Ben Gurion University of the Negev
Jacob Blaustein Institute for Desert Research
Albert Katz International School for Desert Studies
The Wyler Department of Dryland Agriculture

THE EFFECT OF IRRIGATION FREQUENCY AND WATER QUALITY ON THE BIOMASS PRODUCTION AND WATER EXTRACTION PATTERNS OF *Acacia saligna* MATURE SHRUBS

Thesis submitted to the Ben Gurion University
of the Negev in partial fulfillment of the
requirement for the degree of Master of Science

By Emilio Garcia Apaza

September, 2000

Sede Boker, Israel

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Jacob Blaustein Institute for Desert Research
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Thesis submitted in partial fulfillment of the requirement for the degree of
"Master of Science"
At the Albert Katz International School for Desert Studies
Ben Gurion University of the Negev

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Approved by the Chairman

of the Graduated Program Committee……………………..…. Date …………

Abstract page

THE EFFECT OF IRRIGATION FREQUENCY AND WATER QUALITY ON THE BIOMASS PRODUCTION AND WATER EXTRACTION PATTERNS OF *Acacia saligna* MATURE SHRUBS.

E. Garcia
Thesis submitted in partial fulfillment of the requirement for the degree of Master of Science; Albert Katz International School for Desert Studies; J. Blaustein Institute for Desert Research Ben - Gurion University of the Negev

The effects of irrigation frequency, water quality and simulated flood on the biomass production and water extraction patterns of *Acacia saligna* mature shrubs (planted to a density of 2500 shrubs Ha^{-1}) were evaluated in a field trial located at Sede Boker, Israel (31° 08' North and 34° 53' South). Three irrigation frequencies: eight [well-watered (WW)], four (high frequency) and two (low frequency) applications per month were applied using two different water qualities (1 and 6 dS m^{-1}, denoted as F and B respectively). Fresh water (1 dS m^{-1}) was used for flooding. Soil water content in the soil profile to a depth of 2.4 m. was monitored before and after irrigation using a neutron moisture meter. One access tube was located midway between two trees in the row and two additional ones at 1 and 2 m. from the row. During selected drying out periods (between irrigations) sequential water content profiles were analyzed to assess water movement in the soil profile and the water uptake patterns. Consumptive Water Use (CWU) in plots irrigated with brackish water was lower than in plots irrigated with fresh water. Diameters of trunks were measured 20 cm above ground every fifteen days and the Cross Sectional Area (CSA) computed. Total Dry Biomass Production (TDBP) at the end of the trial period was obtained by lopping the shrubs at a height of 1.50 m. The linear correlation between CSA and TDBP was used to estimate the biomass evolution during the 1999 growing period.

The highest CSA was found in the Well-Watered (WW) treatments and high irrigation frequencies. The yields of plots well-watered with B water was roughly 10 times higher than those plots irrigated with runoff (R) only. In the plots irrigated with B water, significant differences in CSA's were found between WW and Low Frequency.

The biomass production increased linearly with CWU, and was not affected by the water quality.

Irrigation frequency increased Gross Water Use Efficiency (GWUE) for fresh water treatment and runoff application had not effect. When runoff was applied there was an increase in GWUE also for the brackish treatment, albeit a small one.

The results of this field trial show a positive significant effect of runoff on biomass production and it is feasible to use brackish water to grow *Acacia saligna* shrubs in arid regions.

The participation of Mr. Emilio Garcia Apaza in the two year research programme “*Agriculture and Biotechnology for Sustainable Dryland Development*” was supported by the Capacity 21 Trust Fund in United Nations Development Program (UNDP) through the national Capacity 21 programme in Bolivia.

Acknowledgements

I am indebted to the people who supported me in the difficult and in the favorable times, in the hard fieldwork, and in the process of presenting the results of this research.

Thanks so much to Dr. Pedro Berliner for his constant encouragement and full support whenever I needed it. Muchas gracias por tu paciencia Pedro!

An especial thanks to Dr. Jhonathan Ephrath, Dr. Klaus Droppelmann and Lizanne Roxburgh for their suggestions in the work. My deep gratitude to all the staff of the Wyler Department for Dryland Agriculture especially to Claudio Wexler, Jossi Goldstein, Dr. Genadi Carmi, Dr. Adit Arasi, Nurit Nin-Ari, Odette Levi. Thanks a lot for helping me!

Many thanks to all the members of the Albert Katz International School for Desert Research, to my professors, especially to Prof. Jiftah Ben-Asher, Prof. Gideon Oron, Dr. Avi Golan, Dr. Moshe Silberbush. The motivation they gave me was very valuable.

A special thanks to Marisol Eggleton, Giorgio Dall'Olmo, and Dr. Surendra Singh for their encouragement. Especial thanks to Dr. Maria A. Doussi, thanks for giving me support and understanding as an entire being all the time.

Thanks to my family, especially my parents for giving me encouragement to continue my studies. I really appreciate your support.

Thanks to the whole community of “Caravan City”, to my friends of the football and basketball team (I enjoyed it!), and to the community of the Midreshet Sede Boker for your genuine friendship.

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ANOVA	Analysis of Variance
AS	Addition of NaCl to the fresh water
ATDB	Annual Total Dry Branches production
ATDBP	Annual Total Dry Biomass Production
ATDK	Annual Total Dry Trunk production
ATDP	Annual Total Dry Phyllode production
ATDT	Annual Total Dry Twig production
B	Brackish water
BP	Biomass production
BW	Water with high salt concentration
CEC	Cation Exchange Capacity
COM	Comparison of Means
CSA	Cross Sectional Area
CSA1	Cross Sectional Area at the beginning of the season
CSA2	Cross Sectional Area at the end of the season
CWU	Consumptive water Use
D	Equivalent trunk diameter
D_d	Dry wood density
ΔL	Difference in effective stored water depth
ΔS	Difference in total water volume in the profile between the first and the last measurement of soil moisture (beginning and end of the season)
DOY	Day of the Year
D_x	Mass of the dry sample of phyllode, twigs, branches, or phyllode litter
EC	Electric conductivity
E_e	Estimated evaporative water losses
E_o	evaporation from Class A Pan
ESP	Percentage of adsorbed exchangeable sodium on the colloidal fraction
ET	Evapotranspiration
δ_i	Fitted value obtained by use of the fitted regression equation
F	Fresh water
FC	Field Capacity
F_x	Mass of the fresh sample of phyllode, twigs, branches, or phyllode litter
GWUE	Gross Water Use Efficiency
HB	High Irrigation frequency using brackish water
HBR	High Irrigation frequency using brackish water and application of runoff
HF	High Irrigation frequency using fresh water
HFR	High Irrigation frequency using fresh water and application of runoff
LB	Low Irrigation frequency using brackish water
LBR	Low Irrigation frequency using brackish water and application of runoff

LF	Low Irrigation frequency using fresh water
LFR	Low Irrigation frequency using fresh water and application of runoff
L_{H2O}	Equivalent water depth
m_d	Dry mass of the woody sample
OM	Organic Matter
PFC	Phyllode fall collection
PWP	Phyllode water potential
R	Runoff
RD_x	Relative water depletion of soil layer x
RGR	Relative growth rate
T_1, T_2	Time of successive measurements of equivalent diameter
TDB	Total Dry Branches production
TDBP	Total Dry Biomass Production
TDK	Total Dry Trunk production
TDP	Total Dry Phyllode production
TDPC	Total Dry Phyllode collection (litter)
TDPS	Total Dry Phyllode sample (sub-sample of TDP or TDPC)
TDS	Total Dissolved solids
TDT	Total Dry Twig production
TD_x	Total dry mass (x = phyllodes, twigs, branches or phyllode litter)
θ	Volumetric water content
TVK	Total dry mass of the trunk
TWC	Total water content
UNDP	United Nations Development Program
V_f	Fresh volume of the woody sample
VWC	Volumetric water content
WA	Water application
WU	Water uptake
WUE	Water use efficiency
WUE_{st}	Average Water use efficiency
WW	Well-watered
WWB	Well-watered brackish
WWF	well-watered fresh
z	depth interval in the soil

1. Introduction

Eighty six percent of the fuel consumed in developing countries is wood. Firewood is usually the principal source of energy for cooking and heating (Arnold, 1978) and it is almost the only domestic fuel in rural areas as well as in some urbanized areas. This dependence severely strains the wood resources in the arid and semiarid lands of developing countries (Lovenstein *et al*., 1993; Zohar *et al*., 1988).

During the dry season or during prolonged droughts when herbaceous fodder is not available, only trees and shrubs can provide the necessary feed for livestock. This is one of the traditional uses of the woody vegetation in arid and semiarid regions. Some tree species may be used for additional purposes. Leguminous shrubs for example, may be used to improve the nutritional status of the soil through their atmospheric nitrogen assimilation capacity. These species of trees are known as multipurpose (and in the case of *Acacia saligna*) fast growing trees and are a source of protein rich fodder, firewood, charcoal, poles, lumber and soil organic nitrogen.

In many arid and semiarid regions, in which rain events are few and far apart, plant or shrub growth on any significant scale would not be possible without the use of stored water in the soil profile. Due to the formation of crusts, or extremely high rainfall intensities, large fractions of the rainwater are lost as surface runoff and do not reach the root zone. Additionally, evaporation from the soil surface is usually high, thus further depleting the already meager amount of water stored in the soil. Biomass production is therefore extremely low in these areas. Water harvesting appears to be a viable solution in those cases (Ben-Asher *et al.*, 1994; Sahuerhaft, *et al*., 1998). During a runoff event the water is conveyed to a lower lying area surrounded by a retaining wall in which it percolates into the soil. In this way the soil profile may be wetted to great depths and once the soil surface is dry the evaporation is only a small fraction of the stored water.

The drawback of this approach is that to implement it, a certain degree of regularity in the flood generating rainfall events is necessary. One of the characteristics of drylands is however their high climatic variability, in particular in terms of precipitation (Bruins *et al.*, 1998). Supplementing runoff events with irrigation appears to be therefore mandatory in order to ensure a constant level of biomass production on a long-term basis. Even though water covers 75 percent of the world's surface, only 0.3 percent is fresh water (FAO, 1995). Distribution of this resource is not homogeneous, and due to the increase in the demand for urban use there is no fresh water available for the irrigation of fuelwood and fodder plantations. The only sources for water frequently available in arid zones are brackish aquifers (Brimberg *et al.*, 1993).

Until recently, the use of brackish water was not considered suitable for irrigation. However, the current water scarcity, primarily in the Negev Desert, has forced Israeli scientists to explore the possibility of including brackish water in the irrigation regimes (Oron *et al.*, 1999). The EC of the saline groundwater in Israel ranges between 2-8 dS/m (about 12000 to 5600 mg/l in TDS) (Rhoades *et al.*, 1992). Orange groves (Goell *et al.*, 1975; Dirksen *et al.*, 1979), saplings of *Dalbergia sissoo* (Singh, *et al.* 1996), *Acacia nilotica* tree (Minhas *et al.*, 1997) and Eucalypt trees (Sweeney, *et al.*, 1997) have already been successfully grown using brackish water. The application of brackish water to relatively resistant shrubs and/or trees may therefore be feasible

When water is the limiting factor biomass production is usually linearly related to transpiration and the slope of this relation, WUE (Water Use Efficiency) is rather constant for each species. It is not clear if the use of brackish water will result in WUE's different from those obtained with fresh water.

In the case of runoff irrigation the salts may be leached below the root zone and a relatively low salt environment maintained in the rhizosphere in spite of irrigation with brackish water.

Tree productivity is generally not well documented for dry regions. Biomass production has been studied in temperate zones but water use and WUE of the species studied were usually not addressed. Preliminary results of irrigation trials of *Acacia saligna* in which runoff was supplemented with brackish water showed that it is a feasible approach in drylands but the response of the shrub to the various factors has not yet been quantified.

The objective of this research was to evaluate the effect of runoff application and two levels of water quality at different irrigation frequencies have on the biomass production of a leguminous shrub (*Acacia saligna).*

Our hypothesis were:

Ho_1: The production of shrub biomass is not affected by the use of brackish water

Ho_2: Highest production is attained with the highest irrigation frequency

Ho_3: Addition of Runoff during winter increases biomass production.

2. *Review of Literature*

2.1. The scarcity of the resources

Rural and urban concentration people require food, energy, drinking water, and shelter. In areas in which the dependence on wood fuels is often almost total, the dwellers impose a heavy toll on the surrounding countryside. These requirements have led to the scarcity of natural resources, which in drylands are mainly water, fodder and firewood, the latter as a source of energy (FAO, 1995; Lean *et al*, 1990).

2.1.1. ***The water scarcity***

Less than 3% of the world's water is fresh and more than three quarters of it is frozen, mainly at the poles. 98% of the remaining fresh-water lies underground. Only about a hundredth of a percent of the world's total water is easily available to terrestrial life, including man.

Since 1950, the world's use of water has increased three and a half times over and per capita use has almost trebled. Americans have the highest consumption per capita of water, about 2.300 cubic meters per year; Canadians use about 1.500 cubic meters and Australians 1.210. However, most of Africa and the Middle East, Northwest Mexico, parts of Chile and Argentina, and nearly all of Australia suffer of a severe water shortage.

People, as well, receive grossly unequal amounts of fresh water. About 2 billion people in 80 countries around the world live in areas suffering from chronic water shortage and, as human and animal population grows, the crisis gets worse (FAO, 1995).

2.1.2. ***The firewood scarcity***

Two billion people are caught in the “poor man’s energy crisis”- the shortage of fuelwood (Lean *et al*, 1990; Sauerhaft *et al*, 1998). More than 100 million people live in areas where there is already an acute scarcity of fuelwood (Saouma, 1981), which means that they are unable to satisfy their minimum energy needs for cooking and heating. The shortages are most acute in regions of Africa, mountainous areas of Asia (Himalayas in particular), and on the Andean Plateau in Latin America (FAO, 1995). This shortage has been attributed to the over-exploitation of forest and woodlots by the rural poor, as human numbers, and energy needs, increase (Sahuerhaft *et al*., 1998). The clearing of trees and vegetation enhances erosion, thus reducing soil fertility. Erosion, desert encroachment, loss of biomass productivity and reduced water retention of soil follow in the wake of deforestation.

2.2. Water Use in Arid and semiarid lands

Small amounts of precipitation and low availability of natural water sources characterize arid and semiarid lands. This natural shortage of water has been an incentive to search for additional sources of water currently not intensively exploited. Such non-utilized water sources include high-quality fresh runoff, and brackish water from shallow and deeper aquifers.

2.2.1. ***Runoff water for plant production***

Runoff farming allows agricultural activity in areas that normally do not receive enough rainfall. This is achieved by concentrating runoff from a collecting area (catchment) into a smaller and lower lying receiving area, where water is stored in the soil profile. This water may be used efficiently, and transpiration regulated to allow plants to produce biomass throughout the dry season (Ben-Asher *et al.*, 1994)

Cultivation of trees for firewood and fodder in such systems was proposed as a solution to deforestation as the required water is stored independently of the tree cover (Lovenstain *et al*., 1991).

2.2.2. ***Brackish water use in irrigation***

In arid and semiarid lands, brackish water is usually available as groundwater (Sheng *et al*., 1997; Brimberg *et al*., 1993) or in rivers and lakes (UNESCO, 1956; Bonne, *et al*., 1975; Mcleod *et al*, 1999). Brackish water can be defined as saline water that significantly restricts its direct use, without however, preventing completely its use (Bonne *et al*, 1975). Water from deep brackish aquifers has already been used for irrigation in Israel (Pasternak *et al*, 1975; Oron *et al*., 1995; Oron, *et al*., 1999).

The irrigation in general with brackish water will depend on the levels of salinity and the salt-sensitivity of the used species. The accumulation of salts in the root zone may slow down the plant development. The earliest symptom of a non-halophyte exposed to salinity is that its leaves grow slowly (Munns *et al*, 1986). There will be effects on the stomatal conductance, plant water potential (Pezeshki, *et al*., 1986) and as salt concentration increases above a threshold level, both the growth rate and, ultimate the size of plants progressively decrease (Maas, 1996). The long-term effects include increase in osmotic potential due to high salt concentrations, particularly in old leaves (Munns, et. al 1986). Agricultural crops irrigated with brackish water will require relatively large quantities of brackish water to leach salts out of the root zone (Ayers, *et al*., 1985).

When crops are irrigated with saline water during the dry season, the soil moisture increases and the salt concentration and osmotic pressure of the soil solution decreases, allowing moisture and nutrient absorption by crops (Shen *et al*., 1997). On the other hand the water deficit is not believed to limit growth to salt-stressed plants, more likely, energy becomes limiting for growth because more is expended in order to accumulate ions and solutes needed for osmotic adjustment (Maas, 1996)

2.2.3. ***Frequency of Irrigation***

Plant productivity in semiarid environment depends largely on water availability. Water stress affects practically every aspect of plant growth, modifying the anatomy, morphology, and physiology. Soil water deficit reduces stomatal conductance, transpiration and photosynthetic rates (Saeed, *et al*., 1998; Kramer, 1969), which result in reduced biomass production (Howell, 1990).

Developing appropriate irrigation regimes requires knowledge of both the timing and the amount of water to apply in order to optimize production. The determination of the timing and/or application of amount of water may be accomplished through soil or plant based measurements (Fereres *et al*., 1990; Hsiao, 1990; Campbell *et al*., 1990). Normally a number of treatments are applied and the one with the best performance is chosen. Differences in 5, 10, 15 and 20 days between irrigation with saline water have been used for orange tree production (Grivas, 1976; Goell *et al*., 1975), and 35 days (Shalhevet, *et al*., 1990) with fresh water. Using drip irrigation for grapefruit trees intervals of 3 days with brackish water and 28 days for fresh water were recommended (Shalhevet, *et al*., 1990).

The irrigation frequency is related to the water uptake by the plant. High irrigation frequency with brackish water may be used to increase productivity of trees and crops (Minhas *et al*., 1997) and may leach the salts away of the root zone (Bernstein, 1981). On the other hand, plants receiving frequent irrigation may be subjected to water-logging, particularly in soils with high exchangeable sodium which induces swelling and/or clay dispersion and consequently poor water infiltration (Rhoades *et al*., 1990).

2.2.3.1. *Drip Irrigation.*

With surface irrigation, water is applied at intervals ranging from some days to several weeks, depending on the storage capacity of the soil, the crop, and the environmental conditions. Crops usually show a pronounced increase in yield when the soil moisture in the root zone is maintained at a high level, minimizing the occurrence of moisture stress. This condition can only be achieved by increasing strongly the irrigation frequency, which is feasible only with trickle or drip irrigation.

The dripper is a small device that allows the water to discharge from a lateral supply line at a very low and constant rate, from 2 to 30 l $hour^{-1}$, depending of the type of dripper. These systems usually operate at pressures of 1 to 3 bars.

The spacing between the lines will depend on the type of crops irrigated. If the rows are very far apart, such as in the case of orchards, it may be necessary to install two or more lines per row of trees.

The water savings associated with drip irrigation result from the fact that there is a non-irrigated zone in between the lines. As water flows out of a dripper, the moisture pattern in the soil has the shape of a bulb. The volume of the wetted bulb depends on the pore size distribution of the soil, the emitter discharge, and the irrigation time. Brackish water may be used because the roots of the plants develop inside the wetted volume where the salt concentration stays constant and equal to that of the irrigation water itself. The salts tend to accumulate in the outer parts of the wetted bulb and often white circles denoting the presence of salt can be seen on the soil surface. The excess salts must be leached either in a natural way by the winter rains or artificially with a spare sprinkler irrigation set when rain is not sufficient (Leliaert, 1987)

2.2.3.2. *Water Use Efficiency*

Water Use Efficiency (WUE) has been defined as the amount of water used per unit of plant material produced (Viets, 1975; Howell, 1990; Jensen *et al*., 1990; Mian *et al*., 1998). The plant material can be expressed as the total biomass and the water use as the total water input to the ecosystem (Han *et al*., 1997). WUE is an almost constant value for each plant species as long as water limits production.

Crops under humid conditions are ordinarily more efficiently in the use of water than the same crops grown under arid conditions (Viets, 1975), as water use is reduced more than the yield. Saeed (1998) and Snyman (1999) found that forage sorghum grown in semiarid and tropical zones, have the highest WUE when irrigated frequently, and watered lightly. Higher irrigation frequency results in higher evapotranspiration and therefore, higher biomass production.

2.3 . Cross sectional area increase in shrubs

The increment of cross sectional area in trunks of various tree species has been studied. The growth of new wood in the stem generally produces a more or less constant ring width (White, J. 1998). The development of the diameter of the trunk is affected indirectly by all the factors that affect the basic physiological processes (cell division and elongation, photosynthesis, respiration, hormone synthesis, enzymatic activity and transpiration}. The main environmental factors are solar radiation, relative humidity, water availability, and salinity. In arid regions where drought is severe, available soil moisture can limit shoot growth and thereby lead to the development of a very narrow annual ring or no ring at all (Morey, 1973, Kozlowski, 1971).

2.4. Non destructive estimation of tree biomass

The limited number of trees in field trials makes the destructive estimation of biomass production of trees or shrubs impractical. Therefore, indirect methods are used in order to estimate it (Haase, *et al*., 1995; Reed, *et al*., 1998). The correlation between standing biomass and cross sectional area are well documented (Lott *et al*, 2000; Droppelmann, 1999; Senelwa, 1998; Brown, 1997; Lovenstein *et al*, 1993; Nygren, 1993).

Allometric equations are derived by performing regressions between destructively determined dry masses of trees and the corresponding cross sectional area estimated from field measurements of equivalent trunk diameter (Droppelmann *et al*., 2000; Lott, *et al*., 2000; Lovenstein *et al*., 1993; Harrington *et al*., 1993; Nelson, *et al*., 1999; Senelwa *et al*., 1998).

3. Material and Methods

3.1. Site description

The experimental plot was located in the Sede Boker Campus (31° 08' N, 34°53' E, 400 m.a.s.l.) of the Jacob Blaustein Institute for Desert Research, Ben Gurion University of the Negev (Fig. 1). The region is on the border between arid and hyper-arid (between 0.04-0.05 P/PET ratio) according to the classification of UNEP (1997).

The soil has a typical bulk density of 1480 Kg m^{-3} in the top layer; and an average infiltration rate of 11 mm h^{-1}. Relevant soil characteristics are presented in Table 1.

Table 1. Average soil characteristic at Sede Boker campus (OM: organic matter; EC: electrical conductivity of a 1:1 extract; CEC: cation exchange capacity; ESP: percentage of exchangeable sodium).

Depth (m)	**Clay (%)**	**Silt (%)**	**Sand (%)**	**OM (%)**	**EC (dS/m)**	**pH**	**CEC (meq/100 gr soil)**	**ESP (%)**
0.00-0.15	18.6	21.2	60.2	0.24	3.52	8.3	15.6	25.0
0.15-0.30	22.6	21.2	56.2	0.25	3.19	8.6	15.8	36.5
0.30-0.60	26.6	21.2	48.2	-	8.03	8.4	14.0	59.0

Source: Berliner et al., (1998)

The annual precipitation in 1999 was 40 mm. The long term average annual temperature is 18°C, the average daily temperature in January lies between 6 to 8°C, the average daily maximum temperature in August ranges between 32 to 34°C and the average relative humidity at 14:00 (local time) between 20 to30% (Stern. *et al*. 1986 – Atlas of the Negev). The major pulse of vegetation growth is in late winter and early spring, but the timing and extent of germination are closely tied to rainfall, and, thus, vary substantially from year to year. Examples of woody species that grow in this area of the

Negev are *Tamarix nilotica, Atriplex halimus, Retama raetam, Thymelaea hirsuta* and the regional flora includes a large variety of herbs and geophytes (Alkon, et al., 1985).

3.2. Methods

3.2.1. Experimental design

Thirty-three plots of 75 m^2 each in a factorial experiment with 11 treatments in three randomized blocks were used (Fig. 2). Table 2 describes the treatments.

Table 2. Number of treatments, description, and code used in the experiment.

Treatment Number	Description	Code
1	Runoff	**R**
2	Runoff and irrigated thereafter with fresh water at high frequency	**HFR**
3	Runoff and irrigated thereafter with fresh water at low frequency	**LFR**
4	Runoff and irrigated thereafter with brackish water at high frequency	**HBR**
5	Runoff and irrigated thereafter with brackish water at low frequency	**LBR**
6	Irrigated with fresh water at high frequency	**HF**
7	Irrigated with fresh water at low frequency	**LF**
8	Irrigated with brackish water at high frequency	**HB**
9	Irrigated with brackish water at low frequency	**LB**
10	Well watered using fresh water	**WWF**
11	Well watered using brackish water	**WWB**

Definitions:
Runoff: Flooding once a year
High Irrigation frequency: irrigation once a week
Low irrigation frequency: irrigation twice a month
Well Watered: irrigation twice a week.
For the computations of the amount of water applied, see Section 3.2.7.2.

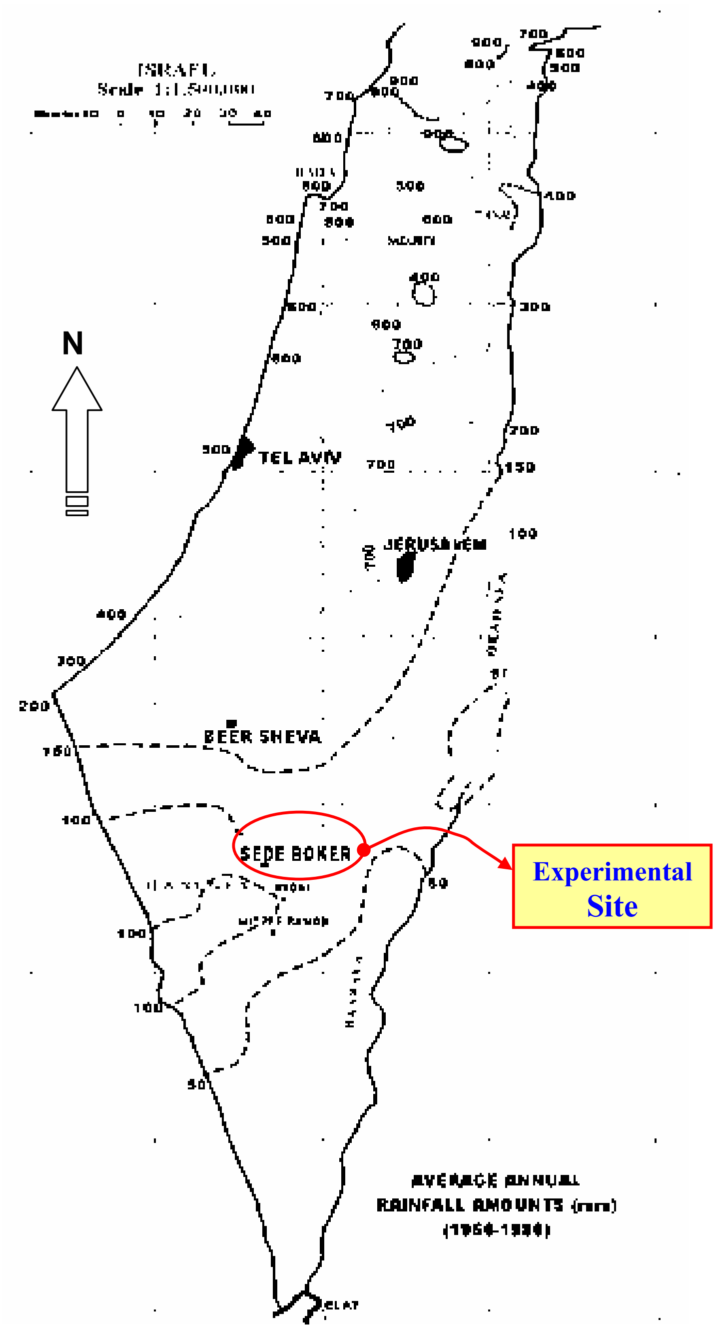

Fig. 1. Geographic location of the study site.

3.2.2. Statistical Analysis

Statistix for Windows v. 2.0 was used to conduct the statistical analysis. For analysis of biomass production and the water uptake, ANOVA was carried out for treatments 2 to 9. Tukey analysis was used to compare means of all treatments. To analyze the correlation between biomass production and CSA, the lack of fit, pure analysis and the analysis of residuals were used according Drapper et al. (1998) and Mead et al., (1993). Plant growth analysis was carried out following Droppelmann et al., (2000) and Hunt (1978).

