lack of more lysimeters to grow *Eucalyptus* trees. During March and September a decrease in diameter growth, compared to the previous month, was observed. No clear trend in diameter increment in the four lysimeters was observed. In general, maximum diameter increment took place between April and August and in February. In isolated cases it even occurred in November. The data is given in Table 4. Maximum linear increment took place in November 1979 and as per indications in November 1978 also. The next lower linear increment took place in the months of April, May and June followed by in July, August, September and October. Linear increment in March was nearly similar to as in October. Minimum linear increment was met in the months of December, January and February (Table 5).

Dry matter production Vs. Water consumption

Against the 31.396, 27.104, 30.942 and 31.570 kg of dry matter produced aboveground in these lysimeters, 3640 (5081), 3630 (5067), 3626 (5066) and 3588 (5001) mm of water were consumed from 30-245 cm (0-245 cm) of soil mass. Since the roots were not extracted in this study, an estimate of root mass was made on the basis of a previous work (Dabral, 1970). The respective dry matter produced for the whole plant (including roots) were 43.245, 37.341, 42.629 and 43.494 kg. Thus the water consumed per kg of the dry matter produced for the aboveground shoot and (whole plant) were 116 (84), 134 (97), 117 (85) and 114(82) mm for 30-245 cm soil depth. The respective figures for 0-245 cm soil depth being 162 (117), 187 (136), 164 (119), and 158 (115), mm of water. 122 mm of water was consumed to produce 1 kg of dry matter for the whole plant. It comes to 167 mm when we consider the utilised aboveground portion, leaving the roots under in the soil, for 0-245 cm soil depth. The data is presented in Table 6.

The data reveals that *Eucalyptus* consumes a fairly large amount of water (Table 1 and 2). Dabral (1970) and Chaturvedi *et al.* (1984) have shown that *Eucalyptus* produced maximum dry matter against unit volume of water consumed, amongst the tree species studied. Growth in terms of dry matter production is the outcome of gaseous exchange involving transpiration, growth rate offers a means for inferring the transpiration regime (Dunin and Mackay, 1982). Lima (1984), reviewing the work on transpiration

Table 3

The Analysis of Variance

Year	Depth of soil mass (cm)	Source of Variance	Sum of Squares	Degrees of freedom	Mean Square	Variance Ratio
1978-79 (Oct.-Sept.)	30-245	ROWS	.27850000 E 04	3	.92833325 E + 03	.26
		COLUMNS	.62296800 E + 06	2	.31148400 E + 06	87.13***
		RESIDUAL	.21449000 E + 05	6	.35748333 E + 04	
		TOTAL	.64720200 E + 06	11		
	0-245	ROWS	.27470000 E + 04	3	.91566675 E + 03	.26
		COLUMNS	.89523900 E + 06	2	.44761950 E + 06	125.23***
		RESIDUAL	.21447000 E + 05	6	.35745000 E + 04	
		TOTAL	.91943305 E + 06	11		
1979-80 (Oct.-Sept.)	30-245	ROWS	.13000000 E + 02	3	.43333330 E + 01	.00
		COLUMNS	.18023200 E + 07	2	.90116000 E + 06	69.47***
		RESIDUAL	.77827000 E + 05	6	.12971168 E + 05	
		TOTAL	.18801600 E + 07	11		
	0-245	ROWS	.16000000 E + 03	3	.53333330 E + 01	.00
		COLUMNS	.25549800 E + 07	2	.12774900 E + 07	98.72***
		RESIDUAL	.77646000 E + 05	6	.12941000 E + 05	
		TOTAL	.26326420 E + 07	11		
1980 (Oct.-Dec.)	30-245	ROWS	.29250000 E + 04	3	.97500000 E + 03	.08
		COLUMNS	.19202590 E + 07	2	.96012950 E + 06	82.90***
		RESIDUAL	.69492000 E + 05	6	.11582000 E + 05	
		TOTAL	.19926760 E + 07	11		
	2-245	ROWS	.28580000 E + 04	3	.95266675 E + 03	.08
		COLUMNS	.28579830 E + 07	2	.14289920 E + 07	123.19***
		RESIDUAL	.69597000 E + 05	6	.11599500 E + 05	
		TOTAL	.29304380 E + 07	11		

Rows - Lysimeters ; Columns - Seasons; *** Significant at 0.1% level of probability.

