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Rainfall interception variations according to Eucalyptus genotypes †

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Abstract: The selection of taxa/genotypes that have a rainfall interception that suits the conditions of each region is key to maintaining water stability and minimizing the effects of drought. This study evaluated rainfall interception on a 7-year-old plantation with the eight genotypes (*Eucalyptus globulus* and *E. nitens x globulus* (high and low productivity), *E. nitens*, *E. badjensis*, *E. smithii* and *E. camaldulensis x globulus)* in Yumbel, Bio-Bio, Chile. In addition, diameter (DBH), total height (H) and Leaf Area Index (LAI) were considered and compared with stemflow (Sf), throughfall (Tf) and interception (INT). The results showed that DBH and H did not infer the rainfall interception parameters. In contrast, Tf and Int varied in each genotype; *E. badjensis* and *E. smithii* had a LAI >5.1 m^2m^{-2} had the minimum Tf and maximum Int; in contrast, *E. globulus* and *E. nitens x globulus* with a LAI< 4.0 m^2m^{-2} showed low Int and high Tf. With Sf did not show differences between genotypes. These suggest the opportunity to select genotypes considering canopy interception to balance productivity and water resources under climate change scenarios.

Keywords: Water Balance; Hydrology; Climate Change.

1. Introduction

One of the key aspects that must be studied to understand the water balance of Eucalyptus plantations is rain intercepting, which considers rainwater that, instead of reaching the soil, is intercepted by the canopy and lost by evaporation [1]. Factors that influence rainfall intercept have been classified into rainfall properties and structural characteristics of vegetation [2]. The properties of the rain, especially the amount, intensity and duration of the rain, most affect the amount of water that reaches the soil [3]. Cavalli et al. [4] determined that as the amount and intensity of the rainfall event increase, the interception will decrease, affecting increases in soil moisture content and, in turn, affecting nutrients and organic matter dynamics in upper soil levels [5] and influencing erosion rates on steep terrains [6, 7].

Differences between eucalyptus species or genotypes can provide an opportunity to select more sustainable plantations that address productive and environmental concerns [8]. Furthermore, identifying genotypes with lower intercept values that maintain a more positive water balance can maintain commercial plantation productivity and less impact ecosystem water sustainability in climate change rainfall reductions [9]. Therefore, our study's objective consisted of evaluating rainfall interception of two varieties of each, *Eucalyptus globulus* and *E. nitens x globulus* genotypes, of high and low productivity, and one of each *E. nitens, E. badjensis, E. smithii,* and *E. camaldulensis x globulus* genotypes.

2. Materials and Methods

The study considered a forest plantation located in Yumbel, Bio-Bio, Chile (37˚8'0.01" S, 72 27'34.70" W); with an average annual temperature of 13.8°C, annual rainfall of 1252 mm and average monthly solar radiation ranged from 5.5 to 32.1 MJ m^{-2}. According to CIREN [10] the soil is classified as Dystric Xeropsamments.

The study was developed between May and September 2020 (autumn and winter) and evaluated a 7-year-old plantation with the genotypes: *Eucalyptus globulus* (high yield: EgH, low yield: EgL), *E. nitens x globulus* (high yield: EngH, low yield: EngL), *E. nitens* (En), *E. camaldulensis x globulus* (Ecg), *E. badjensis* (Eb), and *E. smithii* (Es). The planting spacing for all genotypes was 3 x 2 m (1666 trees ha-1), with 3 plots per genotype. It was the measurement of tree diameter at 1.3 m (DBH) and the total height (H) and the leaf area index (LAI). Then, with the equation proposed by Levia [11] was used (Eq 1) to evaluate gross rainfall (P), throughfall (Tf) and stemflow (Sf).

$$INT = P - Tf - Sf \quad (1)$$

Where INT is total interception by vegetation, P is gross rainfall, and was determined by installing three automatic counter-mounted rain gauges (RainWise model RAINEW-111) outside in open sky conditions to estimate rainfall without vegetation cover. To estimate the Tf measurements, two rain gauges per plot (12 per genotype), where one between the planting rows and the other in the planting row to capture different intercept points along with the plantation canopy (Fig. 1a). In the case of Sf estimates, two rain collectors per plot (6 per genotype) were located within the internal 3 x 3 tree genotype plot, and each collector was connected to a central tree using a plastic hose cut in half attached and tightly sealed with silicone to the bark up to 1.2 m height from the ground surrounding the tree stem in a spiral pattern (Fig. 1b).