3.2.3. Preparation of brackish water

A concentrated salt solution was first prepared by adding 70 gr of NaCl (table salt) to a liter of fresh water. Thus, an electric conductivity of 6 dS m^{-1} was obtained in the irrigation water, assuming that the average electrical conductivity of the fresh water from the National Water Carrier was 1 dS m^{-1}:

$$BW = 5\frac{dS}{m} x \frac{700\frac{mg_{SALT}}{L}}{1.2\frac{ds}{m}} = 2917\frac{mg_{SALT}}{L} \Rightarrow As = \frac{2917}{0.042} = 69452\frac{mg_{SALT}}{L} \cong 70\frac{g_{SALT}}{L} \qquad [1]$$

where:

BW = Water with high salt concentration;

AS = Addition of NaCl to the fresh water

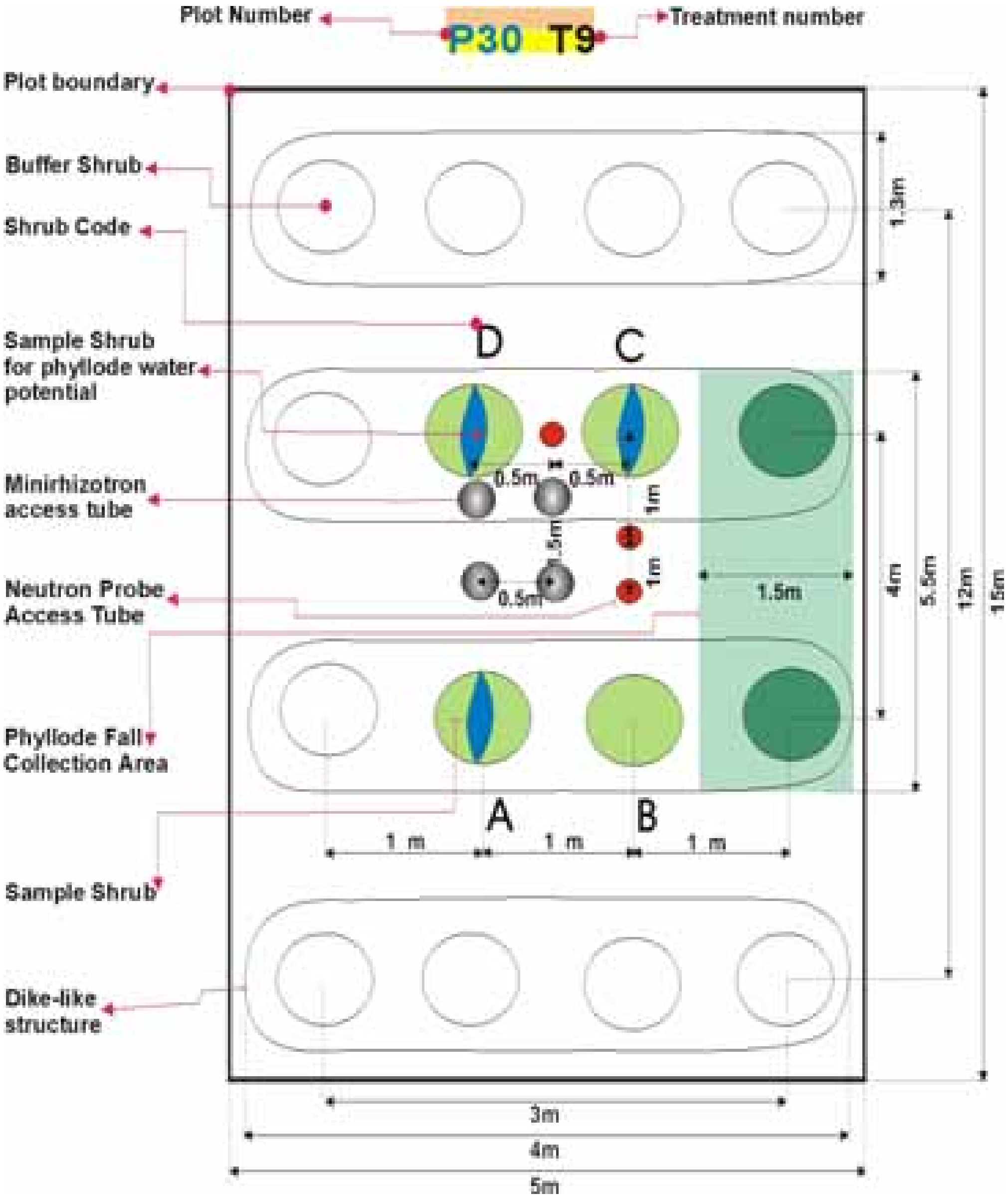

Fig. 2. Description of a single plot.

This solution was injected into the irrigation system at a rate of approximately 5% (4.2%) of fresh water using a proportional injector pump (model DI-210, Dosatron, France) with injection rate of 2% to 10% (1:50 to 1:10) and $10 lh^{-1}$ to $2.5\ m^3/h$ of operating flow range.

3.2.4. Plant material

Acacia saligna (Labill.) H. Wendl. shrubs were raised in a greenhouse and planted in 1995 in plots of 15x5 m at a density of 2500 trees Ha^{-1} (4m x 1m). From August 1995 onwards, all plots received the treatments as mentioned above (see section 3.2.1). In 1999, at the beginning of the experiment, the shrubs were already 4 years old (mature), and had been subjected to the treatments since planting. They reached at the beginning of the season averages heights of 3.0 m, with a cross sectional area of 62.10 cm^2.

3.2.5. Biomass Production

The above ground biomass production during the 1999 season was estimated from the increment of the CSA of the main trunk.

3.2.5.1. *Cross Sectional Area (CSA).*

The CSA was computed from the perimeter obtained in the field:

$$CSA = \frac{D^2 \pi}{4} \qquad [2]$$

where:

CSA = Cross Sectional Area
D = Equivalent trunk diameter at 20 cm above ground

The equivalent trunk diameter (D) was measured every 15 days at a height of 20 cm above the ground on each shrub.

3.2.5.2. *Phyllode Fall Collection (PFC)*

The assimilatory organ of *Acacia saligna* is an expanded flat petiole, termed a phyllode, that replaces the blade of a foliage leaf, and fulfills the same functions (Nativ *et al*., 1999).

The phyllode fall (the phyllodes that fell down due to the age, drought avoidance mechanism or other cause) was collected on all plots every 15 days prior to the irrigation of the low frequency treatment from a 4 m^2 area. Water content of the fresh PFC was determined on sub-samples.

3.2.5.3. *Lopping and Pruning.*

A total of 528 shrubs were lopped (the diameter of 132 of them was determined). This operation took place at the beginning of the winter (October 1999), after the measurement season.

Shrubs were sawed at a height of 1.50 m above ground, leaving from 2 to 3 large strong branches on the main trunk. The biomass was separated into phyllodes, twigs (diameters smaller than 1 cm), and branches (diameter greater than 1 cm). Samples of different sizes and masses were obtained to estimate the density of the wood.

Immediately after lopping, the fresh weight of the cut material was determined. Representative samples of each group were obtained and oven dried at 65^oC, until a constant weight was reached. Average time for total dryness was 2 days for phyllodes, 4 days for twigs and 7 days for branches.

3.2.5.4. *Destructive Biomass Estimation*

The standing biomass production was estimated using the following equation:

$$TD_x = \frac{T}{1+\left(\frac{F_x - D_x}{D_x}\right)} \qquad [3]$$

where:

TD = Total dry mass (Kg)
T = Total freshly harvested mass (Kg)
F = Mass of the fresh sample (Kg)
D = Mass of the dry sample (Kg)
x = Phyllodes, twigs, branches, or phyllode litter

The final computations gave us the Total Dry Phyllode Fall (TDPF), Total Dry Twigs (TDT), Total Dry Branches (TDB).

3.2.5.4.1. Total Dry Phyllode mass (TDP)

The total dry mass of the phyllodes (TDP) was obtained by adding the dry mass of the litter to the mass of the pruned material:

$$\text{TDP} = \text{TDPF} + \text{TDPS} \qquad [4]$$

where:

TDP = Total dry mass phyllodes (Kg)
TDPF = Total dry mass of phyllode fall (Kg)
TDPS = Total dry mass harvested (sampled) or collected in the field (Kg)

3.2.5.4.2. Standing shrub trunk

The basal and top diameter, the height (length) of the trunks and branches left in the plot after lopping were measured to obtain the Total fresh Volume of the Trunk (TVK). We assumed that they were truncated cones. The equation used to obtain the volume is as follows:

$$V = H * \left(D^2 + d * D + d^2\right) * \frac{\pi}{12} \qquad [5]$$

Where:

V = Volume of the truncated cone (m^3)
H = Length (m)
D = Basal diameter (m)
d = Diameter at the top (m)

Therefore, the total fresh volume was computed according:

$$TVK = \sum_{i=1}^{n}\left[H_i * \left(D^2{}_i + d_i * D_i + d^2{}_i\right) * \frac{\pi}{12}\right] + \left[H_t * \left(D^2{}_t + d_t * D_t + d^2{}_i\right) * \frac{\pi}{12}\right] \qquad [6]$$

Where:

TVK = Total volume trunk (m^3)
H = Length of the trunk or branch (m)
D = Basal diameter (m)
d = Diameter of the top in the end of the branch (m)
i ,t = number of branches, trunk

3.2.5.4.2.1. Wood density

The following procedure was used to establish the wood density. First fresh weight and dimensions of the woody sample were obtained. The samples were homogeneous in form (normally cylinders) and heterogeneous in size. These samples were oven dried at 65°C and weighed every day until a constant mass was obtained, normally after 6 to 15 days depending on the thickness of the sample.

The density of the wood was computed according:

$$D_d = \frac{m_d}{V_f} \qquad [7]$$

where:

D_d = Dry wood density (kg m^{-3})
m_d = Dry mass of the sample wood (Kg)
V_f = Fresh volume of the sample wood (m^3)

Comentario [EGA1]:
Correction No. 6

The dry mass of the trunk, was computed using:

$$TDK = D_d * TVK \qquad [8]$$

where:

TDK = Total dry mass of the trunk (Kg)
D_d = Dry wood density (kg m^{-3})
TVK = Total Dry Volume of the trunk (m^3) which is used because once is dry the sample it reduces its volumes and affect the Total volume

3.2.5.4.3. Whole shrub-dry biomass

The Total Dry Biomass Production (TDBP), was computed, as:

$$TDBP = TDP + TDT + TDB + TDK \qquad [9]$$

3.2.6. Estimation of seasonal Biomass Production

Allometric relationships for each biomass components were developed (TDP, TDT, TDB, TDK, TDBP) according to the procedure of Droppelmann *et al*. (1999):

$$BP = a + b*CSA \qquad [10]$$

where:

BP = Biomass production (Kg)
b = Slope
a = Constant
CSA = Cross sectional area (m^2)

To work on it, we pool through the origin.

For water quality and irrigation frequency treatments, the Groups Regression procedure [Mead *et al.* (1993), Drapper *et al*. (1998)] was used to determine the lack of fit. This procedure uses analysis of variance to test whether the slopes of the models are significantly different due to the lack of fit and pure error of the observations.

A visual analysis of residuals against predicted values was used to check for systematic bias.

The variables analyzed were phyllodes, twigs, branches, and whole shrub. Regression analysis was carried out using the Statistix statistical package V 2.0.

3.2.7. Water uptake

3.2.7.1. *Volumetric Water Content (VWC).*

The VWC was estimated using the Neutron Scattering Method. Access tubes were inserted in the soil to a depth of 2.4 m.

3.2.7.1.1. Access tubes installation**.**

Ninety aluminum tubes (50.8 mm inside diameter and 2.5 mm of thickness) were installed in 33 plots. During the process, we found both rocky and hard clay layers at 1.80 m depth. Three tubes were installed per plot, one in the tree row between two sample shrubs and two tubes between the rows at 1 and 2 m distance from the row (Fig. 2).

To insert the tubes a semi-mechanic hydraulic hammer system was used. A drill, with an out side diameter of 0.5 mm more than that of the tubes, was hammered into the soil with a 40 kg cylinder hammer lifted with a hydraulic machine. The drill extracted from the hole with a hydraulic jack.

The aluminum tube protrudes 7 cm above ground. The tubes were closed with a rubber bung at the top of the tube. A tight fit between soil and tube was achieved. It took approximately 40 days to install all the tubes.

Moisture measurements were carried out at depths 15, 30, 45, 60, 75, 90, 105, 120, 150, 180, 210 and 240 cm. The measurements were carried out before and after irrigation.

3.2.7.2. *Irrigation and Runoff*

The plots of the treatments with runoff received 18 m^3 (equivalent water depth of 250 mm) of water per plot and the flooding coincided with the natural runoff events that occur during wintertime.

The irrigation was applied with a drip irrigation system. Each of the four rows of trees within each plot were surrounded by a dike-like structure (made of plastic sheets)

(Fig. 2). This ensured no surface water flow outside the dike. Due to the relatively low hydraulic conductivity, the dike was usually flooded. The trickle irrigation system includes: a control unit, bomb, flow meter, flushing valve, and principal and lateral plastic pipes running along the rows of shrubs. The drippers were pressure compensated integrated in the line with a discharge of 4 l hr^{-1}, with one additional pressure compensating bubble dripper per tree with a discharge rate of 24 l h^{-1}. The control of the system was semi-automatic with manual valves in each plot and one main automatic stopcock for the whole experiment.

3.2.7.2.1. Irrigation volumes

Irrigation needs were calculated using the following equation (after Arnon, 1972):

$$L_{H_2O} = \frac{\sum_{i}^{n} \left(FC_i - \theta_i\right) * 10 * z_i}{100} \qquad [11]$$

where:

L_{H2O} = Water Lamina to be applied (mm) at field capacity
FC = Moisture content at Field Capacity (30%)
θ = Measured volumetric water content (%)
z = Depth of the measured soil layer (cm)
i = Number of depth intervals

Due to high evaporative losses, we increased the volume of water applied by 50% on all plots as from DOY 198. Those applications were started once we identified that the pre-drawn phyllode water potential was higher than expected even in the well-watered treatments.

3.2.7.3. Water Uptake.

The uptake between two irrigation or consecutive measurements after the irrigation, was computed as

$$WU = \sum_{n=i}^{n} \frac{(\theta_{t2} - \theta_{t1})}{100} * z_i * 10 \qquad [12]$$

where:

WU = Water Uptake (%)
θ = Volumetric water content (%)
z = Depth interval (cm)
t_1 = Initial time
t_2 = Last time
i = Number of layers

3.2.7.4. Phyllode Water Potential

Predawn and mid-day Phyllode Water Potential (LWP) were measured using the Pressure Chamber Method (Scholander, 1965) with a pressure chamber (ARI II Arimad , Kfar Haruv, Israel).

The Phyllodes for predawn measurements were sampled before sunrise (between 5:00 – 6:00 hours) prior to stomatal opening. During the afternoon on the day previous to the measurement, mature fully developed phyllodes were selected. Phyllodes were covered with aluminum foil. A total of 99 phyllodes (3 phyllodes/shrub) were covered for each measurement date. On the morrow, phyllodes were cut gently, and immediately placed in a cool-box. The time interval between covering and sampling was 12 h.

After sampling the phyllodes enveloped in aluminum was removed and the phyllode placed in a plastic bag with wetted paper. The petiole-like extreme of the phyllode was cut again with a razor blade in order to obtain a uniform flat cut surface. The phyllodes were placed through the pressure chamber lid with so that the cut surface could be seen clearly once the lid was closed.

The pressure was applied slowly at the rate of 0.5 bar/sec until water bubbles come out of the xylem. The LWP's were routinely measured every 15 days, prior to irrigation.

4. Results

4.1. Standing biomass

The components of the standing dry biomass 5 years after planting were analyzed. An Analysis of Variance (ANOVA) was carried out for treatments 2 to 9. For the Comparison of Means (COM) using Tukey test, all treatments were used. Shrubs that died at the end of the five years were removed from the statistical analysis.

4.1.1. ***Phyllodes dry matter***

In terms of phyllode biomass production, the COM shows that WWF had the highest yield (10.64 Kg/shrub). This treatment produced seven times more than R (1.31 Kg/shrub), twice more than HFR (6.11 Kg/shrub) and 50 per cent more than WWB (7.45 Kg/shrub). WWF was significantly different from all other treatments with the exception of WWB. On the other hand, R, LBR, LF and, LB were similar and had the lowest production of phyllode biomass (Table 3).

The ANOVA for treatments 2 to 9 for the three factors and their interactions, shows that there are significant differences (p=0.05) between treatments with runoff and without runoff, and between irrigation frequencies. No differences due to water quality were observed (Annex 1. Table 1).

4.1.2. ***Branch dry matter***

The COM showed that WWF produced the highest branch dry biomass (12.82 Kg/shrub). The lowest production was for R (1.13 Kg/shrub) and LF (3.00 Kg/shrub). Among all other treatments (2 to 9) HF (6.30 Kg/shrub) was the highest. The COM shows significant differences between WWF and WWB, and all other treatments.

Table 3. Wood density and standing dry biomass production of *Acacia saligna* after five years grouped by components. Values followed by the same small letter are not statistically different at the α=0.01 level according to Tukey Test. (For the notation, refer to the text).

Treatment		**Wood density (kg/m^3)**	**Phyllodes (Kg/shrub)**	**Branches (Kg/shrub)**	**Twigs (Kg/shrub)**	**Trunk (Kg/shrub)**	**Whole Shrub (Kg/shrub)**
R	1	565.72	1.31 c	1.14 c	1.69 c	1.21 e	5.35 d
HFR	2	657.76	6.12 b	6.25 bc	6.71 ab	8.19 bc	27.26 bc
LFR	3	471.11	5.65 b	4.65 bc	5.25 bc	4.59 cde	20.15 c
HBR	4	642.79	5.61 b	4.53 bc	5.92 b	6.31 cd	22.37 bc
LBR	5	527.47	4.89 bc	4.42 bc	5.43 bc	4.83 cde	19.57 c
HF	6	592.74	5.03 b	6.29 bc	5.92 bc	6.37 cd	23.61 bc
LF	7	439.89	3.93 bc	3.00 c	3.96 bc	3.49 de	14.39 cd
HB	8	640.03	5.37 b	5.18 bc	5.67 bc	6.20 cd	22.42 bc
LB	9	505.86	4.04 bc	3.07 bc	4.97 bc	4.28 cde	16.36 cd
WWF	10	713.81	10.64 a	12.82 a	10.89 a	16.12 a	50.47 a
WWB	11	715.30	7.45 ab	8.76 ab	7.98 ab	10.70 b	34.88 b

The ANOVA (treatments 2 to 9) for branches between treatments shows that there is a highly significant difference between irrigation frequencies (p=0.01). High irrigation frequencies produced more biomass than low irrigation frequencies. There are no differences due to water quality and runoff application (Annex 1. Table 2).

*4.1.3. **Twig dry matter***

The COM shows that WWF had the highest biomass production of twigs (10.89 Kg/shrub) and the lowest was R (1.69 Kg/shrub) (Table 3). A similar biomass production was obtained for HFR, WWB, and WWF. This group was different from all other treatments.

The ANOVA (treatments 2 to 9) shows a significant difference between high and low irrigation frequency treatments (only at p=0.05); but no differences due to runoff application or to water quality (Annex 1 Table 3).

4.1.4. ***Trunks dry matter***

The trunk dry matter was computed by using the density of wood and volume of the trunk as we discussed in section 3.2.5.4.

The highest biomass production was 16.12 Kg/shrub for WWF; the lowest was R with 1.21 Kg/shrub. For R and all low irrigation frequencies, the production was similar, but this group was different from the high irrigation frequencies. WWF and WWB are significantly different from all other treatments (Table 3).

For trunk dry matter, the ANOVA ($p=0.01$ and treatments 2 – 9) show a behavior similar to that found for twig and branch (Annex 1. Table 4).

4.1.5. Whole shrub dry matter

As for all other biomass components, the COM shows that the highest production was in WWF (50.47 Kg/shrub), which was eight times higher than R (5.35 Kg/shrub).

Differences were observed between R, WWB, and WWF, with R having the lowest production. In addition, these three treatments were different from all other treatments.

The ANOVA (treatments 2 to 9) show significant differences between high and low irrigation frequency treatments ($p=0.01$). A significant difference was found between treatments with runoff and without runoff ($p=0.05$). No differences were found between brackish and fresh water treatments (Annex 1 Table 5).

4.2. Allometric equations

4.2.1. **Cross sectional area (CSA) and dry biomass**

Biomass was related to CSA, using the database from which dead shrubs were removed and forcing the regression through the origin. The reason for the latter is that there is no accumulation of shoot without increment of the section area according to Nygren, *et al.*, (1993), and Droppelmann *et al.* (1999). The following equation was used:

$$\text{BIOMASS} = b\ \text{CSA} \qquad [13]$$

where b was the regression slope.

Allometric equations for phyllodes, twigs, branches, trunk, and whole shrub were derived. The different values of the regression equations are presented in the Table No.4, Fig.3 – 4 and Annex 3. (Fig. 1 Table 1)

Table 4. Linear regression equation parameters and statistics for the relationships between dry biomass production and cross sectional area for *Acacia saligna* shrub found at the end of season 1999.

Shrub component	**Slope**	**SE of slope**	**significance slope at p=**	**MSE**	**R^2**	**N**
Phyllodes	0.06723	0.00129	0.000	1.9380	0.95	128
Twig	0.07290	0.00153	0.000	2.7454	0.95	128
Branch	0.07671	0.00183	0.000	3.9367	0.93	128
Trunk	0.08757	0.00161	0.000	3.0242	0.96	128
Whole Shrub	0.30440	0.00411	0.000	19.773	0.98	128

Legend:
SE: Standard error; p: probability level; MSE: Mean square error; N: number of observations

Comentario [EGA1]: Correction No. 9

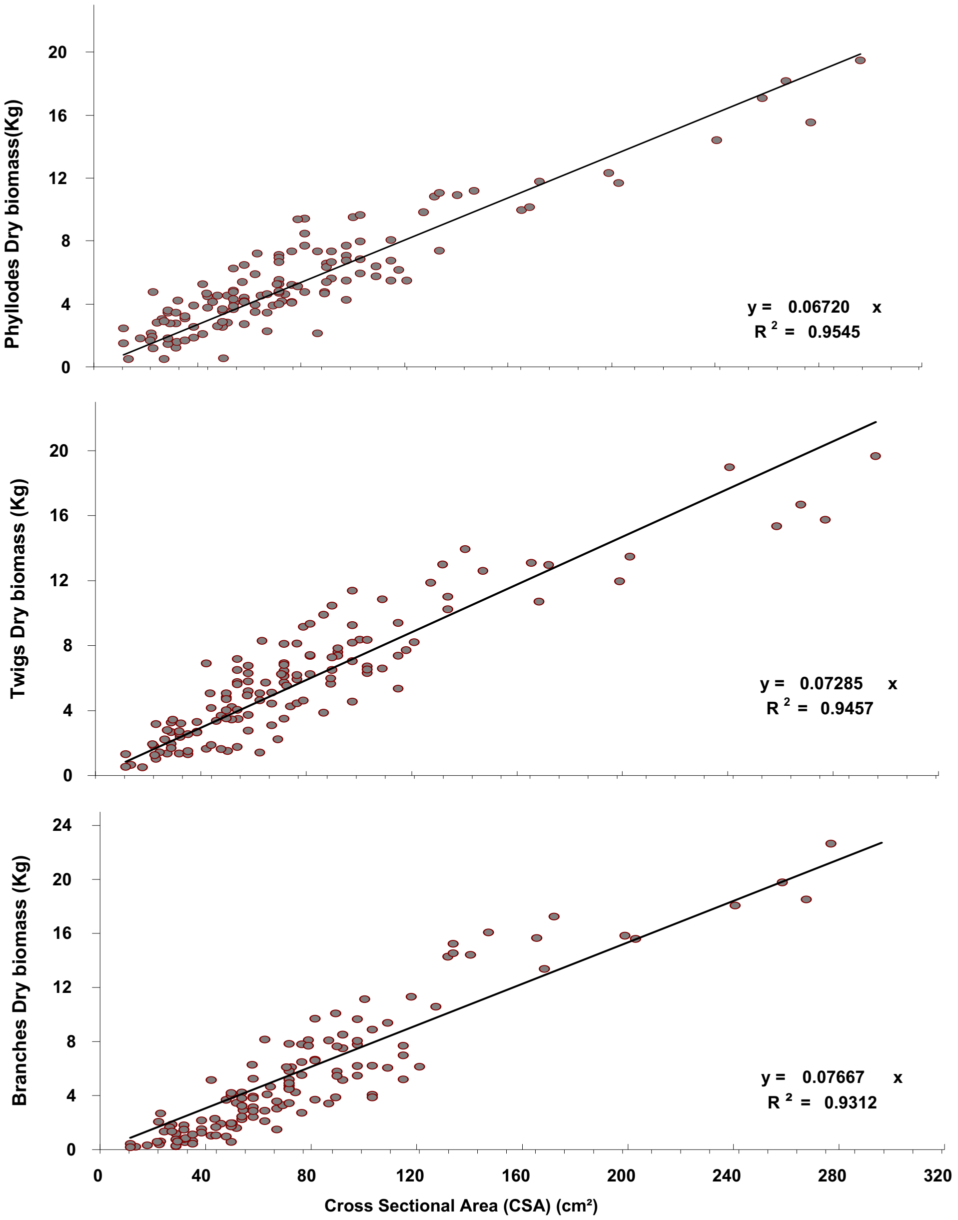

Fig. 3. Correlation between Cross sectional Area (CSA) and Total Dry Biomass Production. The statistics for these regressions are presented in Table 4.

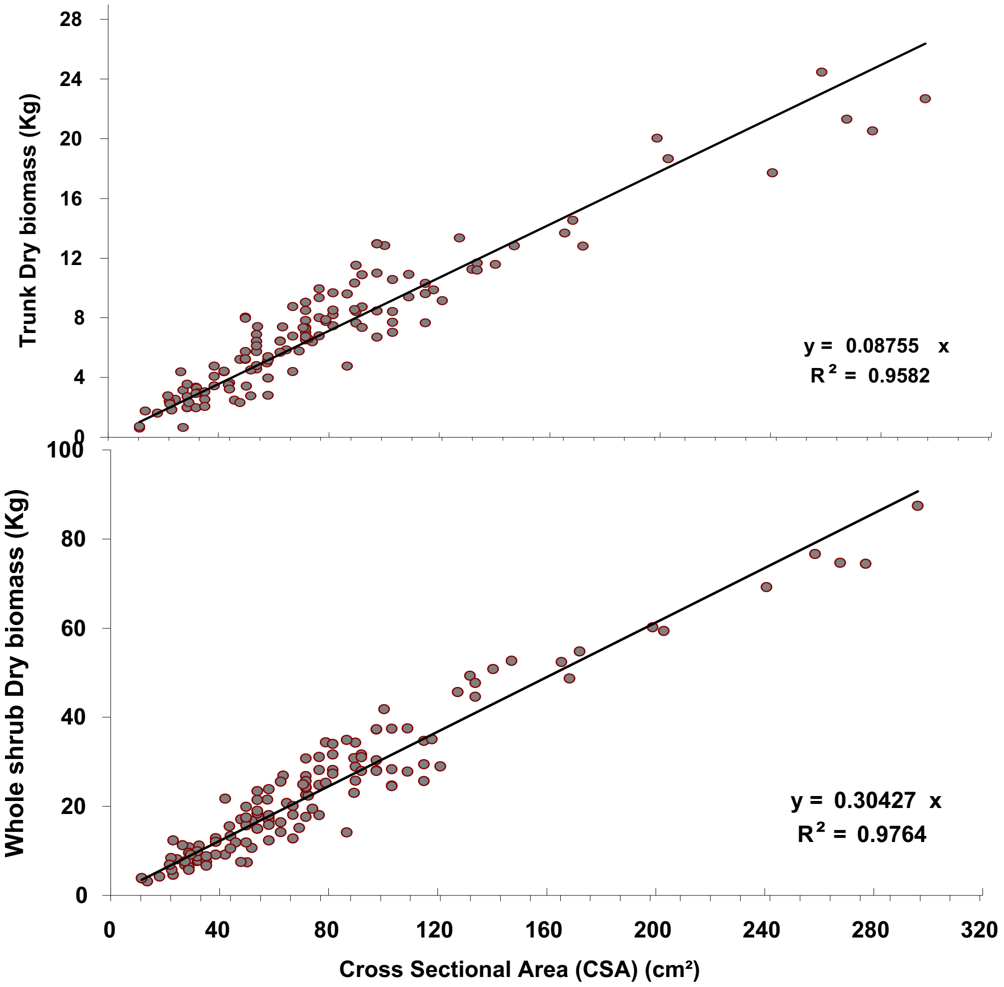

Fig. 4. Correlation between Cross sectional Area (CSA) and Total Dry Biomass Production for the trunk and whole shrub. The statistics for these regressions are presented in Table 4.

We found no difference in the slopes due to water quality, irrigation frequency, or runoff application (Annex 2 Table 1-12).

The slopes of the components are similar and lower than 0.1. This means that we may gain an additional 0.1 Kg of biomass production (for phyllodes, twigs, branches, trunk separately) for every additional square centimeter of increment in the cross sectional area.

The TDBP (Whole shrub of *Acacia saligna*) showed a slope of 0.3. Therefore, the fitted line regression predicts an additional gain in mass of 0.3 Kg for every additional unit of cross sectional area.

4.2.2. **Analysis of residuals values**

The residuals are defined as the *n* differences $e_i = Y_i - \delta_i$, $i=1,2\ldots n$, where Y_i is an observation and δ_i is the corresponding fitted value obtained by use of the fitted regression equation. The assumptions are that the errors are independent, have zero *mean*, have a constant variance σ^2 and follow a normal distribution. Thus if our fitted model is correct, the residuals should exhibit the above mentioned characteristics (Draper *et al.*, 1998).

Comentario [EGA2]: Correction No. 10

We examined the distribution of residuals on the unrefined data (that is from 132 and 128 shrubs) of phyllodes, twigs, branches, trunk and whole shrub, separated by water qualities. We checked the non-normality of the structure through the Normal Plot of Residuals (histograms and cumulative distribution) and the frequency distribution of the population, according to Mead (1993) and Draper *et al.* (1998) (Annex 5 Fig. 1-5).

The characteristic of the residual values for whole components of the shrub were "lighter-tailed" than the normal and 9.8% were away from the population mean (Fig 5). This means that the population follows a non-log distribution, and the use of a linear correlation justified.