Table 4

Table showing Diameter/Radial increment in (cm)

< increment less than recorded in the previous month
> increment greater than recorded in the previous month

Lysimeter / Months	Oct. '78	Nov. '78	Dec. '78	Jan. '79	Feb. '79	Mar. '79	April '79	May '79	Jun. '79	July '79	Aug. '79	Sep. '79	Oct. '79	Nov. '79	Dec. '79	Jan. '80	Feb. '80
1	0.82	1.50/0.68	1.66/0.16	1.90/0.24	2.41/0.51	2.66/0.25	3.10/0.44	3.57/0.47	4.09/0.52	4.76/0.67	5.25/0.49	5.31/0.05	5.44/0.13	5.48/0.04	5.57/0.09	5.69/0.12	5.90/0.21
			<	>	>	<	>	>	>	>	<	<	>	<	>	>	>
2	0.55	0.78/0.23	1.18/0.40	1.36/0.18	1.59/0.23	1.74/0.15	2.02/0.28	2.45/0.43	3.03/0.58	3.53/0.50	4.15/0.62	4.29/0.14	4.59/0.30	4.79/0.20	5.19/0.49	5.29/0.10	5.40/0.11
			>	<	>	<	>	>	>	<	>	<	>	<	>	<	>
3	0.60	0.90/0.31	1.28/0.38	1.48/0.21	1.85/0.37	2.02/0.17	2.44/0.42	3.00/0.56	3.56/0.56	4.04/0.48	4.66/0.62	4.74/0.08	4.97/0.23	5.49/0.52	5.79/0.30	6.11/0.32	6.28/0.17
			>	<	>	<	>	>	=	<	>	<	>	>	<	>	<
4	0.68	0.98/0.33	1.29/0.31	1.62/0.33	2.04/0.42	2.26/0.22	2.73/0.47	3.34/0.61	3.89/0.55	4.54/0.65	5.21/0.67	5.32/0.11	5.60/0.28	5.72/0.12	5.82/0.10	5.94/0.12	6.08/0.14
			>	>	>	<	>	>	<	>	>	<	>	<	<	>	>
Mean	0.66	1.04/0.38	1.35/0.30	1.59/0.24	1.97/0.37	2.17/0.20	2.57/0.40	3.10/0.53	3.64/0.54	4.17/0.57	4.82/0.65	4.92/0.13	5.15/0.24	5.36/0.22	5.59/0.22	5.86/0.27	5.91/0.15
			<	<	>	<	>	>	>	>	>	<	>	<	=	>	<
Seasonal Radial increment				1.31			1.13				1.82				0.99		

Table 5

Table showing $\frac{\textit{Height}}{\textit{Linear increment}}$ in (m)

< increment less than recorded in the previous month
> increment greater than recorded in the previous month

