Crown architecture and fog-plant relationship in a tree plantation trial in South Perù

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Abstract: In fog-dependent pre-desertic environments, tree crowns represent good water collectors by intercepting humid fog-wind, that represents the main water resource. The competition for and the uptake of scarce resources is generally controlled by tree plants by using the development of structural elements, i.e. through an adjustive process of a more or less plastic and reactive tree architecture. Coupling fog and vegetation surface is dependent from water-vapour fluxes and physical and physiological characteristics of the vegetation. The architecture of trees interfaces to the neighbouring environment in term of occupation of bio-volume (carried out both by root and crown systems), and physiological ability (evapotranspiration control) to survive severe water stress. Quantity of condensed water fit directly with the height, at least relatively to the canopy height of Caesalpinaea spinosa population. The paper deals with the description of crown form, branching system, leaf form, specific area, and density as modelised in 5 species (*Acacia saligna, Caesalpinea spinosa, Casuarina equisetifolia, Parkinsonia aculeata, Prosopys pallida*) used for a plantation trial (start: june 1995) in a fog-dependent ecosystem of the Pacific coastal hills in Mehja, South Perù. The dynamics of the crown meta-population was observed by monitoring the modification of crown architecture since the first growing season after plantation. In the field, fog interception was indirectly observed by measuring the amount of water resulting from crown throughfall. Fog capturing efficiency was either investigated at three height levels by comparing the amount of water collected by tree-samples placed in rotation at different height from the ground. The amount of water collected by unit of leaf area per species (ref. to 1 m^2) has been compared with the quantity of water collected by standard fog collectors. *Acacia saligna* shows the highest value of specif area per leaf, while *Casuarina equisetifolia* has the maximum leaf density per crown unit. Besides opposite strategy of crown architecture, *Casuarina equisetifolia* and *Acacia saligna* show the highest values of fog collection.

1. INTRODUCTION

The uptake of and the competition for scarce resources is generally controlled by tree plants by using the development of structural elements, i.e. through an adjustive process of a more or less plastic and reactive tree architecture, directly linked to leaf-area sapwood ratio, as a phenotypic response to environment constraints (Mencuccini & Grace, 1995). Coupling fog and vegetation surface is dependent from water-vapour fluxes and physical and physiological characteristics of the vegetation. In the coastal hills of the South Peru, fog represents the main source of water supply for survival and growth of the vegetation. In the tree-stand relics surrounding the area of study (Research Station of Las Cuchillas, Mejia, Dept. of Arequipa), the fog-water seems to be sufficient for the maintenance of tree individuals: the amount of collected (i.e. pontentially available) water it is proportional to the crown volume (see chapter Calamini et al. **b.**). Acclimation (*sensu* Borghetti, 1998) mechanisms to water stress exhibited by native species (*Caesalpinaea spinosa, Duranta* spp.) base on the ability to activate just some sectors of crown per growing season but maintaining a permanent vitality of the whole-individual meristems, i.e. by controlling crown archictecture dynamics. On the other hand, long- and short-term dynamics of relic stands are directly affected by grazing disturbance, both as regards the fate of regeneration (e.g. seeds predation, seedlings browsing by domestic animals), and to physical properties of the soil. In parallel, indirect disturbances given by man activities linked to grazing, as like as cutting and local fires, are present. Very little is known on fog/plant relationships during early stages of tree life, as well as on how the amount and the seasonal regime of water influence seedling establishment and crown construction. The general hypothesis of the research is that, all state factors being equal, the grater is the exposed surface of individual crown, the greater are survival probabilities of the seedling as linked to water intercepting (i.e. collecting) capacity. The paper aims at understanding the coupling pattern of planted trees and fog, and the crown development under controlled, and undisturbed conditions. Crown architecture features of juvenile individuals belonging to five species, both native and exotic were

surveyed in a plantation trial, and fog capturing activity by seedlings crowns was investigated.

1.1 Materials and methods

In the test site of Las Cuchillas (Mejia, Dept. of Arequipa: see Bartolucci et al., 1996), a sub-sample of 40 seedlings -8 plants per species- was selected to test fog collection activity by juvenile tree crowns. The sub-sample was derived by a randomised structuring of trial treatments, as presented in chapter Calamini et. al., **a**. The selected species are *Parkinsonia aculeata* (**PA**), *Prosopys pallida* (**PP***)*, *Acacia saligna* (**AS***)*, *Casuarina equisetifolia*(**CE***)*, and *Caesalpinaea spinosa*(**CT, CT1**). The individuals of the last species belong to two cohorts: **CT**, individuals trasplanted after six month-breeding in nursery; **CT1**, individuals transplanted after one year in nursery.