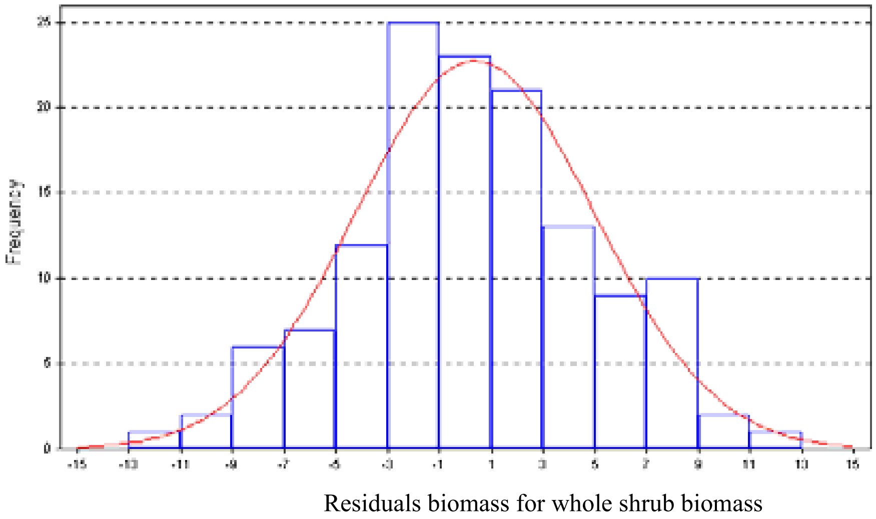

Fig. 5. Histogram of the residuals for whole shrub

4.2.3. ***Error analysis of fitness***

For the biomass estimation, the ranges of the relative error for whole *Acacia saligna* shrub as a function of cross sectional area (CSA) were separated according to fresh and brackish water qualities and presented in Fig. 6. The magnitudes of error for the different components of the shrub are presented in the same way, in Annex 6 Fig. 1-4.

The relative error was computed as the absolute value of (Lovenstein *et al.* 1993):

$$\mathrm{Re} = \frac{\left| Biomass_{Observed} - Biomass_{\Pr edicted} \right|}{Biomass_{Observed}} \qquad [14]$$

Where $\mathrm{Biomass}_{\mathrm{Observed}}$ and $\mathrm{Biomass}_{\mathrm{Predicted}}$ represent the measured and calculated biomass of shrub respectively.

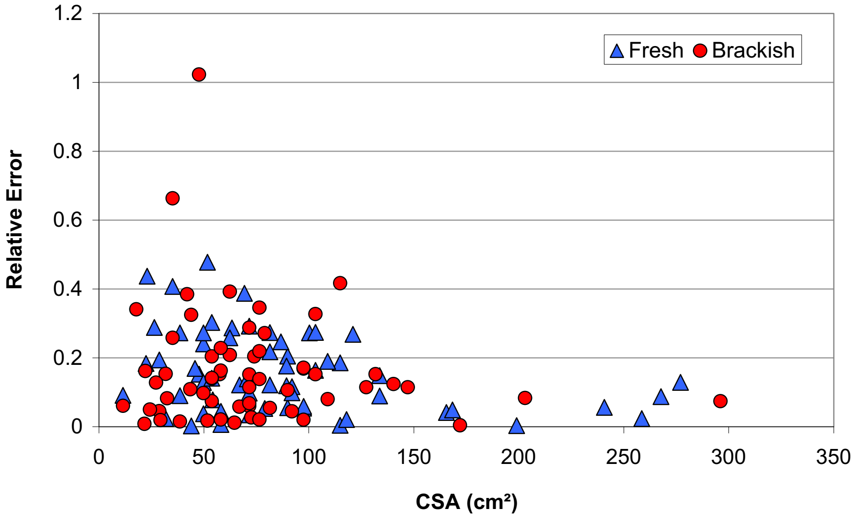

Fig. 6. Absolute values of Relative Error in the estimation of above ground whole shrub dry biomass as function of the Cross sectional Area (CSA) separated according to water quality.

One can see that there is a decrement of the error with each increment of the diameter of the trunk and 95% of the errors and CSA are between 0.4 and 200 cm², respectively. In spite of this, the tendency is similar for both water qualities.

4.2.3.1. Calculation of pure error and lack of fit mean square

We computed the pure error and the lack of fitness, results are presented in Annex 1 (Table 12-16). On basis of this test, there appears to be no reason to doubt the adequacy of the model.

4.2.3.2. Comparison of regression for fresh and brackish water applications

In Fig. 7, the Last Cross sectional Area (CSA2) is presented as a function of dry biomass irrigated with fresh and brackish water. The correlation for both cases were computed separately [Annex 2. (Fig. 1- 2)]. No significant difference was found between their slopes.

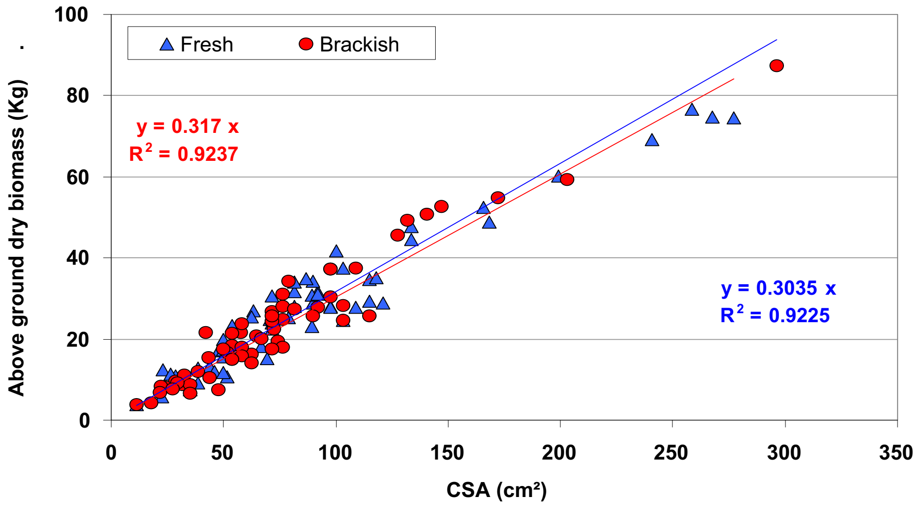

Fig. 7. Relationship between above ground dry biomass of the whole shrub and Cross Sectional Area (CSA) for both water qualities.

4.3. Production of biomass during the 1999 season

4.3.1. *Cross Sectional Area (CSA) evolution*

In Fig. 8 the evolution of CSA during the experimental period in 1999 is presented. Well-watered shrubs performed better in comparison to all other treatments. Until Day of the Year (DOY) 120 all treatments showed a flat response. After that, the well-watered plots had a higher increment until DOY 295, and decreased thereafter.

This tendency was more or less constant and similar in all treatments. Such is the case of WWB and HF, that had the same trend all the season, as well as LF and LB. The exception was for HF, which grew better than HB. A clear response of this was after DOY 220.

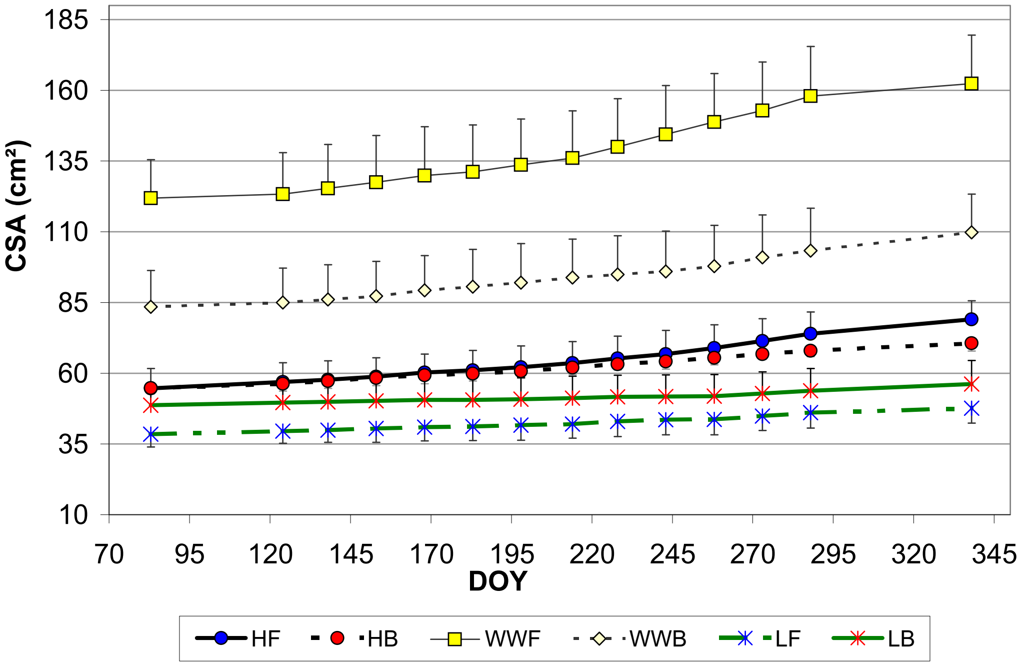

Fig. 8. Cross Sectional Area (CSA) development of treatments without runoff application during 1999. Vertical bars indicate standard deviation. To the legend refer the text.

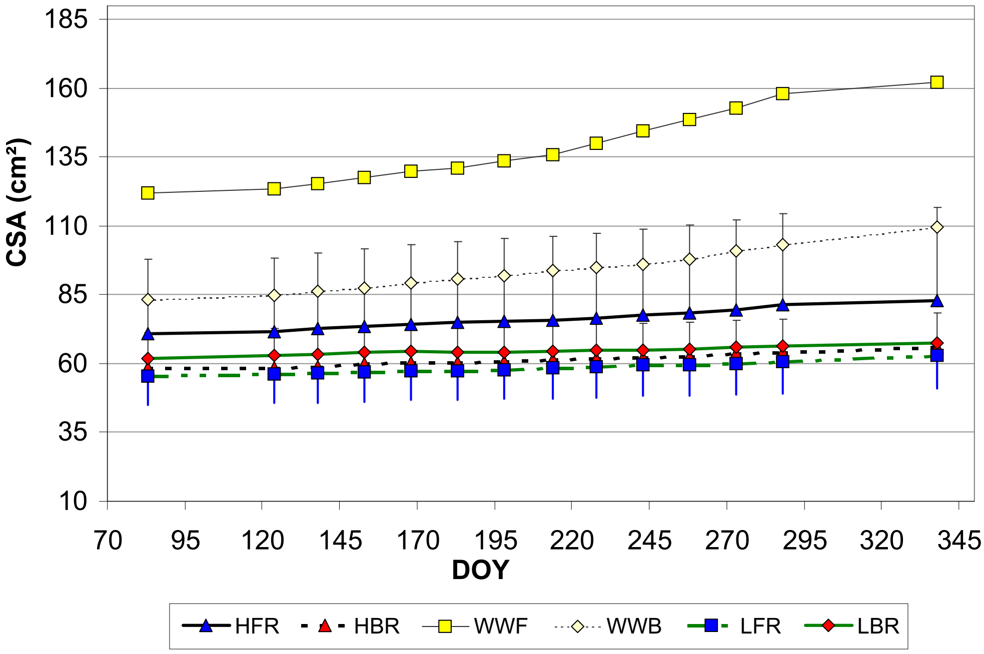

Fig. 9. Cross Sectional Area (CSA) development of treatments with runoff application. Vertical bars indicate standard deviation. Legends are detailed in section 3.2.1.

On the other hand, we did not see differences in the evolution due to water quality application.

The evolution of all plots with runoff and well-watered plots are presented in the Fig. 9. LFR, LBR, HBR show an average of 60cm^2 during all the year with a small increment towards the end of the season, without differences in trend. The CSA of HFR was observed already higher at the beginning of the season. The well-watered plots were always higher than the rest.

HF had a larger CSA when compared to HFR. No difference was found between HBR, HB and between LFR, LBR during the season (Annex 4. Fig. 3 - 4).

4.3.1.1. Production of Biomass

The production of biomass during 1999 was estimated from the difference in CSA's (ΔCSA) between DOY 83 and 338.

The high irrigation frequency increased the ΔCSA. There was significant difference between HF and HB. Between LF and LB no difference was found (Annex 4: Fig. 2). No differences between LFR and LF, and LBR and LB were observed (Annex 4: Fig. 4). Also, no significant difference between for the ΔCSA's of HBR and LBR was found. There were large differences between HFR and LFR in ΔCSA (Table 5, Annex 4: Fig. 5).

Table 5. Growth evolution and absolute growth rate of *Acacia saligna* shrub during 1999 grouped by treatments. Values with same small letters are not statistically different at level α=0.01 according to Tukey test.

DOY	**R**	**HFR**	**LFR**	**HBR**	**LBR**	**HF**	**LF**	**HB**	**LB**	**WWF**	**WWB**
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**
83 **CSA1**	22.51 d	70.86 bc	55.49 bcd	58.33 bcd	61.88 bcd	54.70 bcd	38.50 cd	54.74 bcd	48.69 bcd	121.87 a	83.43 ab
124	23.34	71.62	56.06	58.60	62.94	56.89	39.49	56.28	49.63	123.36	84.97
138	23.77	72.74	56.60	58.91	63.52	57.71	39.88	57.28	49.89	125.37	86.13
153	24.36	73.68	57.03	59.80	63.94	58.84	40.47	58.28	50.28	127.53	87.29
168	25.19	74.44	57.36	60.28	64.31	60.24	40.99	59.23	50.57	129.91	89.30
183	25.56	74.88	57.39	60.51	64.19	61.12	41.25	59.89	50.65	131.17	90.64
198	26.00	75.29	57.82	60.75	64.19	62.19	41.61	60.68	50.82	133.67	92.08
214	26.15	75.86	58.38	61.40	64.30	63.61	42.06	61.97	51.18	136.04	93.77
228	26.36	76.68	58.99	61.91	64.78	65.29	42.96	63.20	51.65	140.00	94.87
243	26.07	77.66	59.45	62.37	64.99	66.84	43.57	64.20	51.81	144.36	95.97
258	26.07	78.56	59.45	62.60	65.23	68.98	43.67	65.44	51.88	148.82	97.81
273	26.14	79.48	59.98	63.81	65.94	71.40	44.94	66.85	52.85	152.91	100.90
288	26.10	81.29	60.74	64.26	66.21	73.91	46.06	67.93	53.82	157.99	103.31
338 **CSA2**	26.86 d	82.94 bc	63.12 bcd	66.16 bcd	67.56 bcd	79.03 bc	47.64 cd	70.60 bcd	56.19 cd	162.33 a	109.70 b
Difference in growth **ΔCSA**	4.35 d	12.08 b	7.63 d	7.83 d	5.69 d	24.33 b	9.14 d	15.86 d	7.50 d	40.46 a	26.28 b

Comentario [EGA1]: Data from All-Ave-LAST2.sx

Comentario [EGA2]: Data from All-Ave-LAST2.sx but without taking into account the dead shrubs, funged, siks

For ΔCSA's ANOVA (treatments 2-9), a highly significant difference between high and low irrigation frequency and, fresh and brackish water application were observed (Annex 1 Table 8).

The ANOVA for the treatments that received no runoff (treatments 6-11) showed that quality and frequency were significant factors and strong interaction between both factors was observed (Annex 1 Table 11).

4.3.2. ***Relative growth rate (RGR)***

Larocque (1993) defines the relative growth rate (RGR) as the increase in biomass adjusted by the previously accumulated biomass per unit time. It is a measure of the production capacity of a plant that is independent of secondary processes such as us defense, support, or reproduction. The main advantage derived of using RGR is that it allows the comparison of development eliminating growth differences that arise from initial size differences. The growth in a given unit of time is a percentage of the plant size at the beginning of the period and this percentage change as the plant increases in size. Often the percentage declines as size increases (Hunt, 1978). We computed RGR using (Hunt, 1978) replacing biomass with CSA as they are linearly related:

$$RGR = \frac{\log CSA_2 - \log CSA_1}{T_2 - T_1} \qquad [15]$$

where:

RGR = Relative Growth Rate
CSA_2 = Cross sectional area (or biomass production) at time T_2
CSA_1 = Cross sectional area (or biomass production) at time T_1
T_2, T_1 = Time of successive measurements

The RGR increases after flooding the plots, and was especially high for R. (Fig 10). The Well-watered treatments (both fresh and brackish water) had a nearly constant RGR until the beginning of summer, from which time onwards there were different rates of increment in mass.

The fluctuations in RGR were higher for low irrigation treatments than for high irrigation frequency. After DOY 233 there was a severe decrease for low irrigation and no so marked for high irrigation (Fig. 11 and Fig. 12).

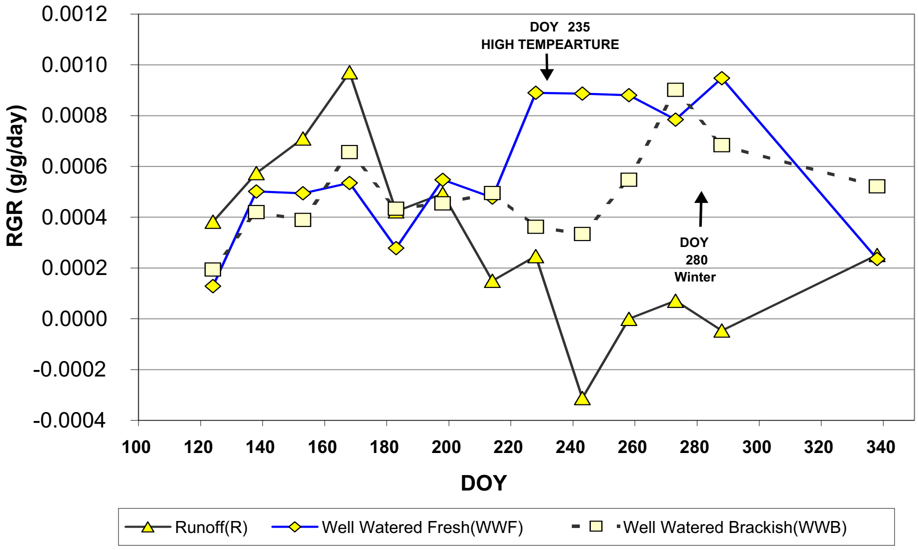

Fig. 10. Relative Growth Rate in *Acacia saligna* during 1999 for different treatments (For legends refer to the text).

The units of RGR correspond to the biomass calculated with the CSA, since that there is linear correlation between them. Towards the end of the summer RGR values of WWB, HF, HFR, HB, and LF decreased. But R, LBR, HBR, showed a small increment.

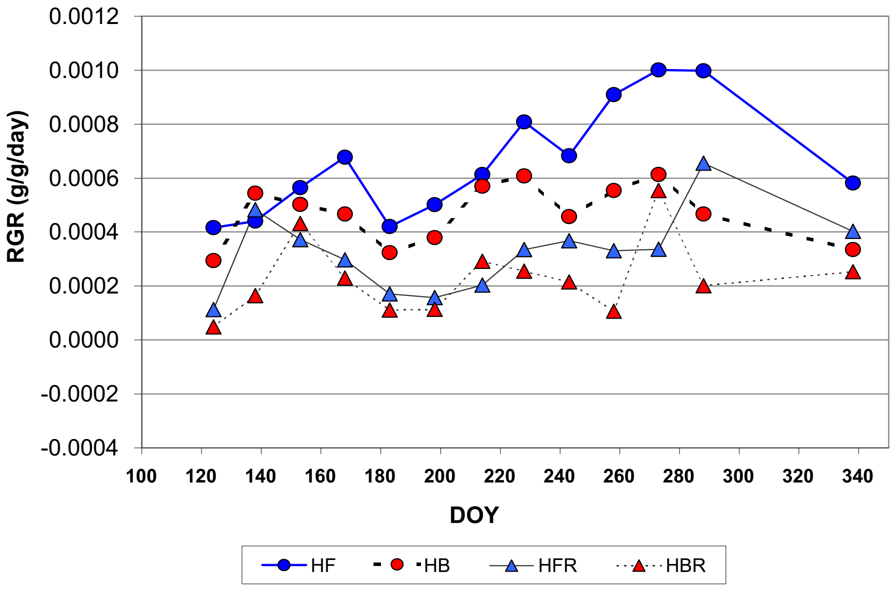

Fig. 11. Relative Growth Rate of *Acacia saligna* during 1999 for high irrigation frequency treatments. (For the legends refer to the text).

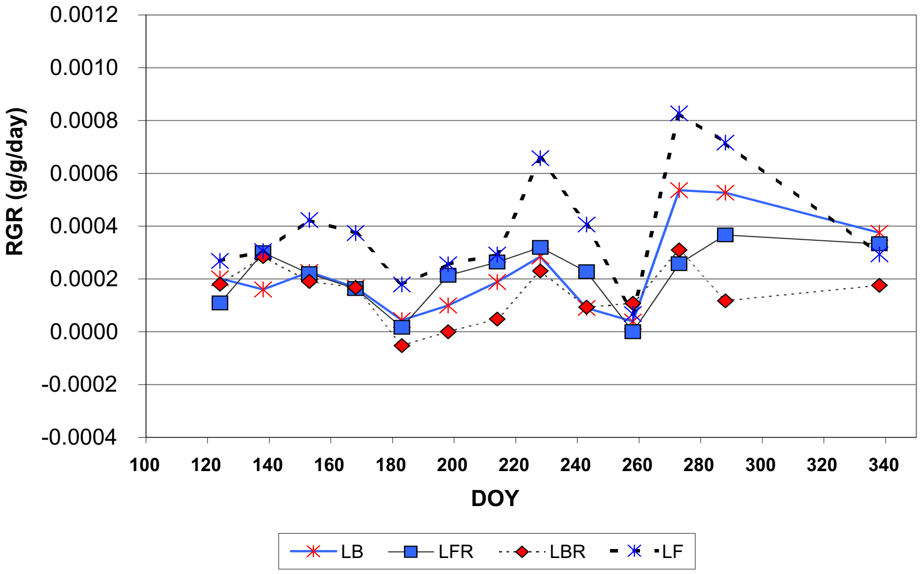

Fig. 12. Relative Growth Rate of *Acacia saligna* during 1999 for the low irrigation frequency treatments. (For the legends refer to the text).

4.4. Biomass production (season Feb 1999 – Oct 1999)

The annual dry biomass for the season was computed by using the regression equations values found for phyllodes, twigs, branches, and whole shrub (Table 4) and the difference in CSA's (DOY 83 to DOY 338). The ANOVA and all statistic analysis were carried out in the some way as for standing biomass. A number of shrubs died, some were attacked by insects and fungus, and the data from those shrubs was not included in the analysis.

4.4.1. ***Annual Total Dry Phyllode (ATDP) production***

The COM showed that the highest ATDP was for WWF (2.90 Kg/shrub), 3 times more than R (0.34 Kg/shrub), twice more than HFR (1.41 Kg/shrub) and 53 percent more than WWB (1.90 Kg/shrub) (Table 6).

The ANOVA (treatments 2 – 9) shows a highly significant difference between irrigation frequencies and water qualities. High irrigation frequency and fresh water had the highest phyllode production. Likewise, a highly significant interaction between irrigation frequency and water quality was found. The highest ATDP production was observed when shrubs were irrigated at high frequency and with fresh water. ATDP obtained with LF was similar to the obtained with HB (Table 6).

4.4.2. ***Annual Total Dry Branch/Twigs (ATDB/ATDT) production***

The annual computed dry biomass production is presented in Table 6. The highest production for ATDB (3.31 Kg/shrub) and ATDT (3.15 Kg/shrub) were for WWF. The lowest productions in both cases were for R. HF for ATDB (1.59 Kg/shrub) and for ATDT (1.53 Kg/shrub) had the best production among the treatments 2 to 9. This data shows a highly significant difference between WWF and HFR, HF, WWF for both ATDB and ATDT.

The ANOVA, for both ATDB and ATDT, showed the same behavior as for ATDL (Annex 1. Tables 18 and 19).

Table 6. Annual dry biomass production of *Acacia saligna* grouped by different components. Different small letters show the significance at level rejection α=0.01. (For the notation, refer to the text).

Treatment		**Phyllodes**			**Branches**			**Twigs**			**Trunk**			**WholeShrub**		
		Kg shrub^{-1}	**Ton Ha^{-1}**	**α**	**Kg shrub^{-1}**	**Ton Ha^{-1}**	**α**	**Kg shrub^{-1}**	**Ton Ha^{-1}**	**α**	**Kg shrub^{-1}**	**Ton Ha^{-1}**	**α**	**Kg shrub^{-1}**	**Ton Ha^{-1}**	**α**
R	1	0.34	0.85	d	0.39	0.97	d	0.37	0.92	d	0.44	1.11	d	1.54	3.86	d
HFR	2	1.41	3.53	c	1.61	4.03	c	1.53	3.83	c	1.84	4.60	c	6.40	15.99	c
LFR	3	0.58	1.46	d	0.67	1.67	d	0.63	1.58	d	0.76	1.90	d	2.65	6.62	d
HBR	4	0.55	1.38	d	0.63	1.57	d	0.60	1.49	d	0.72	1.79	d	2.49	6.23	d
LBR	5	0.38	0.94	d	0.43	1.07	d	0.41	1.02	d	0.49	1.23	d	1.70	4.26	d
HF	6	1.40	3.49	c	1.59	3.98	c	1.51	3.79	c	1.82	4.55	c	6.32	15.81	c
LF	7	0.61	1.54	d	0.70	1.75	d	0.67	1.66	d	0.80	2.00	d	2.78	6.95	d
HB	8	0.61	1.54	d	0.70	1.75	d	0.67	1.66	d	0.80	2.00	d	2.78	6.95	d
LB	9	0.50	1.26	d	0.57	1.44	d	0.55	1.37	d	0.66	1.64	d	2.28	5.70	d
WWF	10	2.90	7.26	a	3.31	8.28	a	3.15	7.87	a	3.78	9.46	a	13.14	32.86	a
WWB	11	1.90	4.75	b	2.17	5.42	b	2.06	5.15	b	2.47	6.19	b	8.60	21.50	b

4.4.3. ***Annual dry matter of trunk production***

The highest biomass production of trunks (ATDK) was for WWF (3.78 Kg/shrub) which was six times more than R (0.44 Kg/shrub). The better performance among the other treatments was for HFR (1.84 Kg/shrub) (Table 6). The COM showed that there were significant differences between WWF and HFR, HF, WWB.

The ANOVA showed the same response than in ATDL, ATDB and ATDT (Annex 1. Table 20).

4.4.4. ***Annual Total Dry Biomass Production (ATDBP)***

The highest whole shrub biomass production was for WWF (13.14 Kg/shrub), two times more than HFR (6.40 Kg/shrub) and HF (6.32 Kg/shrub) which showed the best productions among treatments 2 to 9. The lowest production was for R (1.54 Kg/shrub). The COM showed highly significant differences among WWF and HF and HFR (Table 6).

The ANOVA (treatments 2 – 9) showed the same characteristics than the yield components.

In Fig. 13 the significant interaction between water quality and irrigation frequency is presented. Increasing the frequency of irrigation, we increase the ATDBP, much more with fresh water than with brackish water. Nevertheless, one can see that the increment even though small it is positive.

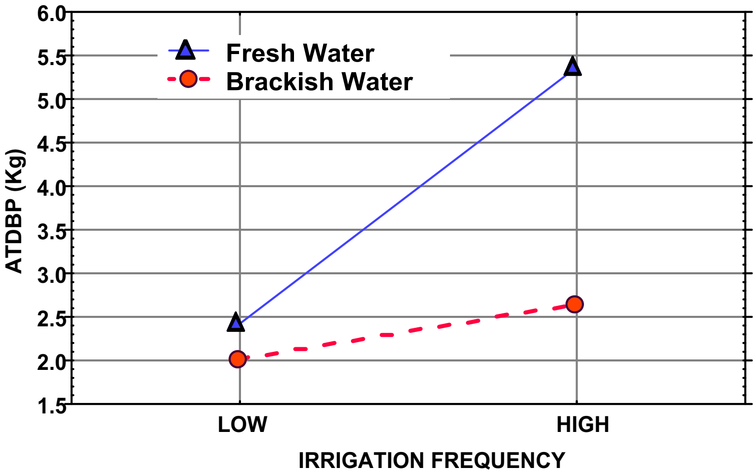

Fig. 13. Factor Interactions (Irrigation Frequency, Water Quality) for ATDBP of *Acacia saligna* shrub during 1999.

4.5. Water Uptake (WU)

4.5.1. ***Seasonal water content***

The total water content in the profile (TWC) measured prior to irrigation throughout the season is presented in Figs. 14 and 15. The data obtained from plots in which we detected the presence of a hard impermeable layer were removed from this computation. Fig. 14 A, the two well-watered treatments are compared to the runoff treatment. A difference approximately of 60 mm between the two WW's is apparent after DOY 140. Fig. 14 B, the high frequency treatments are presented and a difference of close to 10 mm is apparent from DOY 160. Fig. 14 C shows the low frequency treatments in which a very small difference is observed. The TWC for treatments irrigated with brackish water during the season shows a higher TWC than their corresponding treatments that were irrigated with fresh water (Fig. 14 B and C). The high frequency treatments irrigated with fresh water (HF and HFR) shows low water content (Fig. 14 B) and more or less similar than those irrigated at low frequency (Fig. 14 C). This means that the plots with fresh water and low irrigation frequency a larger volume of water had to be applied at the irrigation, but this difference was smaller than corresponding differences for the brackish treatment.

We assume that the reason for the observed differences in TWC between brackish and fresh water applications were due to the lower transpiration rate of the brackish treatments. The accumulation of salts during 4 years led to an increment of the osmotic potential in soils irrigated with brackish water and therefore to a lower transpiration rate.