Lysimeter / Month	Oct. '78	Nov. '78	Dec. '78	Jan. '79	Feb. '79	Mar. '79	Apr. '79	May '79	Jun. '79	July '79	Aug. '79	Sep. '79	Oct. '79	Nov. '79	Dec. '79	Jan. '80	Feb. '80
1	0.925	1.243/0.317	1.482/0.239	1.670/0.187	1.780/0.110	2.092/0.312	3.093/1.000	3.930/0.837	4.861/0.931	5.500/0.639	6.180/0.680	6.560/0.320	6.960/0.460	8.790/1.830	8.970/0.180	9.000/0.030	9.040/0.040
			<	<	<	>	>	<	>	<	>	<	>	>	<	<	>
2	0.583	0.788/0.205	0.948/0.160	1.130/0.182	1.159/0.028	1.407/0.248	2.220/0.812	3.097/0.877	3.890/0.792	4.630/0.739	5.050/0.420	6.260/0.210	5.900/0.640	7.260/1.360	7.440/0.180	7.580/0.140	7.580/0.000
			<	>	<	>	>	>	<	<	<	<	>	>	<	<	<
3	0.605	0.825/0.220	1.034/0.209	1.220/0.186	1.350/0.129	1.653/0.303	2.679/1.025	3.572/0.893	4.680/1.106	5.350/0.672	5.870/0.520	6.410/0.540	6.910/0.500	8.070/1.160	8.150/0.080	8.150/0.000	8.150/0.000
			<	<	<	>	>	<	>	<	<	>	<	>	<	<	=
4	0.707	0.925/0.217	1.167/0.242	1.363/0.201	1.453/0.084	1.822/0.369	2.797/0.974	3.523/0.726	4.425/0.901	5.080/0.655	5.760/0.680	6.350/0.590	6.860/0.510	8.170/1.310	8.420/0.250	8.420/0.000	8.510/0.090
			>	<	<	>	>	<	>	<	>	<	<	>	<	<	>
Mean	0.705	0.945/0.240	1.158/0.212	1.347/0.189	1.436/0.088	1.744/0.308	2.697/0.953	3.531/0.833	4.464/0.933	5.140/0.676	5.715/0.575	6.130/0.415	6.660/0.527	8.080/1.415	8.250/0.172	8.290/0.085	8.320/0.065
			<	<	<	>	>	<	>	<	<	<	>	>	<	<	<
Seasonal Linear increment				0.731			2.095				2.599				2.190		

Table 6

Dry matter production (kg) in Eucalyptus hybrid vis-a-vis water consumption (mm)

LAI : 3.7

(a) = approximately

Lysimeter	OVEN DRY WEIGHT (kg)				Total dry weight (kg)		depth	WATER CONSUMED			Water consumed(mm)	
	Shoot				Shoot (Above ground portion)	Shoot + Root (Total Biomass)	(cm)	Shoot	Root	Total	Based on above ground portion only (a)	Based on whole plant (a)
	Stem	Branch	Leaf	Root								
1	23.372	3.634	4.390	11.858	31.396	43.254	30-245	2642	998	3640	116	84
							0-245	3688	1393	5081	162	117
2	18.400	4.165	4.539	10.237	27.104	37.341	30-245	2635	995	3630	134	97
							0-245	3678	1389	5067	187	136
3	22.065	4.800	4.077	11.687	30.942	42.629	30-245	2632	994	3626	117	85
							0-245	3677	1389	5066	164	119
4	24.488	3.040	4.042	11.924	31.570	43.494	30-245	2604	984	3588	114	82
							0-245	3630	1371	5001	158	115
Total	88.325	15.639	17.048	45.706	121.012	166.718	30-245	10513	3971	14484		
							0-245	14673	5542	20215		
Average per Lysimeter	22.081	3.909	4.262	11.426	30.253	41.679	30-245	2628	0993	3621	120	87
							0-245	3668	1386	5054	167	122

Table 7

Root characters Eucalyptus tereticornis, Age 2 yrs, grown in 3 x 3 x 3m^3 Lysimeters, Year 1977