Figure 1. Example of rain gauge distribution for throughfall **(a)** and collection system for stemflow **(b).**

For INT, Tf, and Sf, a set of linear equations were implemented; in the case of INT ratio, a logarithmic equation was considered; to evaluated differences of genotypes, the likelihood ratio test was used. Analysis was run in R version 4.1.2 and considered a p value <0.05 as significant.

3. Results

Individual tree and stand parameters were obtained for Eb and Es as the superior size (DBH >20.0 cm and H>20 m), then EngH, EgH, and Ecg showed the intermediate size made (DBH between 16.5 and 18.5 cm and H between 16.5 and 19.0 m); finally, EngL, EgL, and Es presented a smaller size (DBH <14 cm and H <16 m). For LAI, Eb and Es showed the maximum LAI values (> 5.7 m^2m^{-2}), EngH, EgH and Ecg obtained intermediate LAI values (average 4.5 m^2m^{-2}) and EngL, EgL and En showed the lowest LAI values (< 3.5 m^2m^{-2}).

Analysis of general equations for the Tf, Sf, INT and INT ratio showed that only for Sf was feasible; therefore, the Tf, INT and INT ratio as a function of LAI were adjusted (Table 1). For Tf (Fig. 2a) a positive linear trend was observed where increases in P affected increases in Tf, and for genotypes Eb and Es the ones with high LAI levels showed the minor increase and the equation with the lower slope. On the other hand, EngH, EgH and En presented a higher increase given by a more significant slope. EngH, EgH, and Ecg showed intermediate values between both previously described scenarios. For all equations, Adj-R^2 were greater than 0.95 and RMSE less than 1.55 showing good fit (Table 1). For Sf, being the only variable that showed a general equation independent of genotype (Fig. 2b), a positive linear trend was observed in which Sf increased as a function of P, and the equation showed a good fit, with Adj- R^2 of 0.98 and RMSE of (1.29). In the case of INT (Fig 2c), an opposite pattern compared to Tf was observed, where genotypes with higher LAI (Eb and Es) showed a higher slope than genotypes with low LAI (EngL, EgL and En) and the equations showed Adj- R^2 > 0.80 and RMSE less than 1.90 (Table 1). Finally, for the INT ratio (Fig 2d), a logarithmic decreasing pattern was observed where the INT ratio tended to decrease as P increased and an asymptotic point was observed for P above 80 mm for all groups. Es and Eb showed the highest ratios, with an asymptote value of 64%. In contrast, EngH, EgH and Ecg, showed a greater decrease in INT ratio with an asymptote value at 54%, while EcgL, EgL, and En showed the greatest decreasing trend, with an asymptote value at 33%. The equations showed an Adj-R^2 ranging from 0.70 to 0.77 with RMSE <1.75 (Table 1).

Table 1. Adjusted models coefficients and statistical criteria values for throughfall (Tf), Stemflow (Sf), rainfall interception (INT) and rainfall interception ratio (INT ratio) variables for all evaluated Eucalyptus genotypes.

Parameter	Group	Genotype	Equation	R^2-adj	RMSE
Sf	General	All	Sf= 0.12 P + 0.01	0.98	1.29
Tf	By LAI	Es & Eb (High)	Tf = 0.43 P -0.07	0.96	1.55
		EngH, EgH & Ecg (Intermediate)	Tf=0.62 P -0.12	0.95	1.30
		EngL, EgL & En (Low)	Tf= 0.87 P -0.09	0.97	1.24
INT	By LAI	Es & Eb (High)	INT=0.56 P -0.09	0.96	1.67
		EngH, EgH & Ecg (Intermediate)	INT=0.36 P-0.02	0.89	1.89
		EngL, EgL & En (Low)	INT= 0.11 P -0.10	0.80	1.90
INT ratio	By LAI	Es & Eb (High)	INT ratio=-13.78 Ln(P)+121.51	0.70	1.44
		EngH, EgH & Ecg (Intermediate)	INT ratio=-20.71 Ln (P) +139.09	0.77	1.22
		EngL, EgL & En (Low)	INT ratio=-30.12 Ln (P)+156.78	0.73	1.40