Comentario [EGA1]: Correction 14

The difference between brackish and fresh water was smaller and became apparent only after DOY 200. The TWC for treatment R decreased monotonically from DOY 110 until DOY 200 and a very small decrease was observed for the rest of the period. The highest water content was for treatment WW, followed by high frequency and, low frequency. The lowest one was for the runoff treatment.

The seasonal change in TWC in the profiles from 120 to 240 cm depth are presented in Fig. 15 A, 15 B, 15 C. The runoff treatment showed a monotonic decrease as from DOY 130. No changes in the TWC of well-watered treatments were observed. A decrease during the first phase (DOY 110 – 200) was detected for all runoff irrigated plots. Increase in water content of the deeper layers was evident for HB, HF, HFR, LFR, and LB towards the end of the season.

The HF and LF were lower than the other treatments (Fig. 15 C). Small increment was observed at the end of the season for LFR, LB, and HF. It appears that for the high frequency treatments there was a difference between fresh and brackish water (Fig. 15 B, C) as we saw for the upper layers.

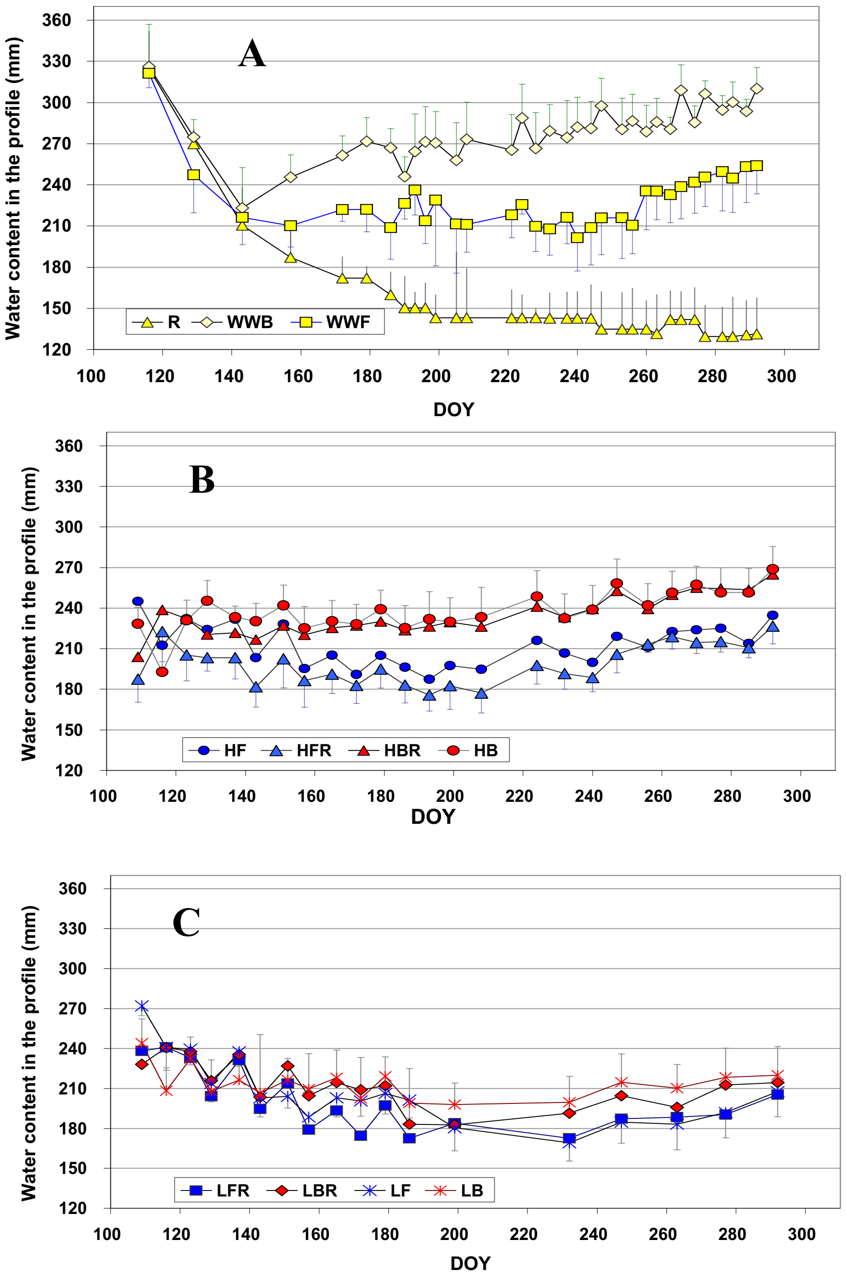

Fig. 14. Seasonal Change in the Total Water Content in the profile (TWC) for all treatments, from 0-120 cm (for the legend refer to the text).

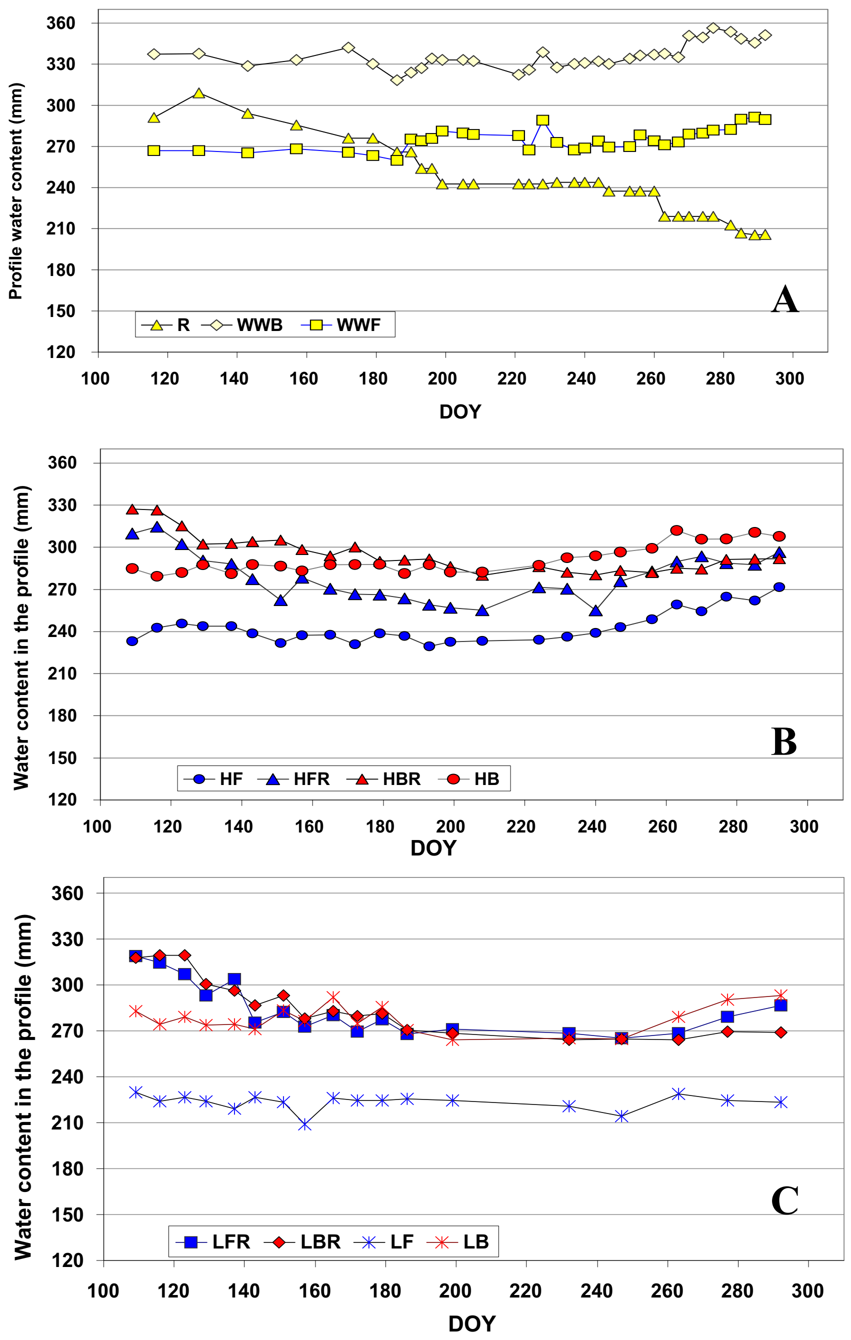

Fig. 15. Seasonal Change in the Total Water Content in the profile (TWC) for all treatments, from 120 to 240 cm (for the legend refer to the text).

4.5.2. ***Soil water content in the profile***

In Figs. 16 and 17 the change in soil water content during a drying out period is presented for some selected plots.

During this drying out period, water content was monitored every 48 or 72 hours.

The plots reached field capacity (FC) to a depth of 30 to 75 cm 24 to 48 hours after the irrigation. After a few days, depending on the irrigation frequency, the water content of the upper layers drops to 5 - 7 %.

Redistribution of water below 60 to 75 cm depths was observed for all treatments and was very marked for the LF and LFR treatments. This is possible due to the fact that they received the larger amount of water.

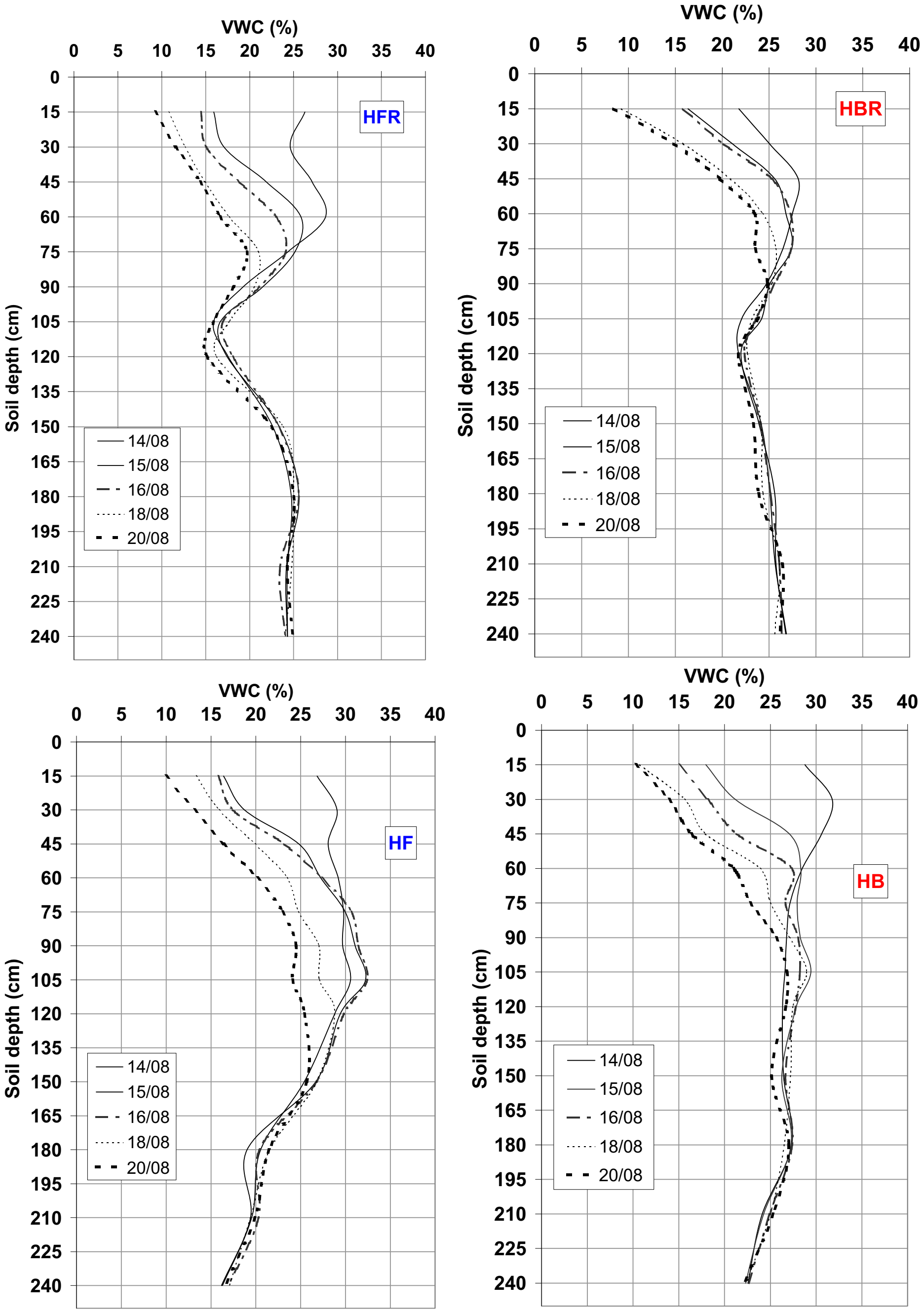

Fig. 16. Sequence of volumetric water content in the soil profile after irrigation, for selected plots during a drying out period (DOY 226-232).

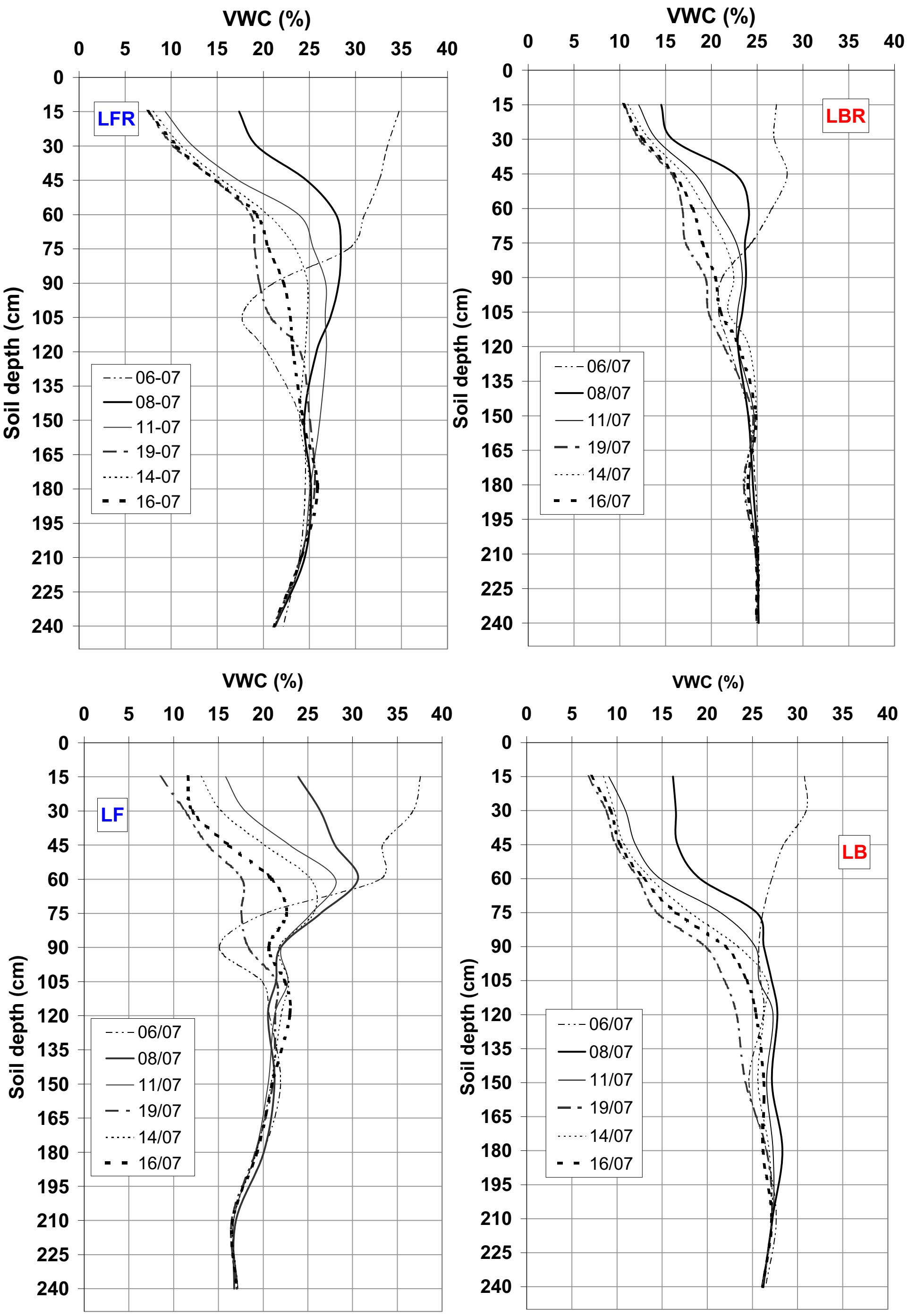

Fig. 17. Sequence of volumetric water content in the soil profile for selected plots during a drying out period (DOY187-200).

4.5.3. ***Water uptake patterns***

The relative depletion of water from various layers was computed for the drying out period (DOY 187-200 and DOY 226-232) as follows:

$$RD_x = \frac{\left(\theta_x^t - \theta_x^{t+1}\right) z_x}{\sum_{i=1}^{n} \left(\theta_i^t - \theta_i^{t+1}\right) z_i} * 100 \qquad [16]$$

where:

RD_x = Relative depletion of layer x
θ = Volumetric water content
Z = Depth of the layer
z = Layer number
.i = time
n = Number of soil layer

RD’s were computed for eight treatments during the above mentioned period. Negative values indicate increase in water content due to redistribution.

Fig. 18 and 19 show the computed RD’s. A common feature of all profiles is that during the first time interval the main water uptake was from the upper soil layer. Plots irrigated at low frequency showed at this time water uptake also in the deeper layers.

In the low frequency treatment six days after the water application, the water is taken up more preferable between 30 to 120 cm depth. In the same period, the treatments with runoff showed uptake at 80 cm and 60 to 120 for LFR and LBR respectively.

After 12 days (last period – WU4) the water is taken up mainly from 75 to 90 cm, with the exception of LF, which took up in the layers from 45 to 60 cm.

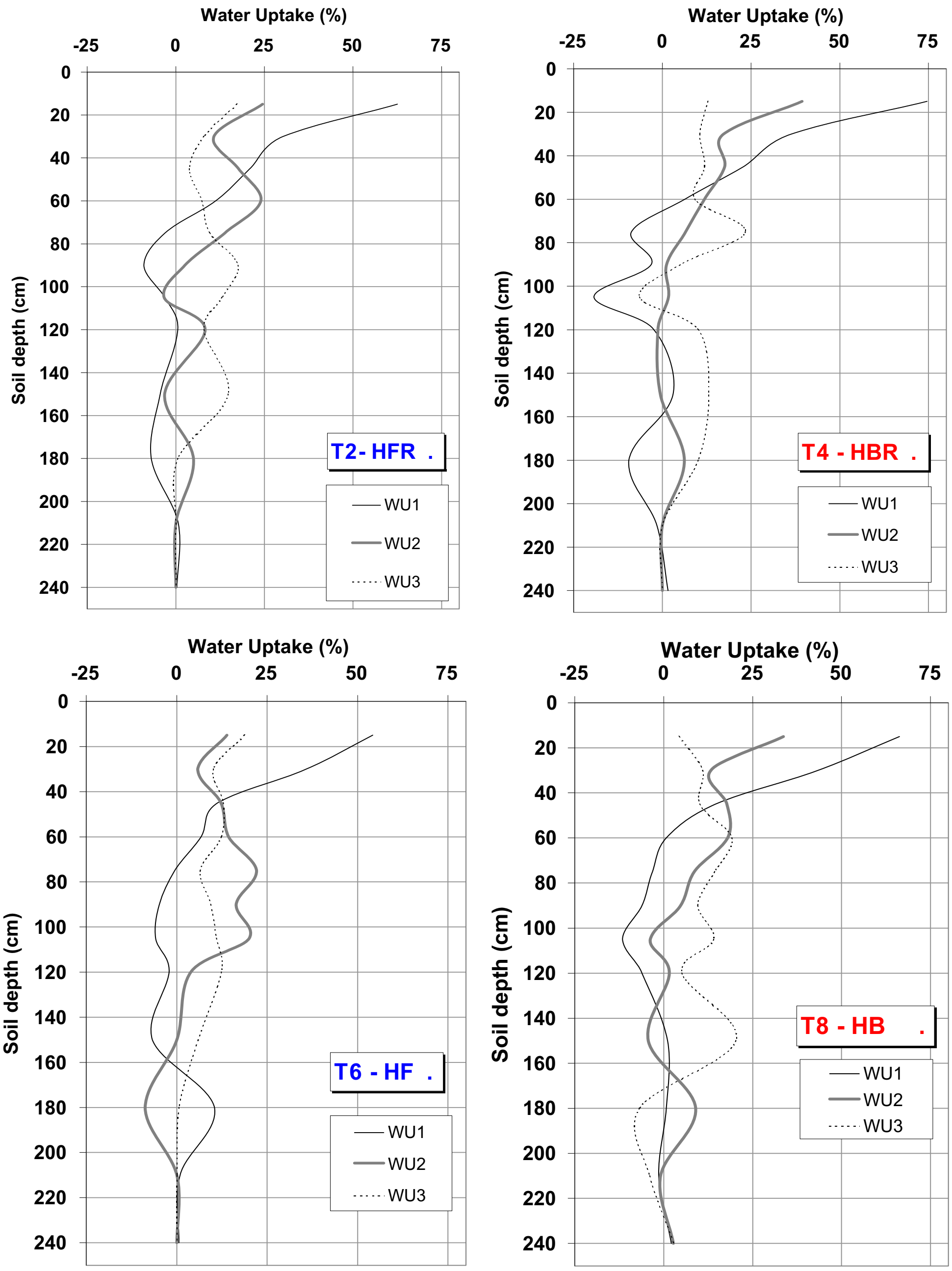

Fig. 18. Water Uptake of *Acacia saligna* shrubs during drying out period (summer 1999). The period is divided into three sub-periods: 6-8/Jul/99 (WU1), from 8-11/Jul/99 (WU2), from 11-19/Jul/99 (WU3). To the legend refer to the text.

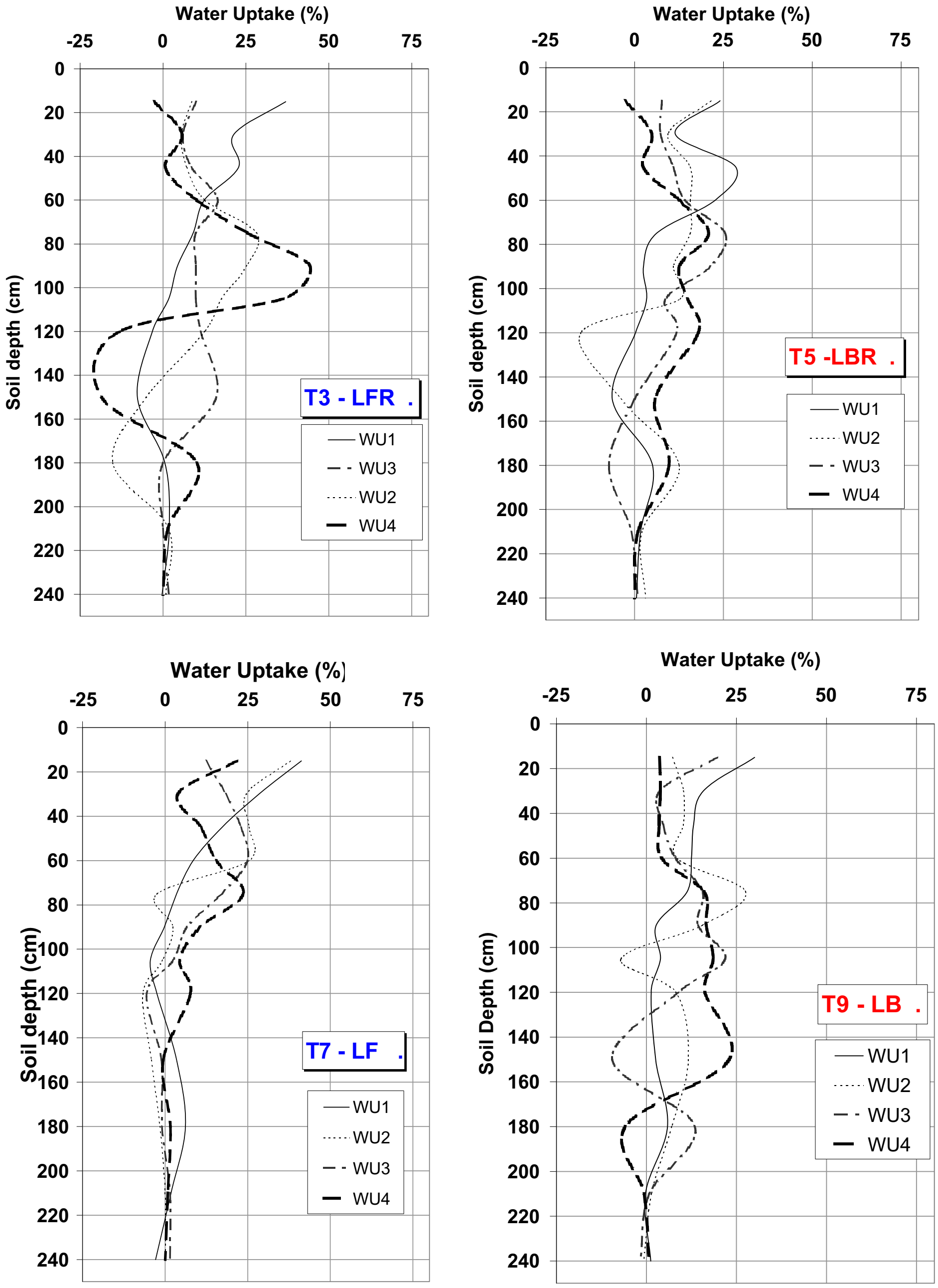

Fig. 19. Water Uptake of *Acacia saligna* shrubs during a drying out period (summer 1999). The period is divided into four sub-periods: 8-11/Jul/99 (WU1), from 11-14/Jul/99 (WU2), from 14-16/Jul/99 (WU3), 16-19/Jul/99 (WU4). To the legend refer to the text.

After fourteen days, the water uptake did not change its patterns. The water was taken up mainly from 90 to 120 cm.

During the last period, prior to irrigation, the water uptake for high irrigation frequency was roughly similar in all the layers of the profile, down to a depth of 220 cm. For the low frequencies, the uptake was a bit different. For LF treatment, the water uptake was until 140 cm, meanwhile for LB the uptake was until 170 cm. On the other hand for LFR the uptake was to 180 cm depth; LBR treatment took the water until 220 cm depth.

All HF treatments showed that water uptake during the first period (one-day after the irrigation) was mainly in the top layers, between 15 and 45 cm. After four days, the main depth of uptake was from 60 cm to 80 cm. After a week and prior to irrigation one can see uptake mainly between 45 to 150 cm. In this period HF showed a small recharge. The others treatments (HB, HBR, and HFR) took up water from the whole soil profile.

The treatments with brackish irrigation showed the same behavior that the fresh waters.

In Fig. 18 Fig. 19 negative values are the results of a local increase in water content (redistribution). These negative values appear deeper for latter period.

Comentario [EGA1]: Correction No.15

4.6. Predawn phyllode water potential (PWP) response

The predawn phyllode water potential was measured prior to irrigation through the season (as detailed in Section 3.2.7.4) and results are presented in Fig. 20. This figure shows the relationship between volumetric water content and pre-down phyllode water potential.

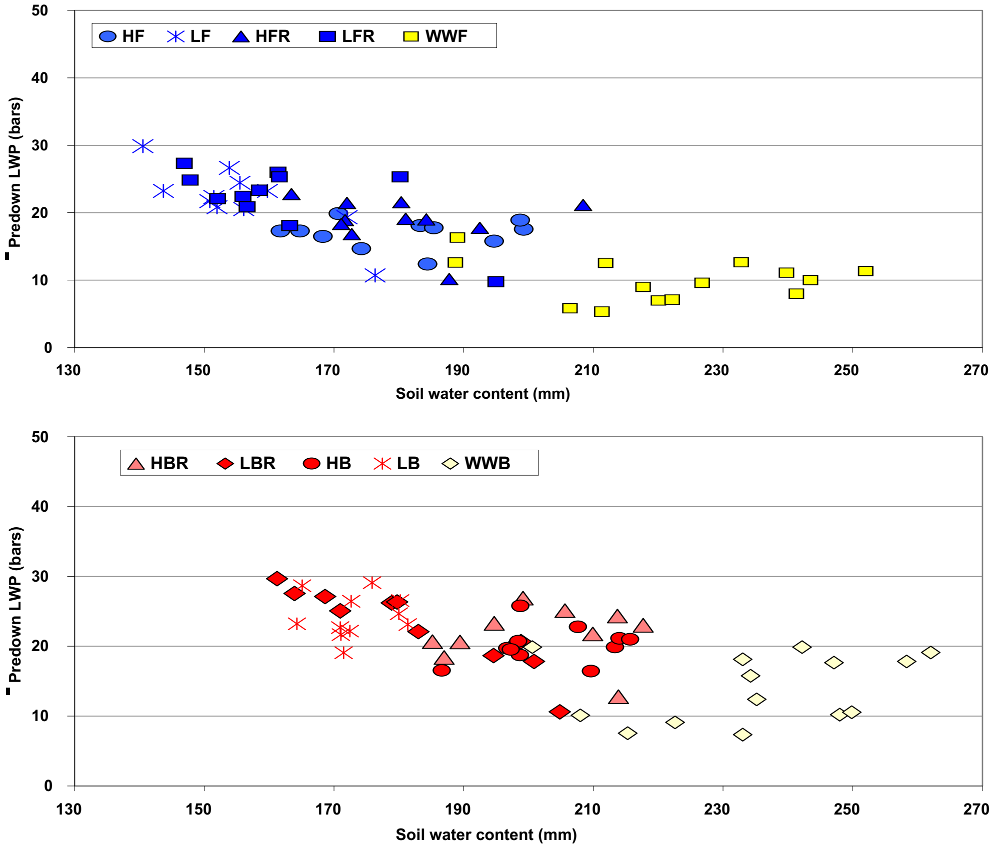

Fig. 20. Volumetric water content and Pre dawn phyllode water potential of *Acacia saligna* during 1999. For the legends, refer to the text.