LYSIMETER No.	Root No.	LENGTH (cm) Tap root	LENGTH (cm) Other roots	TOTAL LENGTH (cm)	Thickness of Tap Root (cm) Root stock	Thickness of Tap Root (cm) Mid Portion	Thickness of Tap Root (cm) End portion	Average Root Thickness (cm)	Root Density Per Lysimeter
	1	175.0	375.2	550.2	4.9	2.1	0.2	2.4	
	2	155.5	288.0	443.5	3.6	0.5	0.2	1.4	
	3	208.5	492.0	700.5	3.8	1.5	0.2	1.8	
	4	234.0	782.5	1016.5	6.6	3.1	0.7	3.5	
	5	138.5	334.2	472.7	3.1	1.1	0.5	1.6	
Total		911.5	2271.9	3183.4					0.00015
2	6	242.0	539.9	781.9	4.9	2.2	0.9	2.7	
	7	155.5	651.3	806.8	5.1	1.8	0.3	2.[illegible]	
	8	153.0	621.0	774.0	4.1	1.6	0.2	2.0	
	9	221.5	1054.5	1276.0	5.6	1.7	0.6	2.6	
	10	168.5	598.0	766.5	4.5	2.0	0.2	2.1	
Total		940.5	3464.7	4405.2					0.00020

and evapotranspiration on eucalypt species has remarked, that the transpiration rates per tree vary among eucalypt species between 20 litres per tree per day to 40 litres per tree per day. Evaporation rates from *Eucalyptus* forest in field condition appear to vary 1.55 mm per day in winter to 6.00 mm per day in summer. The majority of eucalypt species possess some mechanism to control transpiration druing drought stress. Average catchment evapotranspiration of a well stocked eucalypt forest is probably around 1000 mm per year in rainfall regimes in excess of 1200 mm per year and approximately 400 mm per year when the rainfall regime is of the order of 500 mm per year (Lima, 1984). For wetter regions evapotranspiration increases eventually reaching a value of 1500 mm per year for tropical eucalypt forest of lower latitude. Evapotranspiration calculated at this end for two years (1978-80) in 30 to 245 cm soil depth ranged between 1630 to 1652 mm per year, values which should be considered fairly high against an average annual rainfall of 2042 mm. As stated by Stewart (1981) the concept of potential evapotranspiration does not apply to forests, as when the conopies are wet (interception) the latent heat flux (evaporation) is frequently greater than the net input of radiational energy.

In contrast to the earlier findings (Dabral, 1970) of 1.4 mm of water being consumed, under unrestricted supply of water (potential evapotranspiration) to produce 1 gram of dry matter in *Eucalyptus citriodora*, only 0.122 mm of water have been utilized by *Eucalyptus hybrid* to produce 1 g of dry matter under rainfed condition. This also suggests the capability of *Eucalyptus* species to cut down their water consumption under moisture stress conditions, as well as of their capability for luxury consumption under plentiful water availability. It may be mentioned here that *Eucalyptus citriodora* and *Eucalyptus hybrid* may not be differing much in their water consumption behaviour. However, the gain in water economy under soil water stress is lost in terms of time in producing dry matter (Dabral and Raturi, 1983).

It may be mentioned here that in an earlier study made with *Eucalyptus tereticornis* in 3 x 3 x 3m lysimeters, it was observed that even though the root density (L/L^3) was low, say between 0.00015 to 0.00020, the tap roots had penetrated to a depth of 245 cm, the average length of the roots ranging between 150 to 200 cm within 24 months. The root characters are presented in Table 7. Dabral *et al.*(unpublished) studying the root spread in a 15 year old *Eucalyptus hybrid* plantation at New Forest, Dehra Dun observed root penetration upto 3.55 m. Under hard compacted soil (bulk density 1.5), a clustered root system of about 2 m depth with no distinct tap root was observed and due to the hardiness of soil the roots got badly fused with each other. Root within 30 cm depth, parallel to the ground surface were also observed. Carbon *et al* (1980) working in eucalypt forest in Western Australia, have opined that the flow of soil water to roots is related to the distribution of root length per unit soil volume, root system drawing water from deeper parts of the soil when the surface horizon dry and water becomes unavailable there.

Conclusions

(i) Evapotranspiration in 27 months by three years old *Eucalyptus hybrid* trees ranged from 5001 to 5081 mm. The corresponding soil moisture loss from lower soil depths beyond 30 cm was between 3588 to 3640 mm. As such, the real water consumed by *Eucalyptus* trees should be somewhere between 5054 and 3621 mm. Water consumption from 30-245 cm soil depth was slightly lesser than the rainfall received.