A circular plastic film, circuscribing the crown projection of the seedlings, was placed. The constant slope of the film channels the throughfall to a water collector. Two plants per species, having the largest crown, were selected to survey the stem-flow amount by intercepting the water flowing along the stems by neoprene ribbon. To reduce the bias given by condensation on the plastic film, two control devices were placed close to the trial. Moreover, control rain gauges were placed to measure the effect of possible events of rain. The fog-water amount was quantified by volumetric methods and compared with the one collected by standard fog-colectors. Meansurements were taken in the morning, averaging 24 hours. In order to evaluate tree-shelters effect (as far as they have been used as treatment in the plantation trial; see Bartolucci et al. 1996; chapter Calamini et al.) in term of fog condensation, two collecting devices were placed matching control tree-shelters.

In order to characterise the crown shape and architecture, the following parameters were measured: crown size each 5 cm; first order branches: intersection height, diameter at intersection; upper order branches: distance along the lower order branch from the intersection; diameter at intersection, lenghth. On each branch, leaves were counted down and classified according to size classes. Sub-samples of leaves were measured by using a graph paper set. Such morphological data were collected every two months. Biomass was estimated by regression forecasting analysis on destructive samples.

1.2 Plant Morphology

Crown form and architecture models of four of the five analysed tree species result in figg. 1-4. *Prosopis pallida* is still not classified. The species conform to the models of Troll, Attim's and Champagnat as described by Hallé et al. (1978). Average values of morphological characteristics per species at the second vegetative season are given in tab. 1 and 2. *Acacia saligna* and *Casuarina equisetifolia* individuals move away decisively from the remnant species, both in term of morphological parameters, and in crown complexity.

Caesalpinaea spinosa 12-months-transplanted seedlings (**CT1**) as compared to *C. s.* 6-months (**CT**), height and collar diameter being equal, show higher values of leaf area, crown volume, biomass (Tab. 1), and crown complexity (Tab. 2). Within the native species, *Prosopis pallida* shows the highest average values of crown surface and volume, branch surface and crown complexity, despite the fact of having average values of height lower than the other ones. The values of surface and volume per height unit confirm the gap between *Acacia saligna*, *Casuarina equisetifolia* and the other species. The crown complexity (i.e. branching and architecture) plays a major role in separating the individuals, as result by performing a discriminant function analysis. *Acacia saligna* architecture model emphasises the development of branching in term of unit volume, while in *Casuarina equisetifolia* individuals the total crown surface in maximised in relation to the needle-shaped leaves, having a very high specific Leaf Area.

1.3 Fog / Plant relationships

The average values of the total amount of collected water per fog event are given in fig 5. Linear regression functions showing the relationships between collected fog-water amount and morphological parameters are given in figg. 6 and 7. Exotic species (i.e. **AS** and **CE**) show a clear trend in relationships between increasing Crown volume (fig, 6 **CE, AS**), surface, and Leaf area, while non-significant results where detected for native species. Similar results where gathered by relating height and collected water (Fig. 7), even if native species performed better. The higher the plants, the more significant relationships were (expected and) found.

1.4 Conclusion and reccomandation

Determining the crown-architecture models served to explain, at least partially, the relative importance of morpho-parameters and fog-intercepting efficiency. Significant relationships between crown characteristics and the amount of collected fog-water, show a positive trend in the intercepting efficiency while height and crown complexity increases. Significance indicators have lower values in native

species. The understanding of crown architecture pattern suggests to drive further research on the fog capturing systems enlarging studies at individual level in order to determine the effect of specific positioning factors on the whole-individual processes. In parallel, has to be taken into accoutn that inter-individuals competition is stil absent.

Acacia saligna and *Casuarina equisetifolia* individuals grow and collect water by rhythmes and amounts of substantial higher degree in comparison to native species. Nevertheless, while under non-watering treatments *Acacia* individuals show few mortality events (see Chapter Calamini et al. **a.**), *Casuarina* ones, matching hardly acclimation mechanisms according to their architecture dynamic model, i.e. Attim's continuous growth, show a high death rate. *Acacia*, at least in the early stages of life, appears as a more confident species in term of balancing survival, establishment and fog-capturing efficiency in plantation trials whenever watering programmes are not available.

In parallel, *Prosopis pallida* seems to be, in the set of native species, the best one in response to integrating survivorship, establishment and fog-capturing efficiency.