As the water content in the soil decreases, the water potential in the phyllode decreased. This behavior was observed for fresh water as well as for brackish water irrigation. The brackish treatments appear to have a lower predawn PWP for the same water content.

During conditions of high soil water availability, the maximum values of PWP were 11 bars for WWF, and 19 bars for WWB.

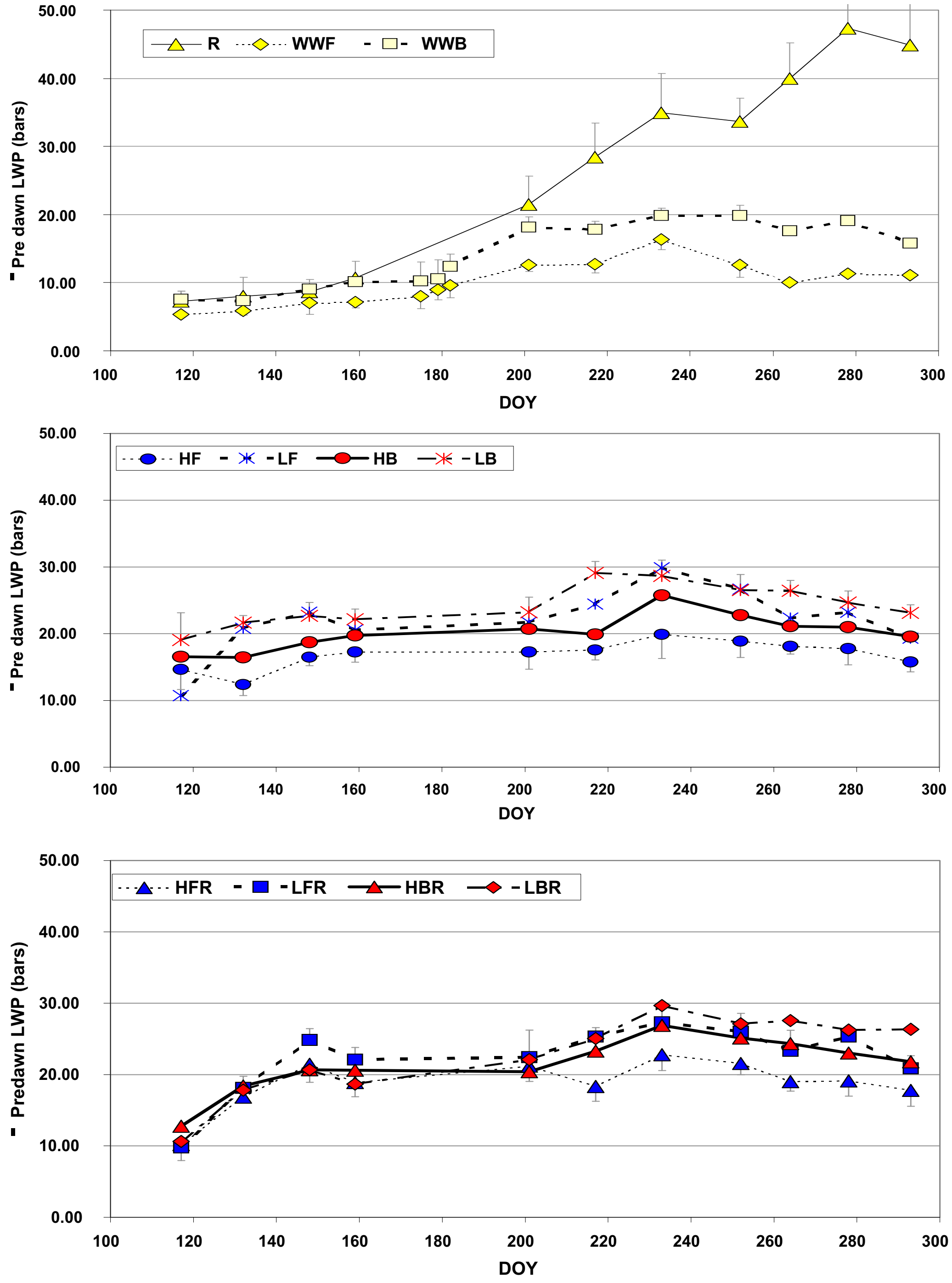

Fig. 21. Predawn phyllode water potential of *Acacia saligna* during season 1999 grouped by treatments (for the legends refer to the text).

These WW plots did not change strongly when the water content in the soil changed, which was between 188 to 250 mm for WWF which correspond to 16 to 5 bars during all the season. For WWB the variation in soil water content was from 200 to 261 mm and corresponds to a span of 7 to 19 bars.

The PWP for the high irrigation frequency varies from 10 to 25 in the range 160 to 215 mm of soil water. On the other hand, the PWP of Low frequencies ranges between 9 to 29 bars, for a span of 140 to 204 mm of water content in the soil.

The phyllode water potential and Day of the Year are presented in Fig.21. The lowest values (above 30 bars for low frequencies f and under 26 bars for High frequencies) were reached after we increased the amount of irrigation and during the summer months. The highest values of pre dawn PWP were reached during late spring.

The plots with runoff and without runoff had a value between 10 to 30 bars. The plots WWB had values between 7 to 20 bars; the WWF had between 5 to 15 bars.

R shrubs had the lowest PWP. R begun from 7 bars, the values went down reaching 44 bars in the hottest days and maintaining more or less those values until the end of the season.

Among plots without runoff application, the low frequency of irrigation had the lowest values. Between water qualities, the brackish water had the lowest PWP. Among plots with runoff application, the behavior was roughly the same until DOY 200 where HFR increased its values and LBR finished the season with the lowest value.

WWB maintained a quasi-constant pre dawn LWP of 18 bars from DOY 200 to 290. WWF had a slightly higher value, which increased towards the end of the season.

4.7. Water application

The total seasonal volume of water applied during 1999 was 785.48 mm. The pan evaporation during the trial period was 2013.3 mm.

Slight differences between computed and applied volumes were due to cumulative errors during the season.

It is worth noting that the high frequency brackish treatments received less water than their corresponding fresh water treatments. A comparable trend but of less magnitude was observed for the low frequency treatments

The highest water application was for the well-watered treatments, followed for High frequencies and the Low frequencies receiving the lowest amount.

Within the group of treatments with high irrigation frequency (WW and High frequencies), there are significant differences.

The volumes applied during the season are presented in the Fig. 22. The highest applications were during the period of July-August, during which time the highest pan evaporation (Fig 23) and solar radiation were measured. We increased the application of water from DOY 193. That application was similar for all the treatments.

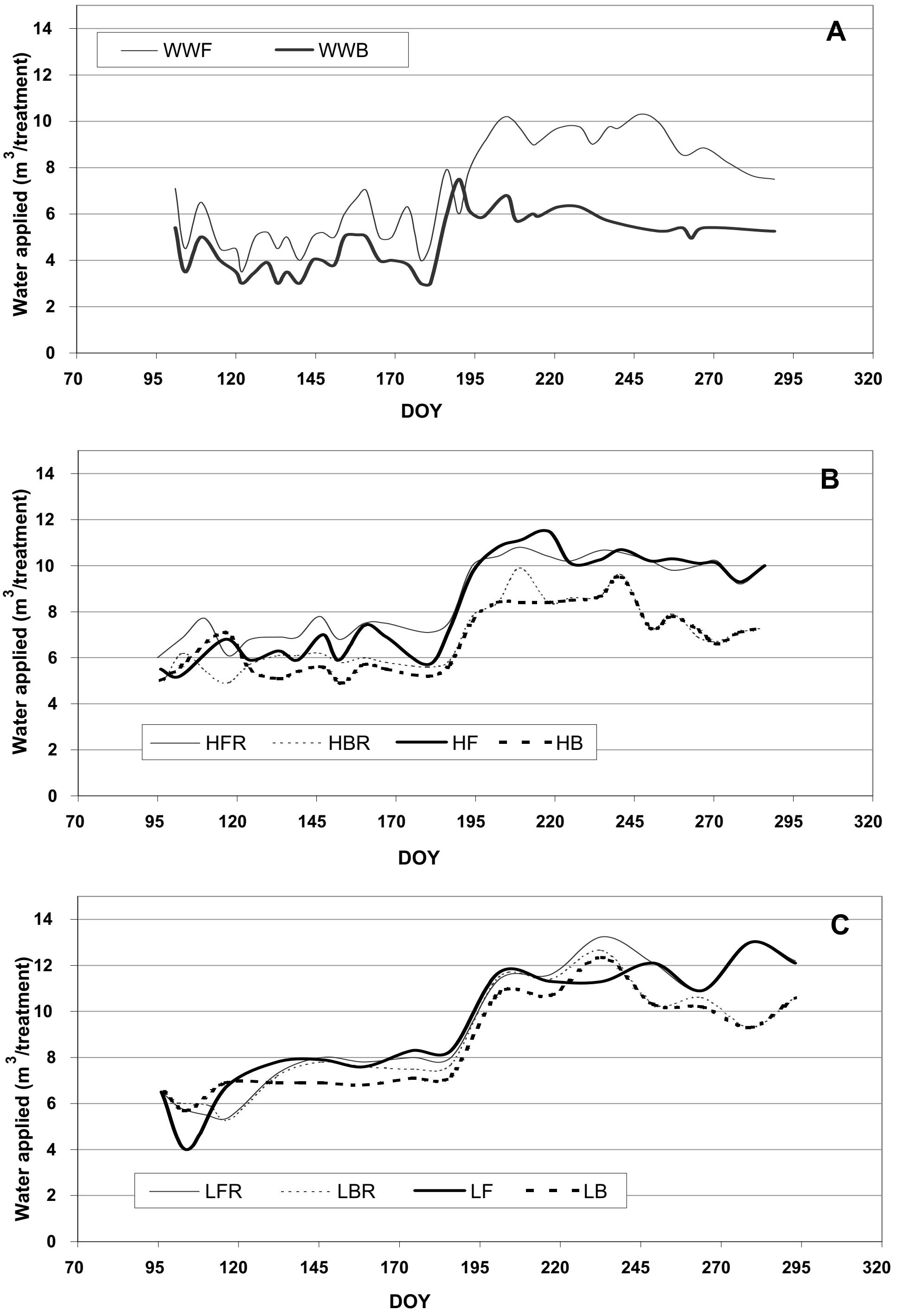

Fig. 22. Water applications to *Acacia saligna* during 1999 grouped by treatments (For the legends refer to the text).

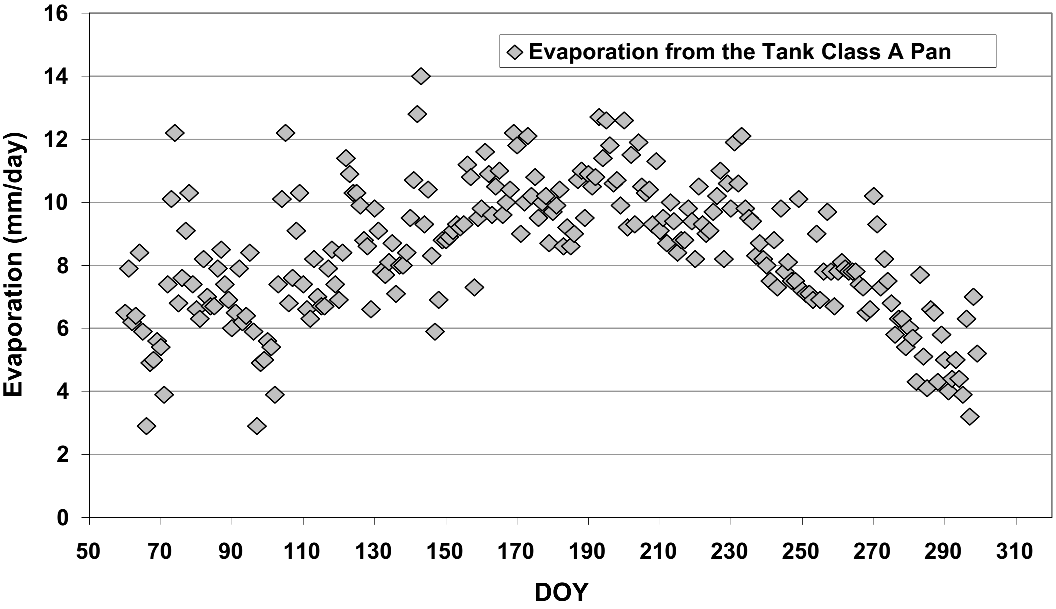

Fig. 23. Water Evaporation from Class A Pan during season 1999. The data were collected from Sede Boker Kibbutz.

4.8. Consumptive water use (CWU)

Annual shrub water consumption from 11-04-99 to 22-10-99 was computed as:

$$CWU = WA + \Delta S \qquad [17]$$

where:

CWU = Water consumption (m^3) during the period 1999
ΔS = Water storage (m^3) (see graph annex 7)
WA = Water applied during the experimental period (m^3)

ΔS was computed using the three access tubes installed in the plot. Assuming that a, b, and c represent areas of 0.5m*1 m, 1m*1m, and 1m*0.5m respectively. We computed the amount of water in the profile as follows:

$$\Delta S = \left[\left(\frac{\Delta L_a}{1000} * 1 * 0.5 \right) + \left(\frac{\Delta L_b}{1000} * 1 * 1 \right) + \left(\frac{\Delta L_c}{1000} * 1 * 0.5 \right) \right] * 2 \qquad [18]$$

where:

ΔS = Difference in total water volume in the profile between the first and the last measurement (beginning and end of the season) (m^3) (See Annex 7)

ΔL = Equivalent water depth stored (1= tube a; 2= tube b; 3=tube c) in all the soil profile (mm)

ΔL_i was calculated according:

$$\Delta L_t = \frac{10 \sum \Delta\theta_i * \Delta z_i}{100} \qquad [19]$$

where:

ΔL_t = Equivalent water depth difference between the two above mentioned dates (mm)

θ = Volumetric Water Content (%)

ΔZ = Layer depth (cm)

t = Number of the tube (tube a=1; tube b=2; tube c=3)

i = Number of layer

Computations were carried out to a depth of 240 cm, from the beginning to the end of the measurement period. There was no rainfall during this period.

Consumptive water use is presented in Fig. 24. The higher CWU was for the fresh water treatments. The order of CWU was (decreasing): Well watered, High frequencies, Low frequencies, and runoff only. The same order was observed for the brackish treatments.

The COM for CWU shows that WWF (6.9 m^3 $shrub^{-1}$) and R (1.19 m^3 $shrub^{-1}$) are different from all other treatments; the first one with the highest and the second with the lowest water use (Fig. 24).

Among treatments 2-9, for high irrigation frequency the highest water use was for HFR. The lowest water consumption in the same frequency was for HB. For LFR, LBR, LF, the CWU is similar and all of them differ from LB, which is the lowest.

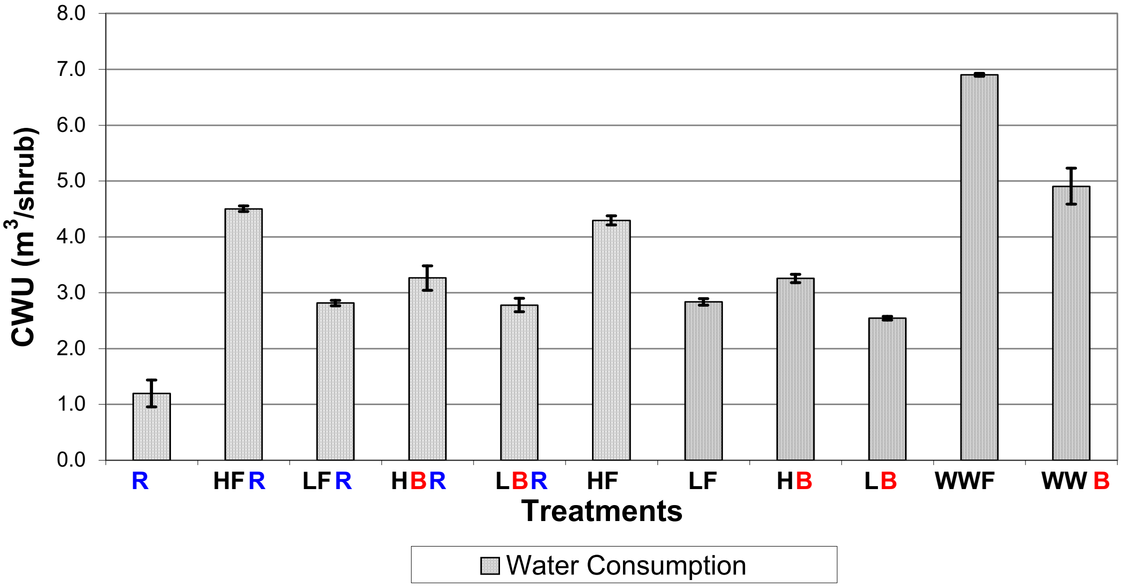

Fig. 24. Consumptive Water Use (CWU) of *Acacia saligna* during 1999 grouped by treatments. Bars indicate the standard errors.

The ANOVA for CWU shows a highly significant difference between brackish and fresh water, and between high and low irrigation frequency (p=0.01). For runoff, there is a significant difference between runoff and no runoff application at p=0.05.

A highly significant interaction between irrigation frequency and water quality was found [Annex 1 (Table 22-23)]. As can be observed in Fig. 25 the increase in CWU was different for treatments receiving runoff and those not receiving runoff. At low frequency, there was no difference for the treatments that received runoff, while the plots that did not received runoff a decrease in CWU for the brackish treatment can be observed.

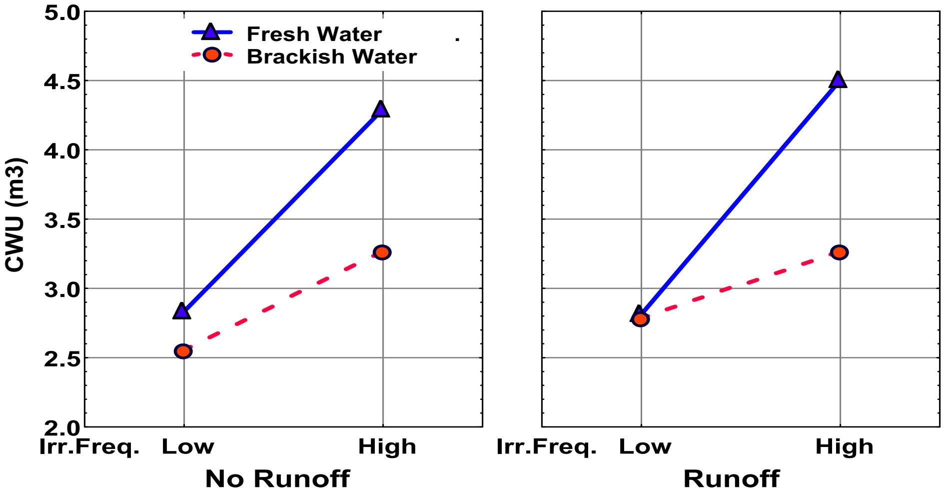

Fig. 25. Plot of means 3-way interaction (Water quality, Irrigation frequency, and Runoff) for water consumption (CWU) of *Acacia saligna* during 1999.

The difference between fresh and brackish CWU at high frequency was slightly higher for the treatments receiving runoff.

4.8.1. **Relationship between ET and Evaporation from Class A pan**

The evapotranspiration and the ET/Eo ratio are presented in Table 7. The highest ET/Eo was WWF for and the lowest was R. LFR, LBR, LF, LB had nearly 0.3 of ET/Eo ratio, which is low to all other treatments. Only LBR was completely different to all well watered treatments.

Table 7. Relationship Consumptive water use, evapotranspiration, and evaporation from Class A Pan (E_o). Values followed by the same letter are not statistically different at α=0.05 level according to Tukey test. (For the notation, refer to the text).

Treatment		**CWU (m^3 shrub $^{-1}$)**	**ET (mm)**	**ET / E_o**	
				E_o = 2013.3 mm	**α= 0.05**
1	R	1.19	298.74	0.15	abc
2	HFR	4.50	1126.00	0.56	ab
3	LFR	2.81	703.31	0.35	bc
4	HBR	3.26	815.60	0.41	bc
5	LBR	2.78	694.99	0.35	c
6	HF	4.30	1073.84	0.53	ab
7	LF	2.83	708.56	0.35	bc
8	HB	3.26	813.93	0.40	bc
9	LB	2.54	636.06	0.32	bc
10	WWF	6.90	1725.65	0.86	a
11	WWB	4.91	1226.52	0.61	a

4.9. Estimation of direct evaporative losses (Ee)

The estimation of direct evaporation water losses from ponded water and through the soil surface was computed using:

$$E_e = CWU - \frac{ATDBP}{WUE_{St}} \qquad [20]$$

where:

E_e = Estimated evaporative water loss (m^3) in the period 1999
CWU = Consumptive water use (m^3)
ATDBP = Annual Total Dry Biomass Production (Kg)
WUE_{St} = Average Water Use Efficiency of *Acacia saligna* (Kg m^{-3})

The ratio $ATDBP/WUE_{St}$ represents the rate of transpiration of the shrub.

There is no field data available for *Acacia saligna* shrubs. An average WUE_{St} was obtained from the data presented by Nativ *et al.* (1999), for a pot experiment

(2.57 Kg m^{-3}). Our assumption is that the shoot/root ratio was constant for all treatments. This statement probably corrects for all treatment while the exception of R. The exact value of WUE will not affects the relative magnitude of E_e.

The E_e, E_e/CWU and the number of irrigations are presented in Table 8. The highest E_e/CWU ratio was for LBR and HBR. The lowest water loss due to evaporation was for treatment R, which is different from the other treatments. Disregarding R, HBR has the highest water loss.

The ANOVA for E_e (treatments 2-9) showed a significant effect of frequency (α=0.01) and quality and runoff (α=0.05) [Table 8; Annex 1 (Table 27)]. No significant interactions were found.

Table 8. Annual Water Losses (E_e) of the various treatments. Different small letters shows significant difference at level α=0.01. (For the notation, refer to the text).

Treatment		**Number of irrigations**	**Average E_e (m^3)**		**Average Ee/CWU**	
R	1	0	0.60	c	0.53	abc
HFR	2	25	2.02	ab	0.45	bc
LFR	3	15	1.79	ab	0.63	ab
HBR	4	25	2.29	a	0.70	ab
LBR	5	15	2.12	ab	0.76	a
HF	6	25	1.84	ab	0.43	bc
LF	7	15	1.75	ab	0.62	ab
HB	8	25	2.18	ab	0.67	ab
LB	9	15	1.66	ab	0.65	ab
WWF	10	52	1.80	ab	0.26	c
WWB	11	52	1.57	b	0.32	c

The evaporation of the water from the soil surface is presented in Fig. 26. We can see that the evaporation varies with the irrigation frequency. For fresh water, we have roughly the same evaporation for all the number of irrigations.

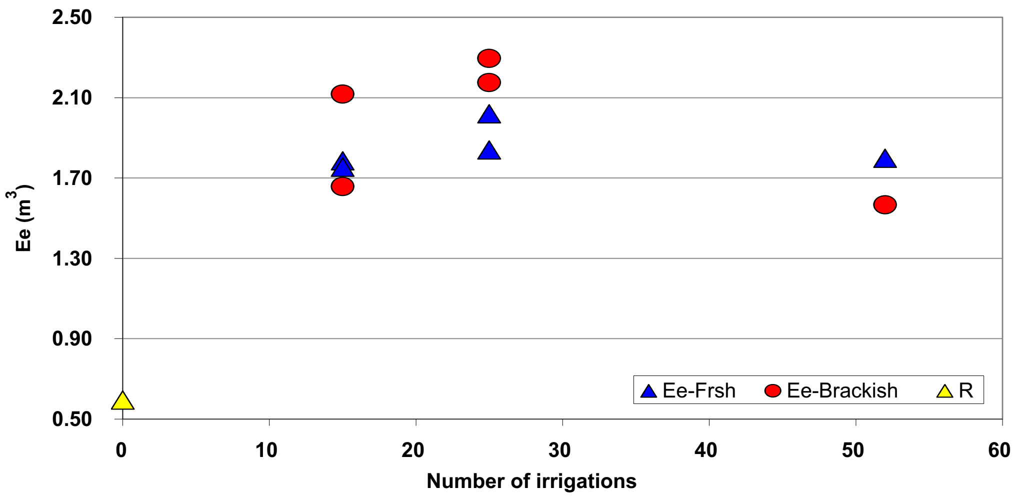

Fig. 26. Relationship between number of irrigations and evaporation (Ee) from the trial plots in 1999.

For both qualities, the response is parabolic, the highest values corresponding to 25 irrigations. The response of the fresh water is "flatter" than the brackish one.

The relation between the number of irrigation and the Ee/CWU ratio is presented in the Fig. 27. A linear correlation is apparent (disregarding R). Surprisingly the lowest ratio corresponds to the treatments that were irrigated at the highest frequency. A possible explanation may be found by the linear correlation between canopy size and number of irrigations. WW and WWB had the largest canopies and therefore the solar radiation flux reaching the bounded water or wet soil surfaces were probably greatly reduced.

The ratio is low for all fresh water treatments, and the lowest are the well water treatments. The highest ratio was observed for brackish watered treatments.

It seems that the highest values of the ratio may be due to the high evaporation losses and less water consumption by the shrub. As we increased the number of irrigations, the ratio decreases.

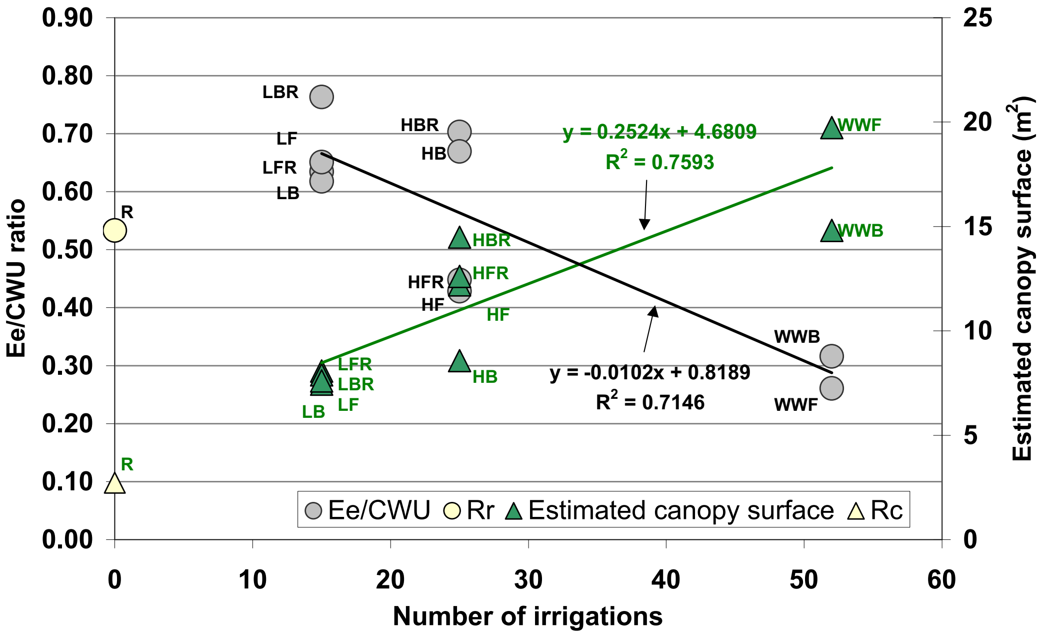

Fig. 27. Ee/CWU and estimated crown cross sectional area (CSA) as a function of the number of irrigations for Acacia saligna during 1999. Rr and Rc (values of Ee/CWU and crown area for the runoff treatment) were not included in the regressions. For the legends, refer to the text.

4.10. Gross Water Use Efficiency (GWUE)

The gross water use efficiency defined as the mass of dry matter per unit of water consumed was computed from:

$$GWUE = \frac{ATDBP}{CWU} \qquad [21]$$

where:

GWUE = Gross Water Use Efficiency (kg m^{-3})

ATDBP = Annual Total Dry Biomass Production (Kg)

CWU = Annual Water consumption (m^3)

The results of GWUE are presented in the Table 9. We can see that the highest GWUE was for the well-watered treatments. The lowest GWUE was for low frequency treatments with no noticeable difference between brackish and fresh water. R was higher than all the low frequencies.

Table 9. Gross Water Use Efficiency of *Acacia saligna* grouped by treatments. Values followed by the same letter are not statistically different at the α level according to Tukey test. (For the notation, refer to the text).

Treatment		**Annual Total Biomass Production ($Kg\ shrub^{-1}$)**	**Annual Water consumption ($m^3\ shrub^{-1}$)**	**Gross Water Use Efficiency (GWUE)**		
				($Kg\ m^{-3}$)	**α= 0.01**	**α= 0.05**
1	R	1.54	1.19	1.20	abc	abc
2	HFR	6.40	4.5	1.42	abc	ab
3	LFR	2.65	2.8	0.94	bc	cd
4	HBR	2.49	3.3	0.76	c	cd
5	LBR	1.70	2.8	0.61	c	cd
6	HF	6.32	4.3	1.47	abc	ab
7	LF	2.78	2.8	0.98	bc	cd
8	HB	2.78	3.3	0.85	c	cd
9	LB	2.28	2.5	0.90	bc	cd
10	WWF	13.14	6.9	1.90	a	a
11	WWB	8.60	4.9	1.76	ab	b

Irrigation frequency increased GWUE for fresh water treatment and runoff application had no effect.