(ii) Water consumption was 56, 17 and 27 per cent for soil depths 0-245 and 60, 14 and 26 per cent for soil depth 30-245 cm of the yearly water consumption during rains, summer and winter respectively.

(iii) The average values of the crop factor (ET/PE) were 2.35 and 3.44 during winter, 0.72 and 1.16 during summer, and 1.68 and 2.20 during rains for 30-245 and 0-245 cm soil depth respectively.

(iv) Maximum linear increment took place in November followed by April, May and June, the next lower pace of increment being met in July, September and October, whereas it was equal in March and October.

(v) Maximum diameter increment took place between April and August and in February.

(vi) Water consumed per kg dry matter produced, based on the whole plant, was 122 and 87 mm for 0-245 and 30-245 soil depth respectively. Since during harvest, only the aboveground portion is extracted; water utilised works out to be 167 and 120 mm for 0-245 and 30-245 cm soil depths respectively.

(vii) The study showed that *Eucalyptus* consumed fairly large amount of water.

(viii) The tap roots of two years old *Eucalyptus tereticron's* in lysimeters penetrated to a depth of 245 cm, the average length of the roots ranging between 150 to 200 cm. In a 15 year old plantation of *Eucalyptus hybrid* roots penetrated upto 355 cm depth.

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Summary

The paper presents the results of water consumption by <u>Eucalyptus hybrid</u> trees during the last 27 months in 3m x 3m x 3m R.C.C. lysimeters. Water consumption from 30 to 24.5 cm depth was slightly lesser than the rainfall received, although water consumption from the entire soil depth (0-245 cm) exceeded the

rainfall, due to the previously stored soil water. Maximum amount of water was consumed during rains and the least during summer.

<u>संकर यूकेलिप्टस</u> का जल उपभोग

डी॰ जी॰ डबराल व ए॰ एस॰ रतूड़ी

सारांश

इस परिपत्र में 3 सेमी॰X3 सेमी॰ X3 सेमी॰ आकार के प्रबलित सीमेंट कंकरीट से बने विलयमापी द्वारा पिछले 27 महीनों में संकर <u>यूकेलिप्टस</u> वृक्षों द्वारा किए जल उपभोग के परिणाम प्रस्तुत किए गए हैं। 30 सेमी॰ से 245 सेमी॰ तक वाली गहराई में जल उपभोग हुई वर्षा से थोड़ा कम रहा, यद्यपि मृदा की पूरी गहराई [0 – 245 सेमी॰] का जल उपभोग पहले से मृदा में जमा हुए जल के कारण वर्षा से अधिक हुआ। सबसे अधिक जल उपभोग वर्षा ऋतु में तथा सबसे कम जल उपभोग गर्मियों में हुआ।

Reference

Carbon, B.A. et al.(1980). The distribution of root length and limits of flow of soil water to roots in dry sclerophyte forest. *Forest science*. 26 (4), 656-64.

Chaturvedi, A.N. (1983). *Eucalyptus* for farming - U.P. Forest Bulletin No. 48, 44.

Chaturvedi, A.N., S.C. Sharma & Ramji Srivastava (1984). Water consumption and biomass production of some forest trees. *Common. For. Rev.* 63(3), 217-223.

Connor, D.J., N.J. Legge and *N.C. Turner* (1977). Water relations of mountain ash (*Eucalyptus regnans* F. Muell.) Forests. *Aust. J. Plant physiol.* 4, 753-62.

Dabral, B.G. (1970). Preliminary observation on potential water requirement on *Pinus roxburghii, Eucalyptus citriodora, Populus casale* (488) and *Delbergia latifolia*. *Indian For.* 96 (10): 775-780.

Dabral, B.C. and *A.S. Raturi* (1983). Some observation on water consumption vis-a-vis growth performance of *Eucalyptus*-*Abstracts*, National symposium on Advances in Tree Science, Dehra Dun.