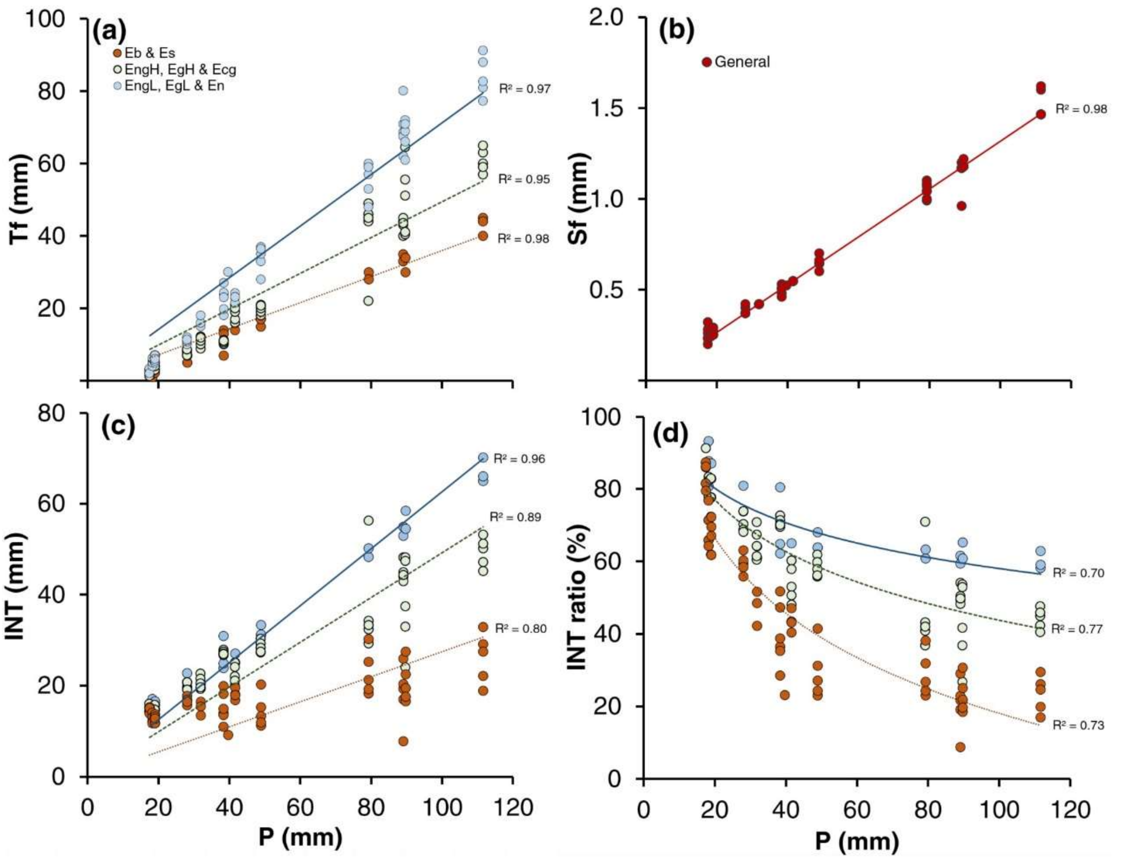

Figure 2. Throughfall (Tf) (a), Stemflow (Sf) (b), Rainfall interception (INT) (c) and Rainfall interception ratio (INT ratio) (d) as a function of precipitation (P) for genotypes of Eucalyptus. Lines in each figure indicate the behavior trend of each group of genotypes.

4. Discussion

The results obtained confirmed the study's hypothesis; rainfall interception varied according to the LAI of each genotype, with the trend that as LAI increased, INT increased and Tf and Sf decreased. Ferreto et al. Ferreto, Reichert [1] obtained a similar result with three Eucalyptus taxa evaluated between 2.5 and 4.5 years old, finding that the INT between species was *E. saligna* > *E. dunnii* > *E. benthamii, LAI* being the principal factor that directly inferred the differences in INT between species. Baleiro et al. [12] and Sari et al. [13] mention that LAI is an excellent indicator for estimating INT in Eucalyptus plantations; it allows providing information on the structure and density of the treetop, which facilitates differentiation of the potential INT between genotypes.

Calder et al. [6] mention that INT is a key factor in the growth of forest plantations; Taxa / genotypes with high INT are more susceptible to water stress because it limits groundwater recharge capacity; therefore, it must be monitored and controlled throughout the productive cycle of the crop. Câmara et al. [14] and Ferreto et al. [15] mentioned that in Eucalyptus plantations, INTs higher than 40% are considered worrying because they generate dependence on high intensity and long-duration rains. In the case of our study, the Eb, Es, EngH, EgH and Ecg genotypes exceed 50% of INT; therefore, this aspect should be considered in the establishment and management of plantations with these genotypes, varying the planting density or carrying out pruning or thinning activities that reduce INT.

5. Conclusions

A selection of taxa according to the characteristics of the local climate, specifically rainfall intercept, is essential. The use of genotypes that adapt to the water availability of the site and have a rain interception that allows the recharge of moisture in the soil will allow the conservation of the crop productivity and avoid the mortality of trees due to water stress. Additionally, it will not affect nearby ecosystems and underground water sources.

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