For the brackish treatment, no significant difference between low and high frequencies could be found and as a result of runoff, no significant improvement in GWUE was observed. WWB was significantly higher than the rest.

The ANOVA indicates that the quality and frequency were significant factors and a strong interaction between them was evident.

The ANOVA performed on the treatments which received no runoff indicated that both factors (water quality and irrigation frequency) were significant at α=0.01 and their interaction at α=0.05 [Annex 1 (Table 24-25)].

*4.10.1. **Interaction between GWUE and experimental factors***

In Fig. 28 the interaction are plotted. It is noteworthy that when no runoff was applied increasing the frequency reduced the GWUE of brackish treatments while it increased those with fresh water.

Conversely, when runoff was applied there was an increase in GWUE also for the brackish treatments, albeit a small one.

*4.10.2. **Correlation between ATDBP and CWU***

The relation between CWU and the ATDBP is presented in Fig. 29. The biomass production (ATDBP) increased linearly with CWU, and was not affected by water quality, the slope of the regression line is 1/1.3 kg m^{-3}.

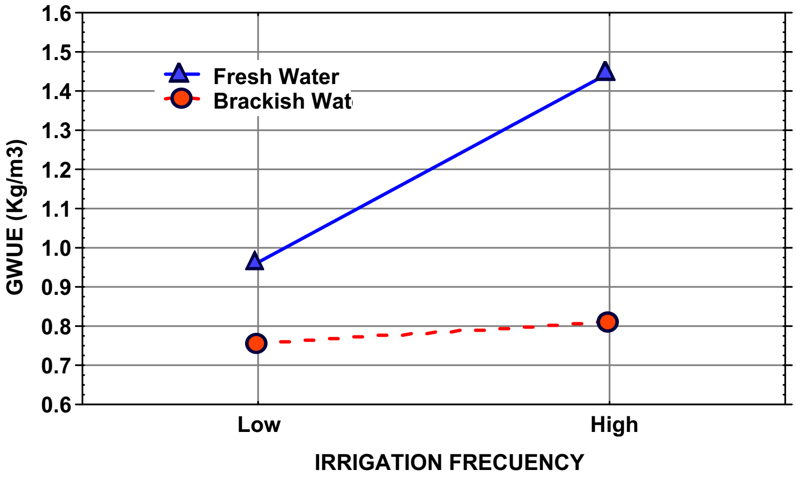

Fig. 28. Plot of means 2-way interaction for Gross Water Use Efficiency (GWUE) of *Acacia saligna* during 1999.

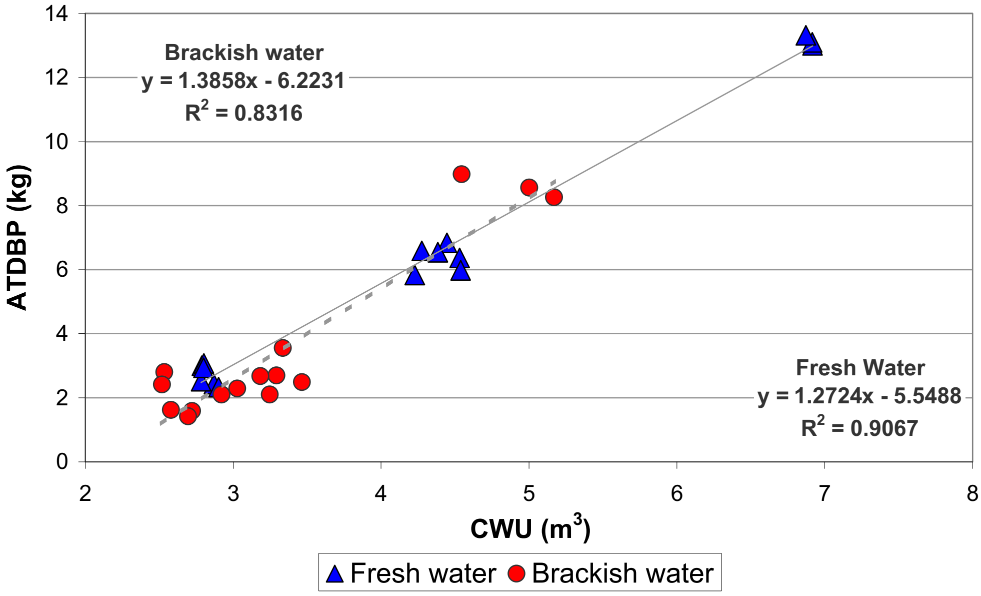

Fig. 29. Relationship between Consumptive Water Use (CWU) and Annual Total Dry Biomass Production (ATDBP) grouped by water quality for *Acacia saligna* during 1999.

5. *Discussion*

5.1. Standing biomass five years after planting

We seek to maximize the biomass production, and frequently the highest yield is obtained by increasing the number of irrigations (Bielorai *et al*., 1964; Shalhevet, 1990). Other authors observed the same trend. Minhas (1997) for two irrigation water qualities (different electric conductivity) and three irrigation frequencies for *Acacia nilotica;* Reed *et al*., (1998) for irrigated *Eucalyptus globulus* with trees maintained at levels of at least 80% of field capacity, and by Berliner *et al*. (1998) who used the same setup as the one described here.

Our results show that there is a highly significant influence of the irrigation frequency on the standing above ground biomass production. The lowest production of phyllodes was found for R, and among irrigated treatments LBR, LF, LB produced the lowest yields.

The effect of the different factors on the yield components was not similar. For phyllodes, runoff and irrigation frequency was significant at p=0.05; for twigs irrigation frequency was significant at p=0.05; for Branches irrigation frequency was significant at p=0.01; for trunk irrigation frequency was significant at p=0.01; and for whole shrub irrigation frequency was significant at p=0.01 and runoff at p=0.05.

For branch (TDB), twig (TDT), and trunk (TDK) production, all the treatments in the low irrigation frequency were lower than the high irrigation frequency. The effect of runoff and brackish water application to improve the production of woody materials is not evident. Similar results were found for *Eucalyptus camaldulensis* trees irrigated with saline drainage water (Electric Conductivity [EC] between 3 to 10.6 dS m^{-1}). These results showed that the growth rate was not affected by salinity (Sweeney, *et al*., 1997).

As we mentioned, the total biomass production was affected by runoff application (p=0.05) as well as the phyllode production at the same level. The former being probably the result of the latter. None of the components was affected by the water quality. We ascribe this behavior to the fact that runoff was significant during the early developmental stages and the brackish water was not yet detrimental.

5.2. Allometric equations (CSA – Above dry Biomass)

Quite a strong correlation was found between CSA and shrub components, and between CSA and whole shrub. These relationships are linear and similar to those found by other authors for the same variables (Droppelmann, *et al.*, 2000; Lott *et al.*, 2000; Lovenstein *et al.*; 1993; Nygren *et al.*, 1993).

The slopes of the various shrub components were similar and lower than 0.1 Kg cm^{-2} (phyllodes, twigs, branches, and trunk). For whole shrub of *Acacia saligna* a slope of 0.3 Kg cm^{-2} was computed.

These slopes (Table 4) of the irrigated treatments were different than those of by Droppelmann *et al.*, (2000) (same shrub specie). The slopes were similar only for the runoff treatment. Our runoff treatments and Droppelmann *et al.*, (1999) plots received different amount of water but both grew on stored water.

5.3. Annual biomass production (1999 season)

Differences due to water quality and irrigation frequency were found for all components and for the whole shrub. The highest yield was for WWF and the lowest R. The high frequency and fresh water applications produced the highest yields for all components (treatments 2-9).

Increase of irrigation frequency increased the annual total dry biomass production (ATDBP), more markedly with fresh water than with brackish water. Irrigation with the latter showed a small but positive increment of the ATDBP.

The production of the treatments with brackish water HB (2.78 kg shrub^{-1}), LB (2.28 Kg shrub $^{-1}$) and WWB (8.60 Kg shrub^{-1}) was higher than that found by Singh *et al*. (1996) for *Dalbergia sisso with* the same level of salinity. The South Asian multipurpose tree grew in water with EC of 6 dS m^{-1} and produced 0.325 Kg plant^{-1} of dry biomass with approximately 918 mm of rainfall.

The LF and HB treatments had the same biomass production i. e. applying fresh water at low frequency (twice a month) produced the same yield as irrigating at high frequency (four times a month) but with brackish water.

5.4. Relative Growth Rate (RGR)

According to Larocque *et al*., (1992), RGR is related to the development of the shrub and the availability of the resources. In our experiment, the RGR was a result of the effect of the treatments and the extreme environmental conditions (high temperature, high radiation, and low relative humidity coupled to high wind speed). This led to different rhythms of shrub development. High irrigation frequencies showed high RGR, throughout the season, which means high growth rate.

At the beginning of the season, there was a pronounced increase of RGR for WWF and WWB, and a sharp increase for R treatment. This means that those shrubs were growing at a quick pace. RGR of R reached a peak on DOY 160 and decreased monotonically till DOY 240. A slight increase was observed thereafter. This was likely due to the drop in the temperature, and the fact that shrubs were drying (or had died) at the end of the season and allowed the survivors to take more resources.

Fluctuations in RGR were higher for LF than for HF treatments. HFR and HBR showed fewer fluctuations than HF and HB. The treatments with runoff application did not have big differences among them throughout the season and were systematically lower than their counterparts without runoff. Likewise, LB and HB at the end of the season had almost the same RGR value.

After increasing the amount of irrigation, WWF, WWB, and HF showed a sudden increment in RGR. Surprisingly, at the same time, LF, LFR, HBR, LB showed a decrease in RGR.

There was a decrease in RGR particularly towards the end of the season especially for WWF, HF, HFR, and LF.

In spite that HF had a lower biomass production than WWF, the peaks of RGR for HF in some periods of development were higher than WWF. HFR had constant RGR during the year and the highest annual biomass production among treatments 2 to 9. This leads us to conclude that less fluctuations of RGR leads to higher biomass productions (Fig. 10-11-12).

The strong drop of RGR during the DOY 160 to DOY 240 for all treatments with the exception of WWF indicates a severe stress due to some environmental factor (Fig. 10-12). It appears that the evaporativity of the atmosphere was too high and water transport to the evaporating surface could be not be matched the treatments (with the exception of WWF).

5.2. Water uptake

The volumetric water content corresponding to the field capacity (FC) was observed in all the treatments to a depth of 30 to 75 cm only during 24 to 48 hours after irrigation. Strong redistribution of water below 60 to 75 cm depths was observed after 48 to 72 hours.

Water uptake patterns were studied in detail during a two week period between irrigations.

During the first time interval the main water uptake was from the upper soil layer. For the next intervals after irrigation, the water uptake for *Acacia saligna* took place mainly between 60 to 90 cm for high irrigation frequency and from 60 to 105 cm for low irrigation frequency. The shrub took the water mainly from the strata where it was available, independently of water quality and runoff. These results compare well with these obtained by Dirksen *et al*., (1979) for citrus tree, Garnier *et al*., (1986) for peach orchard, Singh *et al*., (1997) for different tree species, and Lefroy *et al*., (1999) for sole tree and.

For the LF treatments, the shrub took water mainly from deep layers. This behavior is normal in tress, i.e. *Prosopis caldenia* in shrub-lands during drought periods (Pelaez *et al*., 1994). The water content profiles show that the water uptake (when almost no water available was present in the upper layers) was from deep in the profile due to the runoff applied at the beginning of the season. This argument is strengthened by the fact that plots irrigated at low frequency and had runoff application showed at this time water uptake from deeper layers (105-120cm) a fact which is not evident for the treatments that did not received runoff.

During the period preceding irrigation for HF, 52 % of the water losses were measured in the upper 60 cm. Only 18% of losses were measured to the same depth and 36% of losses were measured between 0- 150 cm depth for LBR.

HF treatments were taking up water mainly from the upper layers and produced high biomass. Conversely, LF treatments took up the water from deeper layers, mainly from 105 to 150 cm. This is probably due to the different population and efficiency of roots in those layers. Meanwhile, for those treatments that produced the lowest biomass shrubs took water from almost all the soil layers due to the length of the drying out period.

5.3. Water consumption

The highest water application was for the highest irrigation frequency.

The higher Consumptive Water Use (CWU) was for the fresh water treatments (WWF and HFR). High interaction between frequency and water quality was observed. Runoff application was significant at p=0.05. This means that the fresh water in the number of irrigations used increased the CWU. Frequent irrigations can keep soil water contents close to field capacity between irrigations. More water is thus available for root uptake (Dirksen *et al*, 1979) showing the above response of HF.

There is a strong effect of the irrigation frequency and the water quality on the water consumption of *Acacia saligna.* A strong interaction between them was found as well. Among the same frequency we found less water used by plants irrigated with brackish water than for fresh water. In this case the ability of the shrub to extract water from the saline solution becomes the controlling factor (Glenn *et al*. 1998).

Sweeney *et al*. (1997) reported similar findings in a trial in which he compared five different water salinities and applications of N and P. He found that Eucalyptus tree irrigated with 7.5 dS m^{-1} had 706 mm $year^{-1}$ of water use, consumption lower than the WU of our shrubs (825 mm/season for HB and LB).

5.4. Evaporation

The computed evaporation (Ee) showed different patterns depending on water quality. The response of the Ee for brackish water was parabolic with a clear peak for 25 irrigations.

On the other hand the fresh water quality had more or less a similar evaporation for the various irrigations frequencies.

When E_e/CWU is plotted against number of irrigations, a linear negative correlation is apparent (Fig. 27). This means that proportionally the well watered plots lost less water by direct evaporation than the less frequently irrigated treatments. The low irrigation frequency had the highest Ee/CWU and the lowest canopy area, and the well-watered treatments had the lowest Ee/CWU and the largest canopy area. This result leads us to the conclusion that the area covered by the canopy was probably the main responsible for reducing evaporation by intercepting the solar radiation.

Results of Ee/CWU from 0.20 to 0.56 have reported for different crops (Gallardo, *et al.*, 1996). Shrub morphology, irrigation technique, site characteristics, and experimental methodology affected them. It appears that our values with the exception of HFR, HF, WWF, and WWB are higher than published results.

5.5. Gross Water Use Efficiency (GWUE)

The highest GWUE was for WW treatments. The lowest was for low frequency treatments with no noticeable difference between brackish and fresh water. For the brackish treatment, no significant difference between low and high frequencies could be found and runoff application had no significant effect.

When runoff was applied there was an increase in GWUE for the brackish treatments as well, albeit a small one (Fig. 28).

The biomass production (ATDBP) increased linearly with CWU, and was not affected by water quality. The WUE of this correlation was 1.3 Kg m^{-3}, which is lower than the values found by Nativ *et al*., (1999) (average of 2.57 g DM L_{H2O}^{-1}) for shrubs grown in pots. The difference between our WUE and Nativ's value is probably due to the fact that in the trial of the latter evaporation from the soil surface was negligible. From the point of view of water use, it is clear that the use of brackish water did not affect the correlation. This means that the mechanism responsible for the decrease in biomass production due to brackish water application is through the decrease in transpiration (Fig. 27).

5. *Conclusions*

The present research studied the effect of different irrigations regimes, two levels of water quality and runoff on the biomass production of *Acacia saligna* and led us to the following conclusions:

For the standing biomass production after five years of growth there is a significant effect of the irrigation frequency and runoff. No effect of the water quality was detected.

For the annual biomass production during the fifth year there was a significant effect of irrigation frequencies, water quality, and their interactions. An increase in the frequency of irrigation increased the biomass of fresh and brackish treatments, even though less for the latter than the former. The runoff irrigation did not have effect biomass production.

There was a strong correlation between CSA and shrub components, and CSA and whole shrub.

The plots with fresh water and in high irrigation frequency (HF, WWF) had less fluctuations of RGR and more constant rhythm of growth.

For high irrigation frequency the water uptake was mainly from the upper layers (30-75 cm depth) and for low irrigation frequency from almost all the layers (90-120 cm depth). The higher water consumption was for fresh water treatments.

The biomass production (ATDBP) increased linearly with consumptive water use (CWU), and was not affected by water quality.

The ratio of evaporation to CWU was negatively and linearly related to the number of irrigations and this behavior was due to the differences in canopy size.

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Annex

Annex 1. Tables of analysis of variance (ANOVA)

Table 1. Analysis of variance for Total Dry Leaves (TDL) of 5 production years in ***Acacia saligna*** grouped by analyze factors (for the legends see the last table).

Comentario [EGA1]: **Using All-Ave-LAST.sx. The treatments are the averaged in Master4-anual.xls.**

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.09691	0.04845	0.07	0.9330	
RUNOFF (B)	1	5.66175	5.66175	**8.14**	**0.0128**	*
QUAL (C)	1	0.25050	0.25050	0.36	0.5579	
FREC (D)	1	4.90829	4.90829	**7.06**	**0.0188**	*
B*C	1	1.10753	1.10753	1.59	0.2275	
B*D	1	0.58130	0.58130	0.84	0.3760	
C*D	1	0.08913	0.08913	0.13	0.7256	
B*C*D	1	3.788E-05	3.788E-05	0.00	0.9942	
A*B*C*D	14	9.73340	0.69524			
TOTAL	23	22.4288				

Table 2. Analysis of variance for Total dry Branches (TDB) of 5 production years in ***Acacia saligna*** grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	2.77379	1.38690	0.68	0.5214	
RUNOFF (B)	1	2.00538	2.00538	0.99	0.3374	
QUAL (C)	1	3.35556	3.35556	1.65	0.2197	
FREC (D)	1	18.8766	18.8766	**9.29**	**0.0087**	**
B*C	1	0.30664	0.30664	0.15	0.7035	
B*D	1	5.12131	5.12131	2.52	0.1347	
C*D	1	2.69668	2.69668	1.33	0.2687	
B*C*D	1	0.03317	0.03317	0.02	0.9002	
A*B*C*D	14	28.4527	2.03233			
TOTAL	23	63.6218				

Table 3. Analysis of variance for Total Dry Twigs (TDT) of 5 production years in ***Acacia saligna*** grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.68884	0.34442	0.21	0.8097	
FREC (B)	1	7.96485	7.96485	**4.96**	**0.0429**	*
QUAL (C)	1	0.00949	0.00949	0.01	0.9398	
RUNOFF (D)	1	2.94037	2.94037	1.83	0.1976	
B*C	1	1.82602	1.82602	1.14	0.3045	
B*D	1	0.19221	0.19221	0.12	0.7346	
C*D	1	0.69935	0.69935	0.44	0.5202	
B*C*D	1	0.03075	0.03075	0.02	0.8920	
A*B*C*D	14	22.5012	1.60723			
TOTAL	23	36.8531				

Table 4. Analysis of variance for Total Dry Trunk (TDK) of 5 production years in ***Acacia saligna*** grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P
BLOCK (A)	2	3.35687	1.67844	1.35	0.2901
FREC (B)	1	36.5354	36.5354	**29.47**	**0.0001 ****
RUNOFF (C)	1	4.80576	4.80576	3.88	0.0691
QUAL (D)	1	0.39645	0.39645	0.32	0.5807
B*C	1	0.03072	0.03072	0.02	0.8772
B*D	1	3.54946	3.54946	2.86	0.1128
C*D	1	1.93924	1.93924	1.56	0.2316
B*C*D	1	0.50486	0.50486	0.41	0.5337
A*B*C*D	14	17.3567	1.23976		
TOTAL	23	5547.03			

Table 5. Analysis of variance for Total Dry Biomass Production (TDBP) of 5 production years in ***Acacia saligna*** grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P
BLOCK (A)	2	26.6913	13.3457	0.84	0.4517
FREC (B)	1	202.079	202.079	**12.75**	**0.0031 ****
RUNOFF (C)	1	79.4575	79.4575	**5.01**	**0.0419 ***
QUAL (D)	1	2.73290	2.73290	0.17	0.6843
B*C	1	20.2498	20.2498	1.28	0.2774
B*D	1	33.5276	33.5276	2.11	0.1680
C*D	1	6.88328	6.88328	0.43	0.5207
B*C*D	1	3.69614	3.69614	0.23	0.6367
A*B*C*D	14	221.978	15.8555		
TOTAL	23	297.295			

Legend:
FREC: 2=High irrigation frequency; 1=Low irrigation frequency
QUAL: 1=Fresh water irrigation; 2=Brackish water irrigation
RUNOFF: 1=With runoff application; 0=Without runoff application
BLOCK = Effect of replication
One star = Significant difference;
Two star = Highly Significant Difference;

c

Table 6. Analysis of variance for the First Cross Sectional area (CSA1) in ***Acacia saligna*** measured in 1999 grouped by analyze factors (for the legends see the last table).

Comentario [EGA2]: Using All-aver-LAST1.sx

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	84.0252	42.0126	0.51	0.6128	
RUNOFF (B)	1	2731.20	2731.20	**32.97**	**0.0001**	**
QUAL (C)	1	346.340	346.340	4.18	0.0602	
FREC (D)	1	108.068	108.068	1.30	0.2725	
B*C	1	212.390	212.390	2.56	0.1316	
B*D	1	147.845	147.845	1.78	0.2029	
C*D	1	755.157	755.157	9.12	0.0092	
B*C*D	1	2.31441	2.31441	0.03	0.8696	
A*B*C*D	14	1159.70	82.8354			
TOTAL	23	5547.03				

Table 7. Analysis of variance for the Last Cross Sectional area (CSA2) in ***Acacia saligna*** measured in 1999 grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	429.221	214.611	1.11	0.3554	
FREC (B)	1	1546.48	1546.48	**8.03**	**0.0133**	*
RUNOFF (C)	1	259.609	259.609	1.35	0.2650	
QUAL (D)	1	55.9434	55.9434	0.29	0.5983	
B*C	1	281.122	281.122	1.46	0.2469	
B*D	1	547.409	547.409	2.84	0.1139	
C*D	1	58.1778	58.1778	0.30	0.5912	
B*C*D	1	6.77644	6.77644	0.04	0.8539	
A*B*C*D	14	2695.35	192.525			
TOTAL	23	8167.53				

Table 8. Analysis of variance for the difference between CSA1 and CSA2 in ***Acacia saligna*** measured in 1999 grouped by analyze factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	1.76229	0.88114	0.36	0.7052	
RUNOFF (B)	1	3.46730	3.46730	1.41	0.2549	
QUAL (C)	1	320.173	320.173	**130.14**	**0.0000**	**
FREC (D)	1	298.196	298.196	**121.20**	**0.0000**	**
B*C	1	2.62106	2.62106	1.07	0.3195	
B*D	1	0.99331	0.99331	0.40	0.5354	
C*D	1	146.142	146.142	**59.40**	**0.0000**	**
B*C*D	1	0.02631	0.02631	0.01	0.9191	
A*B*C*D	14	34.4442	2.46030			
TOTAL	23	807.825				

Legend:
FREQ: 2=High irrigation frequency; 1=Low irrigation frequency
QUALITY: 1=Fresh water irrigation; 2=Brackish water irrigation
RUNOFF: 1=With runoff application; 0=Without runoff application
One star = Significant difference;
Two star = Highly Significant Difference

Table 9. Analysis of variance for CSA1 in ***Acacia saligna*** grouped by Irrigation Frequency and Water quality factors. Treatments 6,7,8,9,10,11.(For the notations, see the last table in this series).

SOURCE	DF	SS	MS	F	P
BLOCK (A)	2	159.128	79.5638	0.99	0.4065
QUAL (B)	1	854.210	854.210	**10.59**	**0.0087** **
FREC (C)	2	17052.2	8526.08	**105.68**	**0.0000** **
B*C	2	1744.72	872.359	**10.81**	**0.0032** **
A*B*C	10	806.785	80.6785		
TOTAL	17	20617.0			

Table 10. Analysis of variance for CSA2 in ***Acacia saligna*** grouped by Irrigation Frequency and Water quality factors. Treatments 6,7,8,9,10,11.(For the notations, see the last table in this series).

SOURCE	DF	SS	MS	F	P
BLOCK (A)	2	181.847	90.9233	1.11	0.3661
QUAL (B)	1	2419.35	2419.35	**29.62**	**0.0003** **
FREC (C)	2	32058.8	16029.4	**196.21**	**0.0000** **
B*C	2	2847.63	1423.81	**17.43**	**0.0006** **
A*B*C	10	816.931	81.6931		
TOTAL	17	38324.6			

Table 11. Analysis of variance for differences CSA1 and CSA2 grouped by Frequency irrigation and Water quality factors. Treatments 6,7,8,9,10,11.

SOURCE	DF	SS	MS	F	P
BLOCK (A)	2	2.50098	1.25049	0.46	0.6466
QUAL (B)	1	398.401	398.401	**145.16**	**0.0000** **
FREC (C)	2	2453.47	1226.74	**446.97**	**0.0000** **
B*C	2	143.863	71.9316	**26.21**	**0.0001** **
A*B*C	10	27.4457	2.74457		
TOTAL	17	3025.68			

Legend:
FREQ: 2=High irrigation frequency; 1=Low irrigation frequency
QUAL: 1=Fresh water irrigation; 2=Brackish water irrigation
One star = Significant different;
Two star = Highly Significant Different

Table 12. Analysis of variance of the regression of CSA2 and TDL of ***Acacia saligna*** showing the lack of fit calculations.

SOURCE	df	SS	MS	f	p
Regression	1	5288.9	5288.9	**2745.13**	**0.0000**
Residual	131	252.391	1.926649		
Lack of fit	66	136.2	2.063609	1.15441	0.28168
Pure Error	65	116.2	1.787582		
Total Corrected	132	5541.291			

Table 13. Analysis of variance of the regression of CSA2 and TDB of ***Acacia saligna*** showing the lack of fit calculations.

SOURCE	df	SS	MS	f	p
Regression	1	6884.82	6884.82	**1774.03**	**0.0000**
Residual	131	508.397	3.88089		
Lack of fit	66	329.7	4.99572	1.81734	0.008466
Pure Error	65.0	178.7	2.74892		
Total Corrected	132	7393.217			

Table 14. Analysis of variance of the regression of CSA2 and TDT of ***Acacia saligna*** showing the lack of fit calculations.

SOURCE	df	SS	MS	f	p
Regression	1	6214.55	6214.55	**2282.1734**	**0.0000**
Residual	131	356.724	2.72308		
Lack of fit	66	291.7	4.48806	1.792244	0.0098
Pure Error	65.0	162.8	2.50416		
Total Corrected	132	6571.27			

Table 15. Analysis of variance of the regression of CSA2 and TDK of ***Acacia saligna*** showing the lack of fit calculations.

SOURCE	df	SS	MS	f	p
Regression	1	8976.44	8976.44	**3004.31**	**0.0000**
Residual	131	391.409	2.98785496		
Lack of fit	66	212.1	3.26236853	1.18231	0.2502
Pure Error	65.0	179.4	2.75930839		
Total Corrected	132	9367.85			

Table 16. Analysis of variance of the regression of CSA2 and TDBP of ***Acacia saligna*** showing the lack of fit calculations.

SOURCE	df	SS	MS	f	p
Regression	1	109973	109973	**5090.01**	**0.0000**
Residual	131	2830.34	21.60565		
Lack of fit	66	1513.4	24.90141	1.36377	0.10619
Pure Error	65.0	1316.9	18.25918		
Total Corrected	132	112803.34			

Table 17. Analysis of variance for ATDL in ***Acacia saligna*** grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.00796	0.00398	0.36	0.7052	
FREC (B)	1	1.34661	1.34661	**121.20**	**0.0000**	**
QUAL (C)	1	1.44585	1.44585	**130.14**	**0.0000**	**
RUNOFF (D)	1	0.01566	0.01566	1.41	0.2549	
B*C	1	0.65995	0.65995	**59.40**	**0.0000**	**
B*D	1	0.00449	0.00449	0.40	0.5354	
C*D	1	0.01184	0.01184	1.07	0.3195	
B*C*D	1	1.187E-04	1.187E-04	0.01	0.9191	
A*B*C*D	14	0.15554	0.01111			
TOTAL	23	3.64801				

Table 18. Analysis of variance for ATDB in ***Acacia saligna*** grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.01036	0.00518	0.36	0.7052	
FREC (B)	1	1.75289	1.75289	**121.20**	**0.0000**	**
QUAL (C)	1	1.88207	1.88207	**130.14**	**0.0000**	**
RUNOFF (D)	1	0.02038	0.02038	1.41	0.2549	
B*C	1	0.85906	0.85906	**59.40**	**0.0000**	**
B*D	1	0.00584	0.00584	0.40	0.5354	
C*D	1	0.01541	0.01541	1.07	0.3195	
B*C*D	1	1.546E-04	1.546E-04	0.01	0.9191	
A*B*C*D	14	0.20247	0.01446			
TOTAL	23	4.74863				

Table 19. Analysis of variance for ATDT in ***Acacia saligna*** grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.00935	0.00468	0.36	0.7052	
FREC (B)	1	1.58257	1.58257	**121.20**	**0.0000**	**
QUAL (C)	1	1.69920	1.69920	**130.14**	**0.0000**	**
RUNOFF (D)	1	0.01840	0.01840	1.41	0.2549	
B*C	1	0.77559	0.77559	**59.40**	**0.0000**	**
B*D	1	0.00527	0.00527	0.40	0.5354	
C*D	1	0.01391	0.01391	1.07	0.3195	
B*C*D	1	1.396E-04	1.396E-04	0.01	0.9191	
A*B*C*D	14	0.18280	0.01306			
TOTAL	23	4.28723				

Table 20. Analysis of variance for ATDK in ***Acacia saligna*** grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.01351	0.00675	0.36	0.7052	
FREC (B)	1	2.28568	2.28568	**121.20**	**0.0000**	**
QUAL (C)	1	2.45413	2.45413	**130.14**	**0.0000**	**
RUNOFF (D)	1	0.02658	0.02658	1.41	0.2549	
B*C	1	1.12018	1.12018	**59.40**	**0.0000**	**
B*D	1	0.00761	0.00761	0.40	0.5354	
C*D	1	0.02009	0.02009	1.07	0.3195	
B*C*D	1	2.016E-04	2.016E-04	0.01	0.9191	
A*B*C*D	14	0.26401	0.01886			
TOTAL	23	6.19198				

Table 21. Analysis of variance for ATDBP of whole shrub ***Acacia saligna*** grouped by factors.