Dabral B.C., S.P. Pant & S.C. Pharasi, Root studies in *Eucalyptus* (unpublished).

Denmead, O.T. and *R.T. Shaw* (1962). Availability of soil water to plants as affected by soil moisture content and meterological conditions Agron. J. 54, 385.

Dunin, F.X. and *S.M. Mackay*, (1982). Evaporation of eucalypt and coniferous forest communities. Proc. (I)- National symp. on forest hydrology Melbourne, 18-25.

Ghosh, R.C., O.N. Kaul and *B.K. Subba Rao* (1978). Some aspects of water relations and nutrition in *Eucalyptus* plantations. *Indian For.* 104 (7): 517-524.

Greenwood, E.A.N. and *J.D. Beresford* (1979). Evaporation from vegetation in landscape developing secondary salinity using the ventilator chamber technique. (1) Comparative transpiration from juvenile *Eucalyptus* above saline ground water seeps. J. Hydrology, 42, 369-382.

Kaul, O.N. and *J.D.S. Negi* (1979). Comparative transpiration rates of six *Eucalyptus* species, *Indian For.* 105 (7): 500-507.

Lima, W.P. (1984). The hydrology of eucalypt forest in Australia-a review in IPEF Institutsded Pesquisas I.E. studies Florestair, ESALR-Univ. of Paulo, Brazil.

Mathur, H.N. and *Hillary Raj, S. Francis* (1980). Ground water regime under Blue-gum at Osamund Nilgiris-initial observations. *Indian For.* 106 (8): 547-554.

Mathur, H.N., Hillary Raj S. Francis & *K Raj Gopal* (1984). Root studies in *Eucalyptus globulus* - Paper presented at National Seminar on Eucalyptus, Kerala Forest Research Institute, Peechi, (Jan. 30-31, 1984).

Raj, Hillary, S.Francis, H.N. Mathur and *K Raj Gopal* (1984). Some hydrological investigations on Blue-gum (*Eucalyptus globulus*) at Osamund (Nilgiris)- paper presented at the National Seminar on Eucalyptus, Kerala Forest Research Institute, Peechi, (Jan-30-31, 1984).

Rawat, P.S., B.B. Gupta and *J.S. Rawat* (1984). Transpiration as affected by soil moisture in *Eucalyptus tereticornis* . seedlings, *Indian For.* 110 (1) : 35-39.

Riekerk, H.,—Lysimetric evaluation of pine tree evapotranspiration Proc. Forest Environment Measurements conference, Oak Ridge (TN), 1983 (in press).

Rutter, A.J. (1968). Water consumption by forests in 'Water Deficits and Plant Growth' Vol. 2 (Ed. T.T. Kozlowski) Academic Press New York, 23-84.

Sinclair, R. (1980). Water potential and conductance of three *Eucalyptus* species in the Mount Lofty Range, South Australia; responses to summer drought. *Aust. J. Bot.* 28, 499-510.

Stewart, K.B. (1981). Evaporation from forests. XC 11 IUFRO World Congress Kyoto, Japan. 130-138.

Stibbe, E. (1975). Soil moisture depletion in summer by an *Eucalyptus* grove in a desert area. Agro-Eco-system. 2, 117-126.

Thomas P.K., K Shandra Sekhar and *B. Holdorai* (1972). An estimate of transpiration by *Eucalyptus globulus* from Nilgiri watersheds. *Indian For.* 98 (3), 168-172.

Tiwari, K M. and *R.S. Mathur* (1983). Water consumption and nutrient uptake by *Eucalyptus*. *Indian For.* 109 (12) : 851-860.

Thornthwaite, C.W. and *J.R. Mather* (1957). Instructions and tables for computing potential evapotranspiration and the water balance Centerton, New Jersey.

Williams, J. and *R.J. Coventry* (1979). The contrasting soil hydrology of red and yellow earths in a landscape of low relief in the hydrology of areas of low precipitation - IAHS Publication. 128, 385-95.