2. REFERENCES

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SPECIES	Diameter (mm)	Height (cm)	Crown Depth (cm)	Cr. Sur. (cm^2)	Cr. Vol. (cm^3)	Bra. Sur. (cm^2)	Leaf Ar. (cm^2)	Biomass (g)
AS	27,6±10,9	107,3±49,6	83,6±48,7	5957,9	407184,4	1967,1	9160,3	1830,8
CE	17,1±7,8	151,3±57,1	122,5±53,3	4477,3	145459,7	1131,9	26918,1	178,1
CT	9,3±3,3	34,4±22,6	29,3±22,3	100.0	723.0	72,7	26.0	13.5
CT1	9,1±1,6	36,3±13,6	33,3±15,7	253,2	2396,4	89.2	71,2	23,8
PA	9,4±3,3	57,9±34,6	50,4±33,6	174,0	2452,9	132,9	-	487,3
PP	10,1±3,8	36,1±10,8	32,1±10,9	629,3	24847,0	190,5	276,0	-

Tab. 1 Main morphological characteristics of tested species. Avg values ± Standard Deviation in columns 1to 3. *Legenda:* **Diameter**= collar diameter; **Crown Depth**= From the intersection of the lowest branch-carrying-leaves to the apex; **Cr. Sur.**: Area of 7the two-dimensional section (E-W) of the crown shell measured **Cr. Vol.**: Volume of the crown. **Bra. Sur.** Exposed surface of the branches modelised on the basis of their length and diameter apical extinction; **Leaf Ar.**= Leaf Area; **Biomass**=Total biomass

a

SPECIES	1st ord. Brnchs (n)	2nd ord. Brnchs (n)	3rd ord. Brnchs (n)	Avg. Σ L. 1st (cm)	Avg. Σ L. 2nd (cm)	Avg. Σ L. 3rd (cm)
PA	2,1	0,5	0	38,2	3,3	0
CT	2,8	0	0	10,5	0	0
CT1	4,3	1,3	0	46,9	5,7	0
PP	7,4	1,5	0,5	149,7	15,6	2,8
CE	25,1	7,7	0,7	775,3	219,1	18,9
AS	7,9	9,2	2,5	394,4	389,7	85

Tab. 2 Branching average characteristics of tested species listed per increasing crown complexityt. *Legenda:* **1st (2nd , 3rd) ord. Brnchs (n):** Number of 1st, 2nd, 3rd order branches; **Avg. Σ L. 1st (2nd , 3rd) (cm):** Average value per population of the Sum of Lengths of 1st (2nd , 3rd) order branches
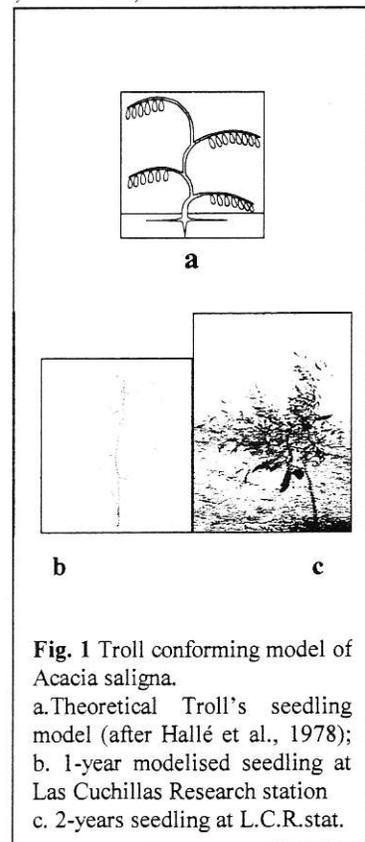
b   **c**

Fig. 1 Troll conforming model of Acacia saligna.
a.Theoretical Troll's seedling model (after Hallé et al., 1978);
b. 1-year modelised seedling at Las Cuchillas Research station
c. 2-years seedling at L.C.R.stat.

Fig. 2 Attim's continuous growth model (after Hallé et al., 1978). *Casuarina equisetifolia* **a**. Seedling model (aft. Hallé et al., 1978); **b**. Pole-stage tree (aft. Hallé et al.1978). **c**. Crown shell as modelised in Las Cuchillas Research Station

Fig.3 Champagnat conforming model in *Caesalpinaea spinosa.*
a.Sapling Champagnat' model (Hallé et al., 1978)
b. Modelised sapling at Las Cuchillas Research Station

Fig. 4 Champagnat modified model after Hallé et al. (1978) **a**. Seedling according to Hallé et al. (1978) **b.** , **c**. Modelised *Parkinsonia aculeata* seedlings at Las Cuchillas Research station

Fig.5 Average amount of fog-water collected per event and species

Fig. 6 Linear regression functions between crown volume and intersepted water. Three of the five tested species

Fig. 7 Linear regression functions between height and intercepted water