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.16315	0.08158	0.36	0.7052	
FREC (B)	1	27.6071	27.6071	**121.20**	**0.0000**	**
QUAL (C)	1	29.6417	29.6417	**130.14**	**0.0000**	**
RUNOFF (D)	1	0.32100	0.32100	1.41	0.2549	
B*C	1	13.5298	13.5298	**59.40**	**0.0000**	**
B*D	1	0.09196	0.09196	0.40	0.5354	
C*D	1	0.24266	0.24266	1.07	0.3195	
B*C*D	1	0.00244	0.00244	0.01	0.9191	
A*B*C*D	14	3.18886	0.22778			
TOTAL	23	74.7887				

Legends:
FREC: 2=High irrigation frequency; 1=Low irrigation frequency
QUAL: 1=Fresh water irrigation; 2=Brackish water irrigation
RUNOFF: 1=With runoff application; 0=Without runoff application
One star = Significant difference;
Two star = Highly Significant Difference

Table 22. Analysis of variance for water consumption (CWU) in ***Acacia saligna*** shrub during the season of 1999 grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.00919	0.00459	0.41	0.6689	
FREC (B)	1	33.8825	33.8825	**3051.93**	**0.0000**	**
RUNOFF (C)	1	2.21598	2.21598	**199.60**	**0.0000**	**
QUAL (D)	1	9.72032	9.72032	**875.55**	**0.0000**	**
B*C	1	0.02039	0.02039	1.84	0.1968	
B*D	1	5.00846	5.00846	**451.13**	**0.0000**	**
C*D	1	3.991E-04	3.991E-04	0.04	0.8523	
B*C*D	1	0.14798	0.14798	**13.33**	**0.0026**	**
A*B*C*D	14	0.15543	0.01110			
TOTAL	23	51.1607				

Table 23. Analysis of variance for water consumption in shrub in *Acacia saligna* grouped by factors disregarding runoff (Treatments 6, 7, 8, 9, 10,11)(for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	604.401	302.201	1.37	0.2979	
FREC (B)	2	1412982	706491	**3203.21**	**0.0000**	**
QUAL (C)	1	222816	222816	**1010.24**	**0.0000**	**
B*C	2	63974.3	31987.2	**145.03**	**0.0000**	**
A*B*C	10	2205.57	220.557			
TOTAL	17	1702582				

Table 24. Analysis of variance for GWUE in ***Acacia saligna*** shrub during the season of 1999 grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.02514	0.01257	0.55	0.5916	
FREC (B)	1	0.43387	0.43387	**18.82**	**0.0007**	**
QUAL (C)	1	1.07462	1.07462	**46.61**	**0.0000**	**
RUNOFF (D)	1	0.08200	0.08200	3.56	0.0802	
B*C	1	0.27724	0.27724	**12.02**	**0.0038**	**
B*D	1	0.01373	0.01373	0.60	0.4531	
C*D	1	0.03013	0.03013	1.31	0.2721	
B*C*D	1	0.01646	0.01646	0.71	0.4124	
A*B*C*D	14	0.32279	0.02306			
TOTAL	23	2.27597				

Table 25. Analysis of variance for GWUE in shrub in *Acacia saligna* grouped by factors disregarding runoff (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.03364	0.01682	0.54	0.6007	
FREC (B)	2	2.58848	1.29424	**41.29**	**0.0000**	**
QUAL (C)	1	0.35939	0.35939	**11.46**	**0.0069**	**
B*C	2	0.25817	0.12908	4.12	0.0496	
A*B*C	10	0.31347	0.03135			
TOTAL	17	3.55315				

Table 26. Analysis of variance for transpiration in ***Acacia saligna*** shrub during the season of 1999 grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.02526	0.01263	0.37	0.6977	
FREC (B)	1	4.16667	4.16667	**121.86**	**0.0000**	**
QUAL (C)	1	4.45482	4.45482	**130.29**	**0.0000**	**
RUNOFF (D)	1	0.04860	0.04860	1.42	0.2530	
B*C	1	2.04167	2.04167	**59.71**	**0.0000**	**
B*D	1	0.01402	0.01402	0.41	0.5323	
C*D	1	0.03527	0.03527	1.03	0.3270	
B*C*D	1	4.167E-04	4.167E-04	0.01	0.9137	
A*B*C*D	14	0.47868	0.03419			
TOTAL	23	11.2654				

Table 27. Analysis of variance for evaporation in ***Acacia saligna*** shrub during the season of 1999 grouped by factors (for the legends see the last table).

SOURCE	DF	SS	MS	F	P	
BLOCK (A)	2	0.02327	0.01164	0.29	0.7503	
FREC (B)	1	0.38254	0.38254	**9.64**	**0.0078**	**
QUAL (C)	1	0.27094	0.27094	**6.83**	**0.0205**	*
RUNOFF (D)	1	0.23404	0.23404	**5.90**	**0.0292**	*
B*C	1	0.05134	0.05134	1.29	0.2745	
B*D	1	0.01260	0.01260	0.32	0.5820	
C*D	1	0.05320	0.05320	1.34	0.2663	
B*C*D	1	0.09004	0.09004	2.27	0.1542	
A*B*C*D	14	0.55559	0.03969			
TOTAL	23	1.67356				

Legend:
FREC: 2=High irrigation frequency; 1=Low irrigation frequency
QUAL: 1=Fresh water irrigation; 2=Brackish water irrigation
RUNOFF: 1=With runoff application; 0=Without runoff application
One star = Significant difference;
Two star = Highly Significant Difference

Annex 2. Fitting the linearity of the line regression

Table 1. Analysis of variance of the comparison of regression slopes between fresh and brackish water applications in last CSA and leaves biomass production.

Analysis of variance	SS	df	MS	F	F 5% 1%
Residual variation about a single quality water	193.72	118			
Sum of residual variations about individual water qualities	191.353	116	1.6496		
Difference (variation of individual lines about a single water quality	2.367	2	1.1835	0.717	3.17

Pooled: $\mathbf{L} = 1.17827+0.05785\ \mathbf{CSA_2}$ RSS: 193.723
Fresh water: $\mathbf{L} = 1.27872+0.05607\ \mathbf{CSA_2}$ RSS: 112.923
Brackish water: $\mathbf{L} = 1.0056+0.0697\ \mathbf{CSA_2}$ RSS: 78.4298
The relationships are not different in any level of significance (the slopes are equal)

Table 2. Analysis of variance of the comparison of regression slopes between fresh and brackish water applications in last CSA and branches biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single quality water	406.426	118			
Sum of residual variations about individual water qualities	394.07	116	3.397		
Difference (variation of individual lines about a single water quality	12.356	2	6.178	1.82	3.17

Pooled: $\mathbf{Br} = -1.3034+0.0886\ \mathbf{CSA_2}$ RSS: 406.426
Fresh water: $\mathbf{Br} = -0.85568+0.08372\ \mathbf{CSA_2}$ RSS: 233.749
Brackish water: $\mathbf{Br} = -1.86348+0.096\ \mathbf{CSA_2}$ RSS: 160.321
The relationships are not different at any level of significance (the slopes are equal)

Table 3. Analysis of variance of the comparison of regression slopes between fresh and brackish water applications in last CSA and twigs biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single quality water	316.96	118			
Sum of residual variations about individual water qualities	299.182	116	2.5792		
Difference (variation of individual lines about a single water quality	17.78	2	8.89	3.45	3.17

Pooled: Tw = 1.10422+0.06463 CSA2 RSS: 316.96
Fresh water: Tw = 1.39867+0.05967 CSA2 RSS: 140.049
Brackish water: Tw = 0.61477+0.07325 CSA2 RSS: 159.133
The relationships are different for both brackish and fresh water applications (the slopes are different)

Comentario [EGA1]: 1: (n-2)
2: (n1+n2-4)
3: 2

Comentario [EGA2]: SS residual/df

Comentario [EGA3]: Suma de los residuos de Brackish y Fresh

Comentario [EGA4]: Diferencia entre el primero y el segundo

Comentario [EGA5]: Que es la regresion con el total de valores

Comentario [EGA6]: Que es la regresion con los datos solo con agua fresca

Comentario [EGA7]: Que es la rgresion solo con los datos de agua salina

Table 4. Analysis of variance of the comparison of regression slopes between fresh and brackish water applications in last CSA and trunk biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single quality water	274.108	118			
Sum of residual variations about individual water qualities	268.284	116	2.31279		
Difference (variation of individual lines about a single water quality	5.824	2	2.912	1.26	3.17

Pooled: Trk = 1.07363+0.08036 CSA2 RSS: 274.108
Fresh water: Trk = 1.43723+0.07853 CSA2 RSS: 155.977
Brackish water: Trk = 0.76589+0.0818 CSA2 RSS: 112.307
The relationships (its slopes) are equals

Table 5. Analysis of variance of the comparison of regression slopes between fresh and brackish water applications in last CSA and whole biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single quality water	2316.05	118			
Sum of residual variations about individual water qualities	2221.25	116	19.148		
Difference (variation of individual lines about a single water quality	94.8	2	47.4	2.46	3.17

Pooled: Who = 2.05273+0.29143 CSA2 RSS: 2316.05
Fresh water: Who = 3.25895+0.27799 CSA2 RSS: 1139.80
Brackish water: Who = 0.52279+0.31202 CSA2 RSS: 1081.45
The relationships are not different at any level of significance (the slopes are equal)

Table 6. Analysis of variance of the comparison of regression slopes between runoff and without runoff in last CSA and whole biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single runoff application	2621.74	130			
Sum of residual variations about individual runoff application	2594.47	128	20.2693		
Difference (variation of individual lines about a single runoff application)	27.27	2	13.135	1.54	3.17

Pooled: Who = -0.21108+ 0.30612 CSA2 RSS: 2621.74
With runoff: Who = -0.05787+ 0.30306 CSA2 RSS: 1424.65
Without runoff: Who = -1.33466+0.32592 CSA2 RSS: 1169.82
The relationships are not different at any level of significance (the slopes are equal for runoff and without runoff)

Table 7. Analysis of variance of the comparison of regression slopes between high and low irrigation frequency in last CSA and whole biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about a single irrigation frequency	1644.27	130			
Sum of residual variations about individual runoff application	1606.79	96	16.7374		
Difference (variation of individual lines about a single runoff application)	37.47	2	18.7375	0.8932	3.15

Pooled: Who = -0.33853+ 0.31331CSA2 RSS: 1644.27
High Irrigation Frequency: Who = -0.04034+ 0.31638 CSA2 RSS: 890.868
Low Irrigation Frequency: Who = 0.09875+ 0.29699CSA2 RSS: 715.927
The relationships are not different at any level of significance (the slopes are equal for high irrigation frequency and low irrigation frequency)

Table 8. Analysis of variance of the comparison of fitted parallel lines between both fresh and brackish water applications in last CSA and leave biomass production.

Analysis of variance	S.S.	d.f	m.s.	F	F 5% 1%
Residual variation about parallel lines	193.315	117			
Sum of individual water qualities	191.353	116	1.6495		
Difference of slopes	1.962	1	1.962	1.19	3.91 6.82

Fitted: L1 = 0.98906+0.058 CSA2
L2 = 0.98906+0.11779 CSA2 RSS: 193.315
Fresh water: L = 1.27872+0.05607 CSA2 RSS: 112.923
Brackish water: L = 1.0056+0.0697 CSA2 RSS: 78.4298
The lines of the equations are parallels.

Table 9. Analysis of variance of the comparison of fitted parallel lines between both fresh and brackish water applications in last CSA and branch biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about parallel lines	406.404	118			
Sum of individual water qualities	394.07	116	3.397		
Difference of slopes	12.334	1	12.334	3.63	3.91

Fitted: Br1 = -1.25902+0.08856 CSA2
Br2 = -1.25902-0.02763 CSA2 RSS: 406.404
Fresh water: Br = -0.85568+0.08372 CSA2 RSS: 233.749
Brackish water: Br = -1.86348+0.096 CSA2 RSS: 160.321
The equation lines are parallels.

Table 10. Analysis of variance of the comparison of fitted parallel lines between both fresh and brackish water applications in last CSA and twig biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about parallel lines	314.296	118			
Sum of individual water qualities	299.182	116	2.5792		
Difference of slopes	15.114	1	15.114	5.86	3.91

Fitted: Tw1 = 0.62045+0.06502 CSA2
Tw2 = 0.62045+0.30114 CSA2 RSS: 314.296
Fresh water: Tw = 1.39867+0.05967 CSA2 RSS: 140.049
Brackish water: Tw = 0.61477+0.07325 CSA2 RSS: 159.133
The equation lines are not parallels.

Table 11. Analysis of variance of the comparison of fitted parallel lines between both fresh and brackish water applications in last CSA and trunk biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5%
Residual variation about parallel lines	269.160	118			
Sum of individual water qualities	268.284	116	2.31279		
Difference of slopes	0.876	1	0.876	0.39	3.91

Fitted: Trk1 = 1.73270+0.07982 CSA2
Trk2 = 1.73270-0.41026 CSA2 RSS: 269.160
Fresh water: Trk = 1.43723+0.07853 CSA2 RSS: 155.977
Brackish water: Trk = 0.76589+0.0818 CSA2 RSS: 112.307
The equation lines are parallels.

Table 12. Analysis of variance of the comparison of fitted parallel lines between both fresh and brackish water applications in last CSA and whole biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 5% 1%
Residual variation about parallel lines	2316.04	118			
Sum of individual water qualities	2221.25	116	19.148		
Difference of slopes	94.79	1	94.79	4.95	3.91 6.82

Fitted: Who1 = 2.08319+0.29140 CSA2
Who2 = 2.08319-0.01896 CSA2 RSS: 2316.04
Fresh water: Who = 3.25895+0.27799 CSA2 RSS: 1139.80
Brackish water: Who = 0.52279+0.31202 CSA2 RSS: 1081.45
The equation lines are not parallels at 1% of significance level, meanwhile at 5% of significance level the lines are parallels.

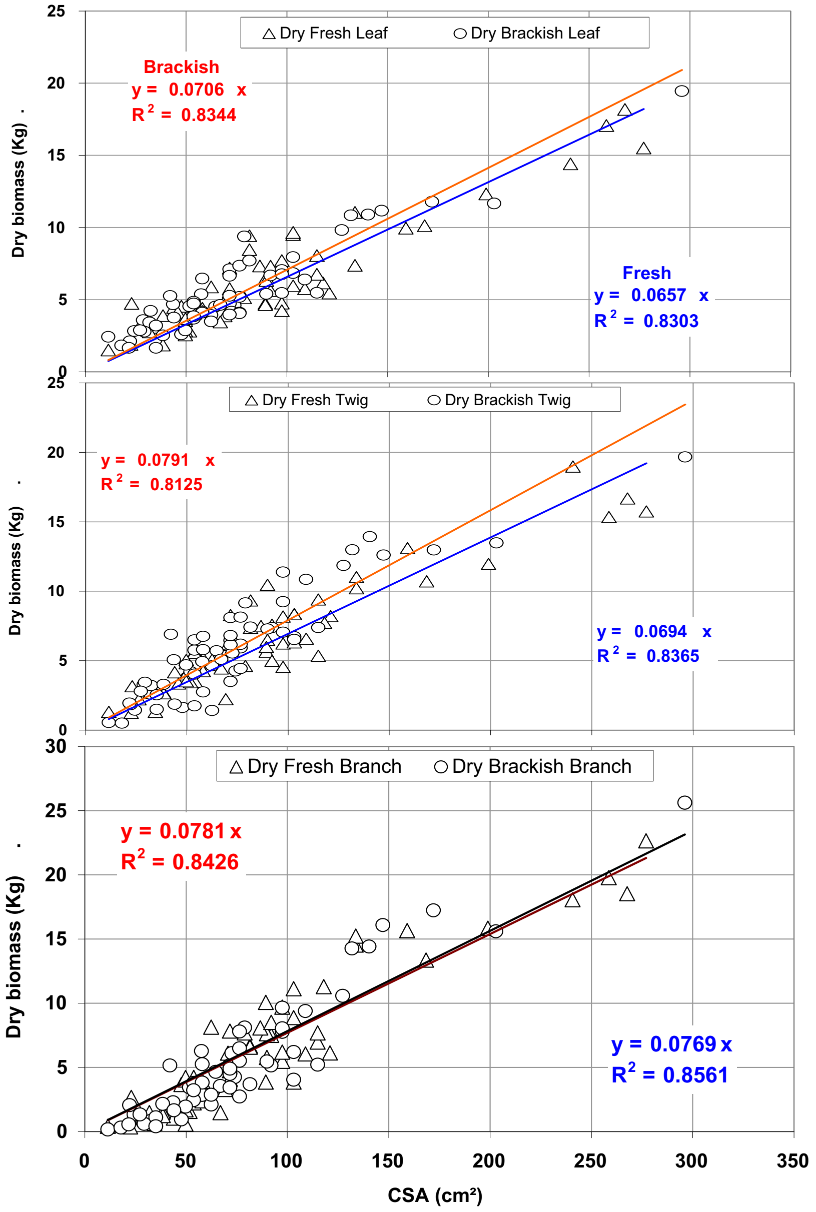

Fig. 1. Relationship of CSA-Dry Biomass Production separated by water quality application.

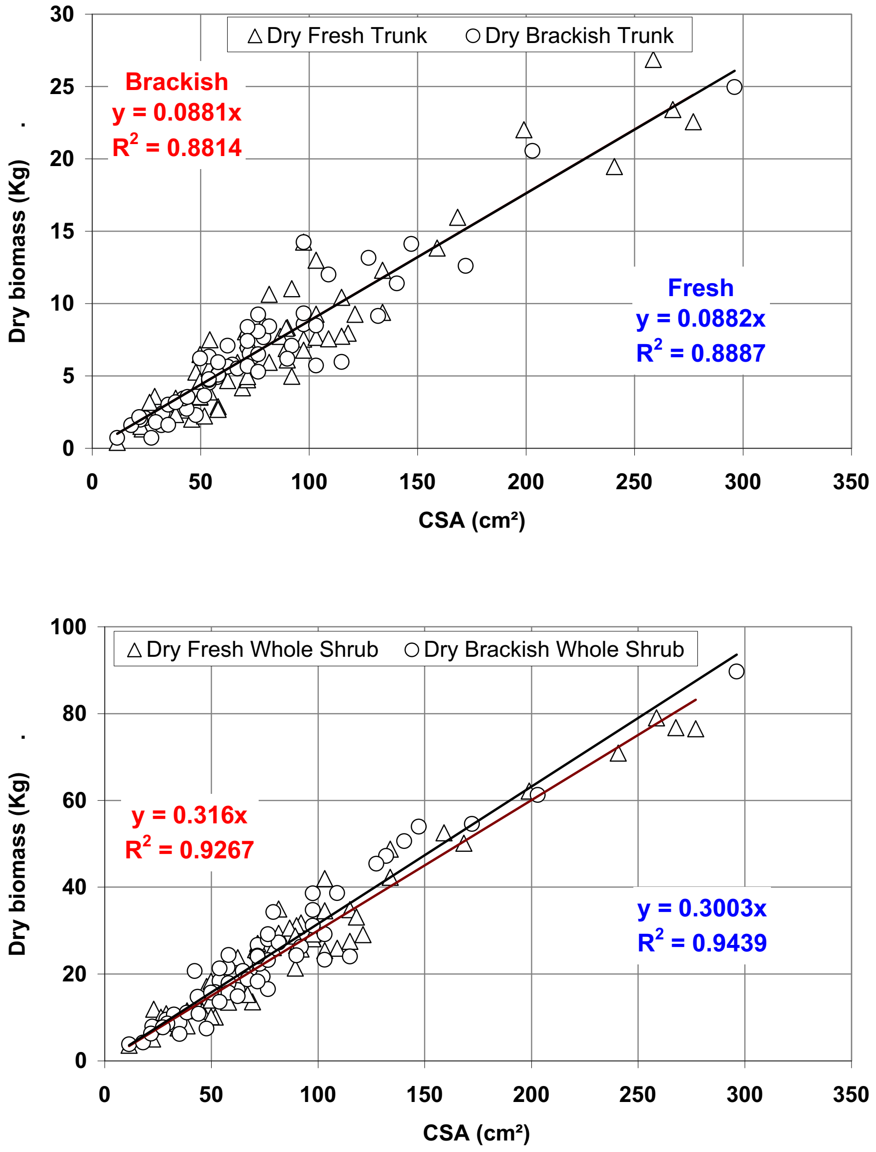

Fig. 2. Relationship CSA-Dry Biomass Production separated by water quality application.

Table 13. Analysis of variance of the comparison of regression slopes between both fresh water and R applications in last CSA and whole biomass production.

Analysis of variance	S.S.	df	m.s.	F	F 1%
Residual variation about parallel lines	1323.55	70			
Sum of individual water qualities	1147.733	68	16.8784		
Difference of slopes	175.8165	2	87.9082	5.21	1.95

Fitted: Who1 = 2.08319+0.29140 CSA2
Who2 = 2.08319-0.01896 CSA2 RSS: 2316.04
Fresh water: Who = 3.25895+0.27799 CSA2 RSS: 1139.80
Brackish water: Who = 0.52279+0.31202 CSA2 RSS: 1081.45
The equation lines are not parallels at 1% neither at 5% of significance level

Annex 3. Linear regressions of the different treatments without pooling

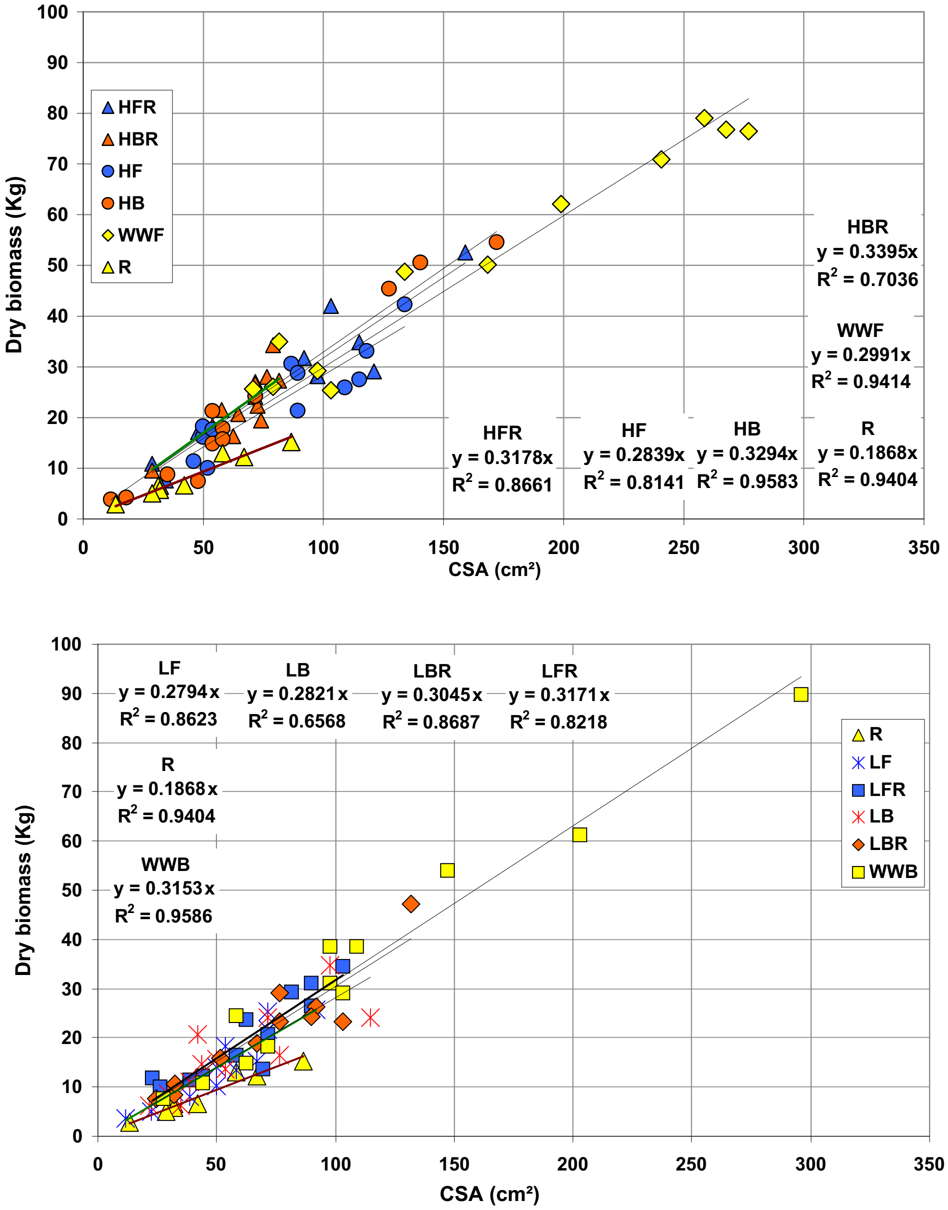

Fig. 1. Relationships Cross sectional Area (CSA) and Total Dry Biomass Production grouped by treatments. The statistics for these regressions are presented in Table 14.

Table 1. Slopes of the regression lines (forced through the origin) for all treatments. Different small letters under values show a significant difference between treatments. The regressions for

	Slope											
Component	R	HFR	LFR	HBR	LBR	HF	LF	HB	LB	WWF	WWB	Pooled
Phyllode	0.04290 b	0.06798 a	0.08587 a	0.08448 a	0.07272 a	0.05886 a	0.07141 a	0.0736 a	0.06735 a	0.06340 a	0.06567 a	0.06723 a
Twigs	0.05031 b	0.07914 a	0.08289 a	0.08904 a	0.08491 a	0.06963 a	0.07473 a	0.08424 a	0.08511 a	0.06441 a	0.07118 a	0.07290 a
Branches	0.03849 b	0.07747 a	0.0755 a	0.06934 a	0.07343 a	0.08027 a	0.06511 a	0.08571 a	0.05615 a	0.07734 a	0.08372 a	0.07671 a
Trunk	0.05506 b	0.09323 a	0.07283 a	0.09665 a	0.07346 a	0.07518 a	0.06813 a	0.08587 a	0.07352 a	0.094 a	0.09472 a	0.08757 a
Whole shrub	0.18676 b	0.31782 a	0.31708 a	0.33951 a	0.30452 a	0.28393 a	0.27939 a	0.32942 a	0.28214 a	0.29914 a	0.31529 a	0.03044 a

Annex 4. Evolution of Cross Sectional Area (CSA) during the season

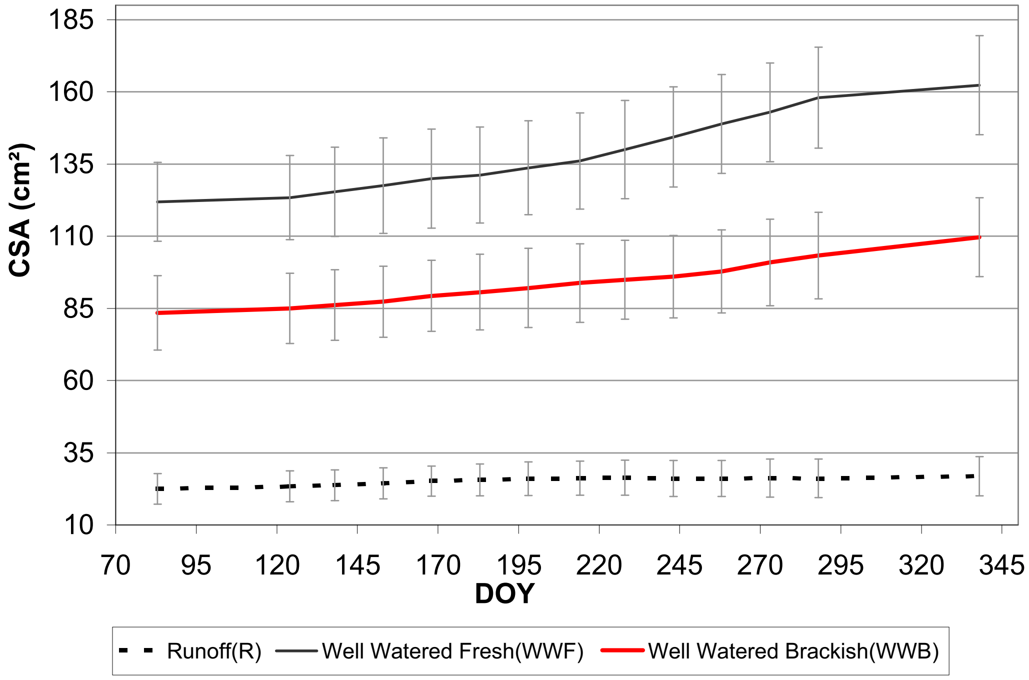

Fig 1. CSA development of *Acacia saligna* of the control treatments (R-WWF-WWB)

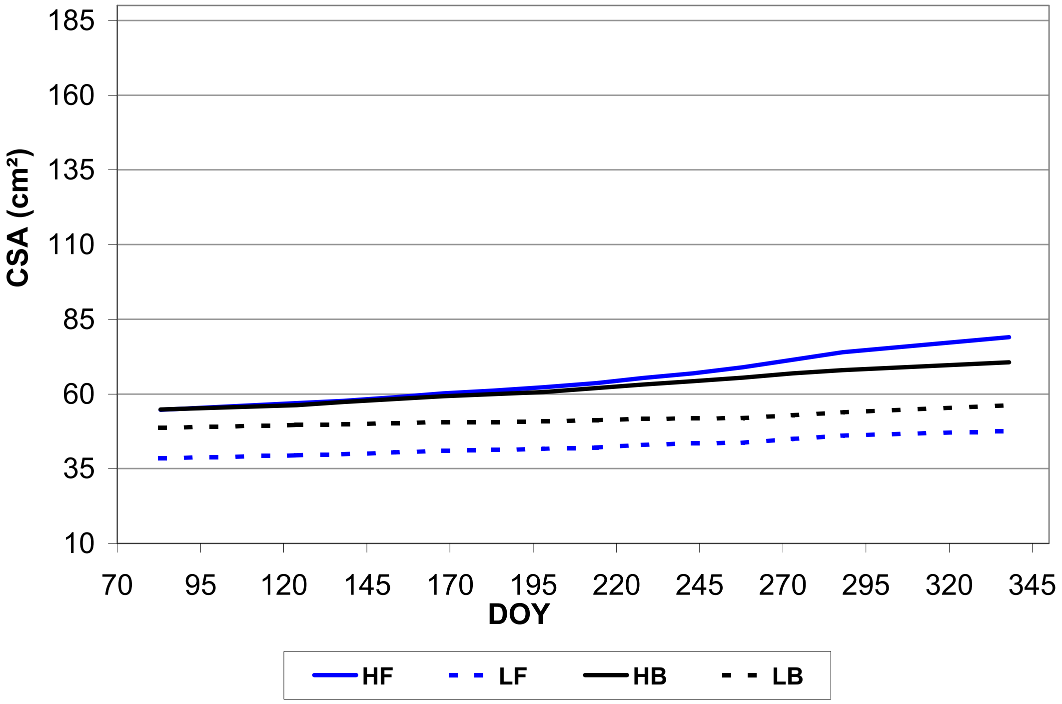

Fig. 2 Effect of Water quality and Irrigation Frequency (without Runoff) on the CSA development of *Acacia saligna*

t

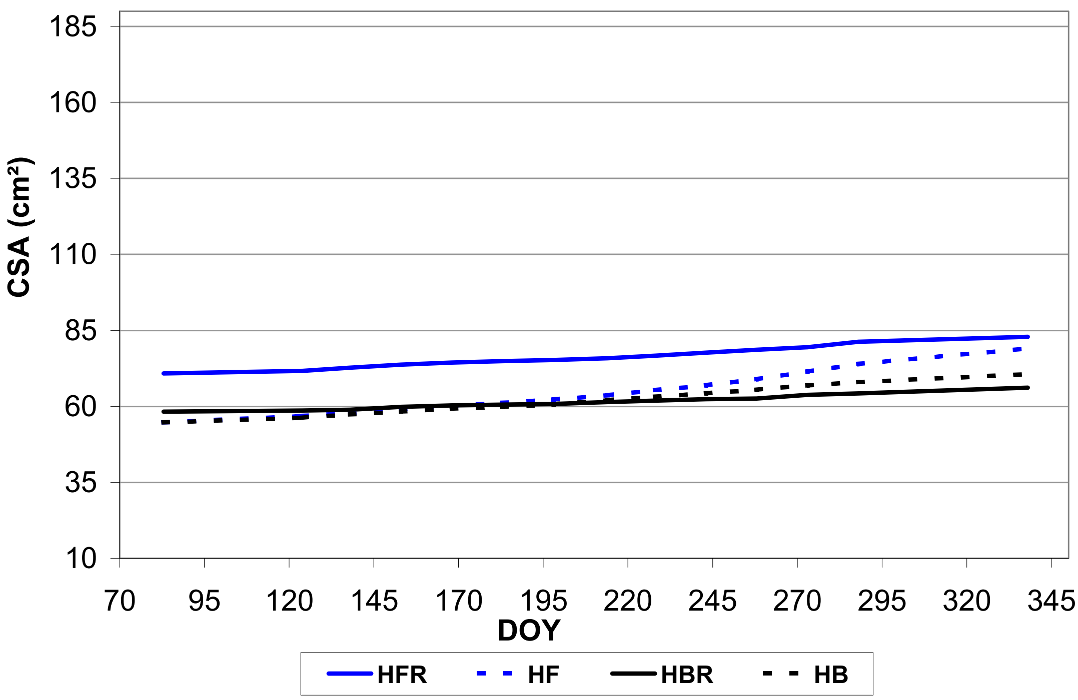

Fig. 3 Effect of Water quality and Runoff application on the CSA development of *Acacia saligna*

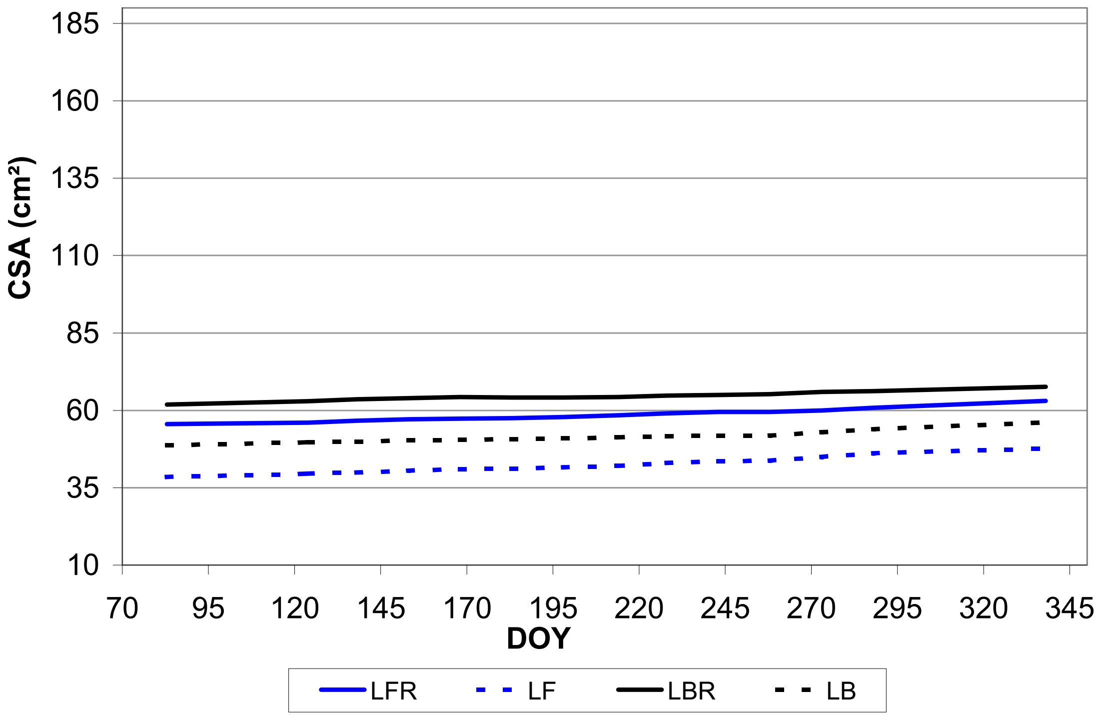

Fig. 4 Effect of Water quality and Runoff application on the CSA development of *Acacia saligna*

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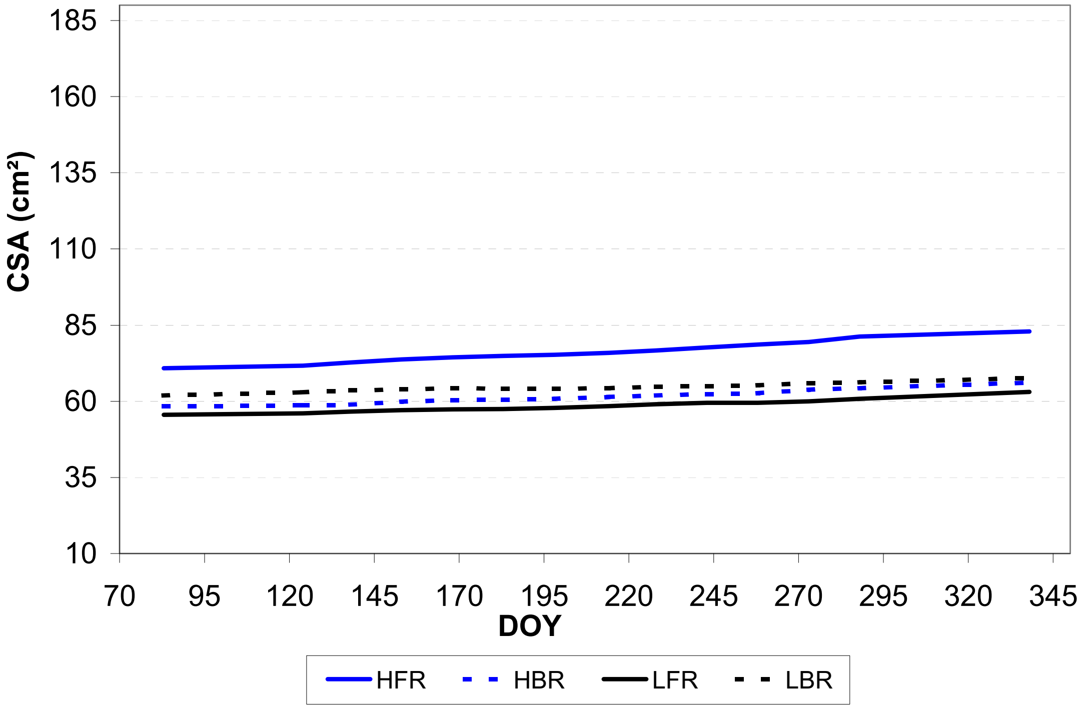


Fig. 5 Effect of Water quality and Irrigation frequency on the CSA development of *Acacia saligna*

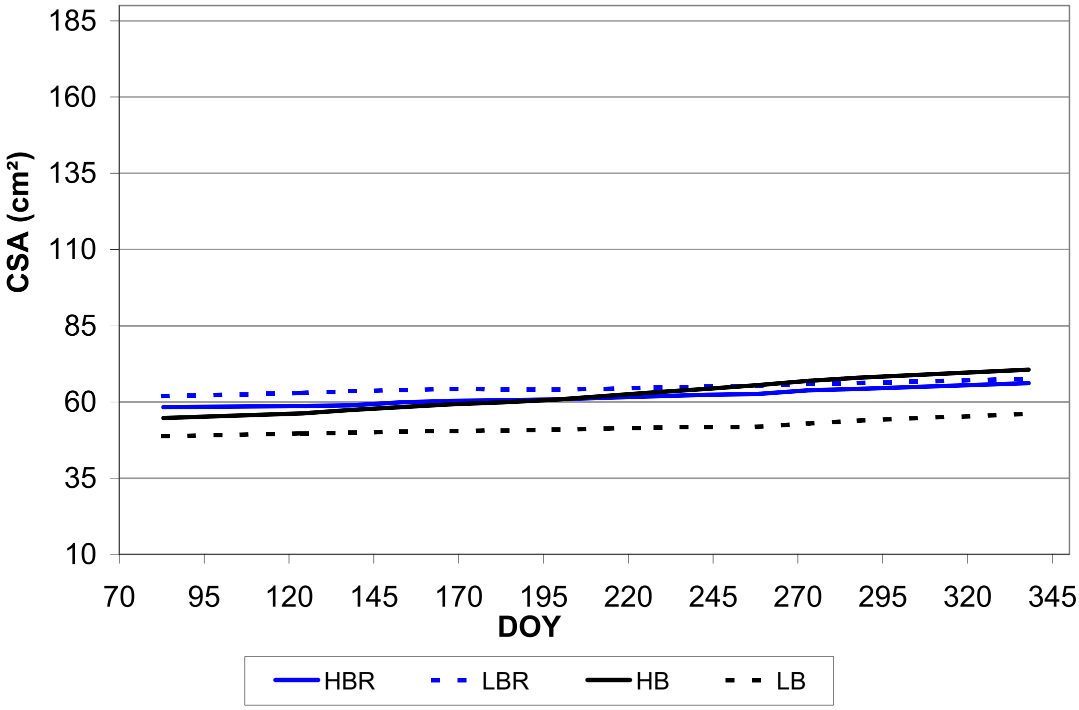


Fig. 6 Effect of irrigation Frequency and Runoff application on the CSA development of *Acacia saligna*

Annex 5. Analysis of residuals

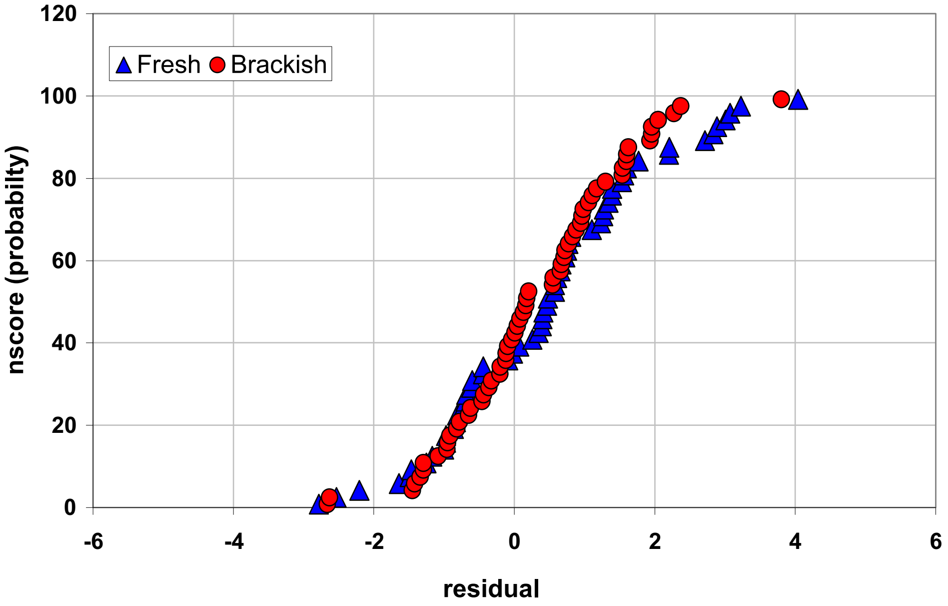


Fig. 1. Normal Plot of the residuals from sixty observations of leaf biomass production separated by water quality application.

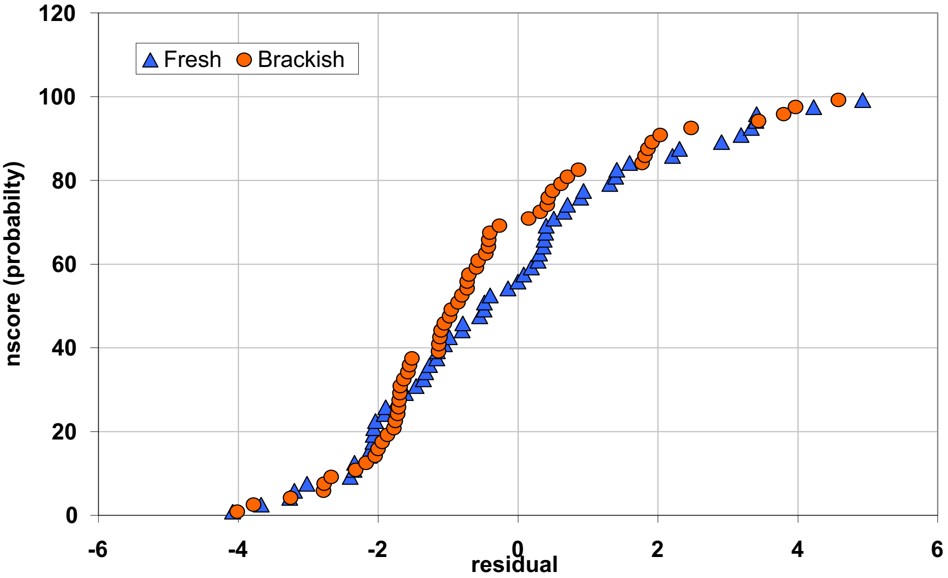


Fig. 2. Normal Plot of the residuals from sixty observations of branch biomass production separated by water quality application.

w

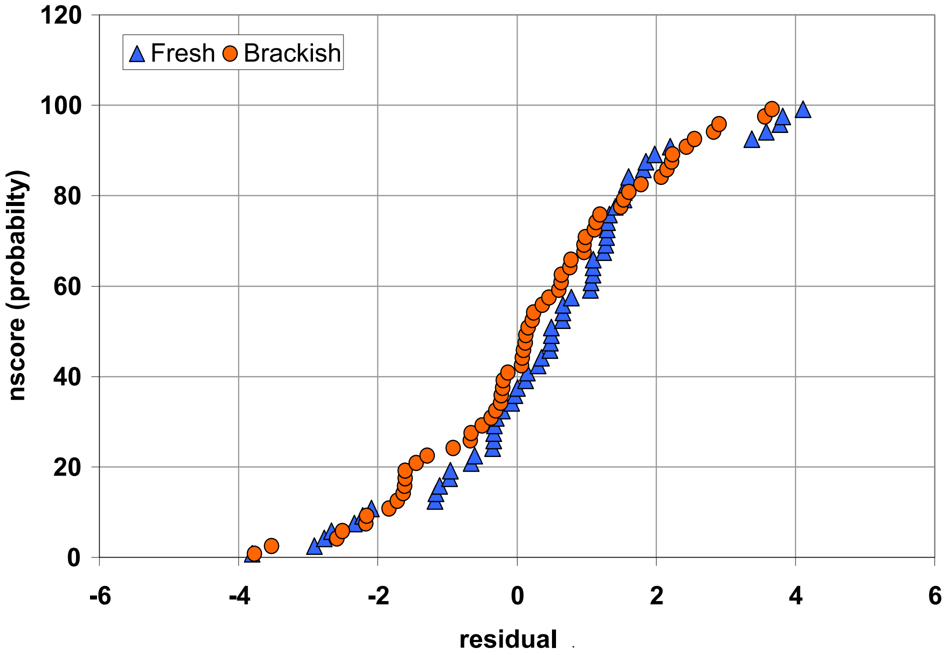


Fig. 3. Normal Plot of the residuals from sixty observations of Twig biomass production separated by water quality application.

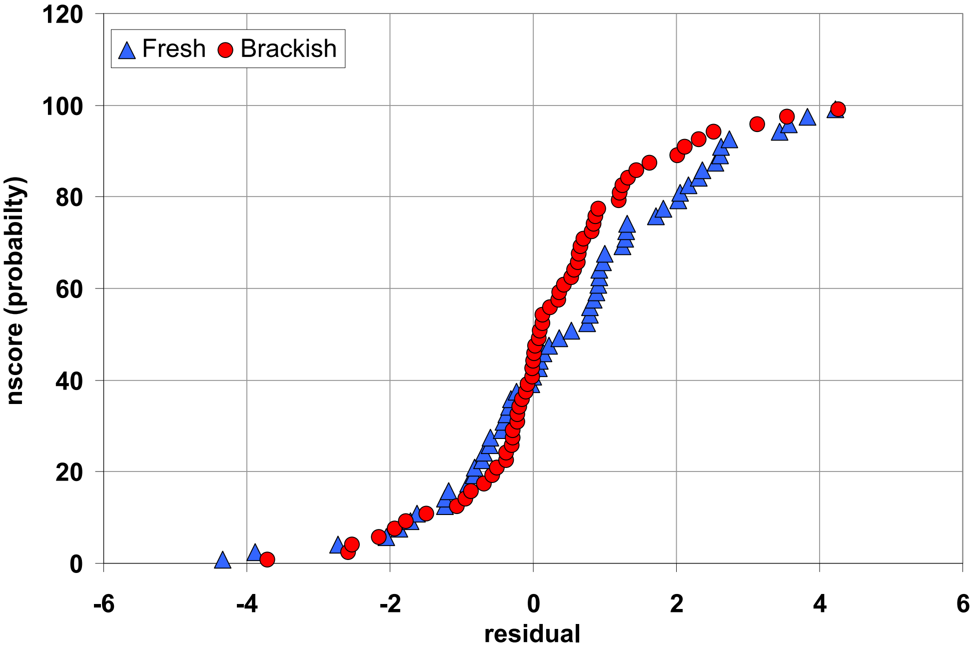


Fig. 4. Normal Plot of the residuals from sixty observations of Trunk biomass production separated by water quality application.

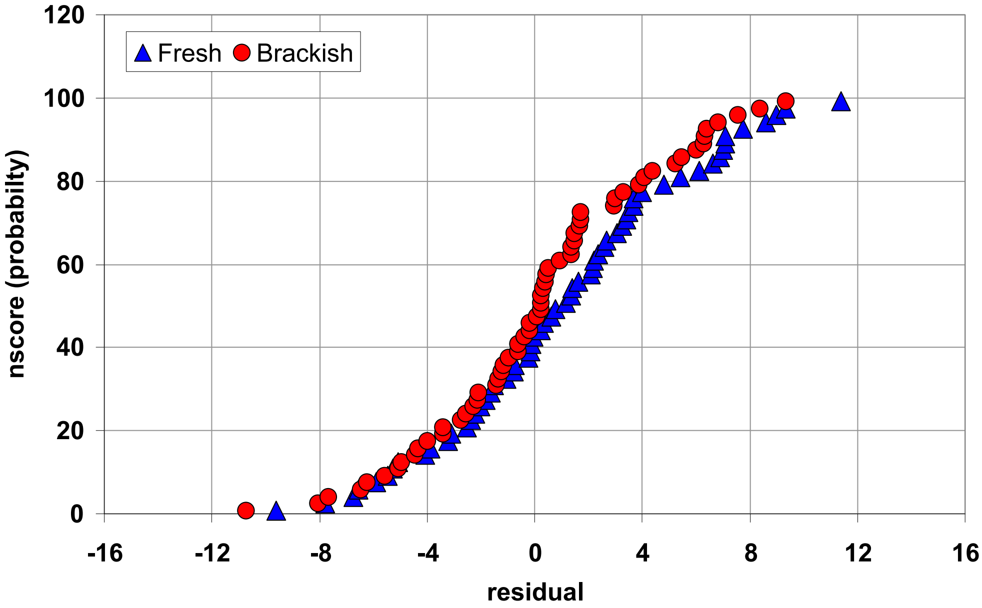


Fig. 5. Normal Plot of the residuals from sixty observations of Whole Shrub biomass production separated by water quality application.

Annex 6. The Analysis of errors to fit the regression equations

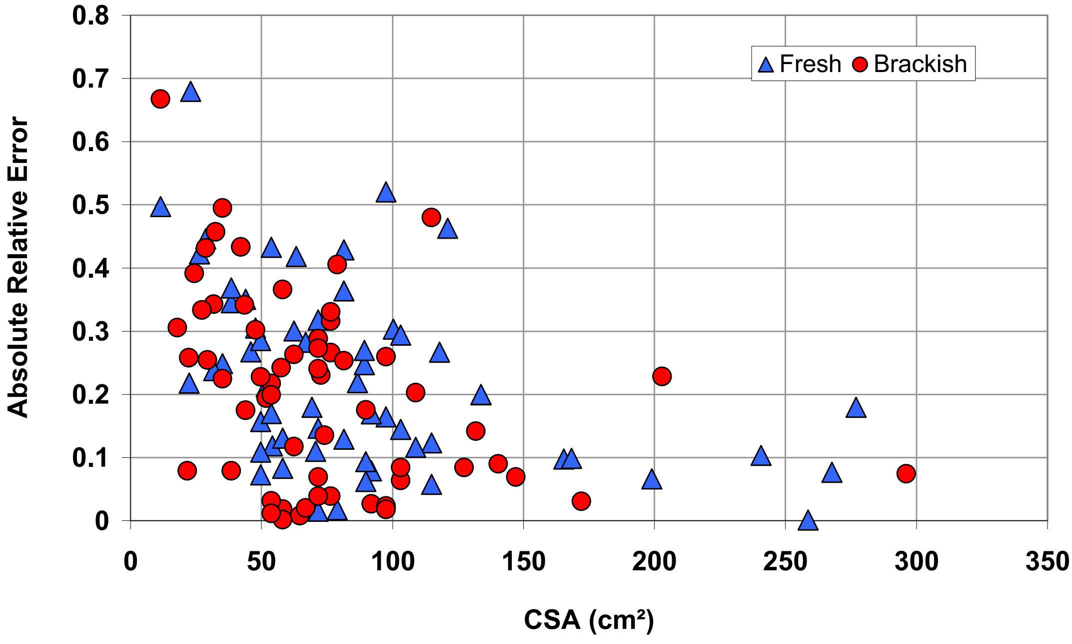


Fig. 1. Absolute Relative Error in the estimation of above ground leaf dry biomass per shrub as function of the Cross sectional Area (CSA) separated by water quality application.

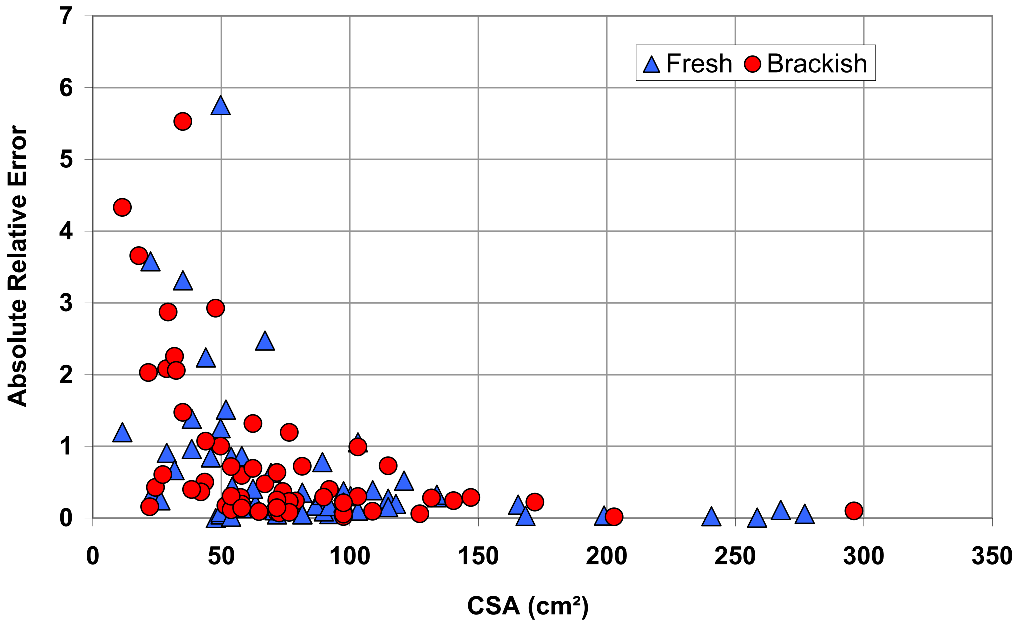


Fig. 2. Absolute Relative Error in the estimation of above ground branch dry biomass per shrub as function of the Cross sectional Area (CSA) separated by water quality application.

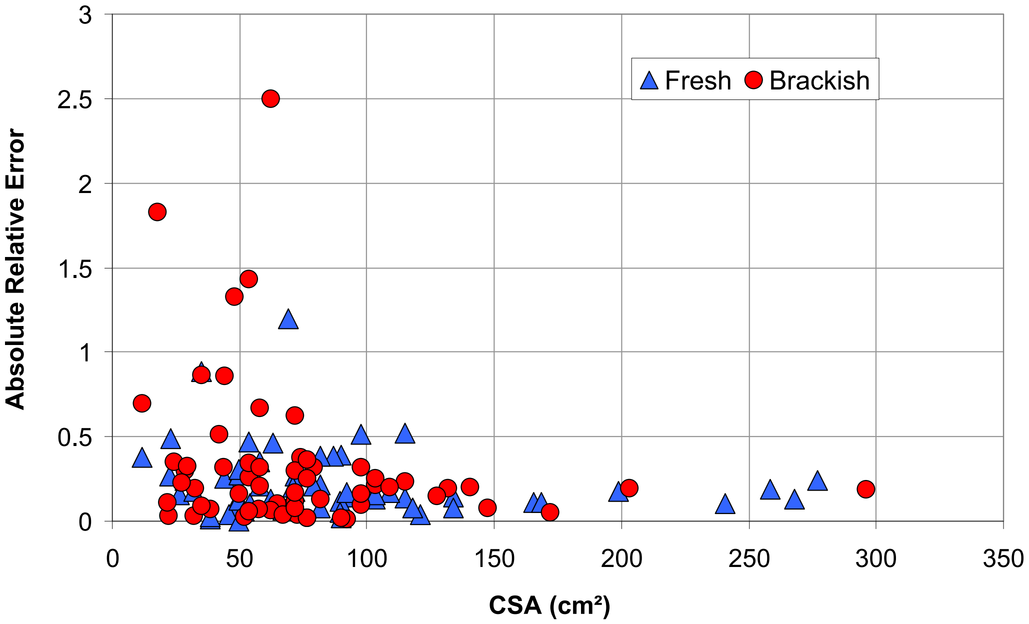


Fig. 3. Absolute Relative Error in the estimation of above ground twig dry biomass per shrub as function of the Cross sectional Area (CSA) separated by water quality application.

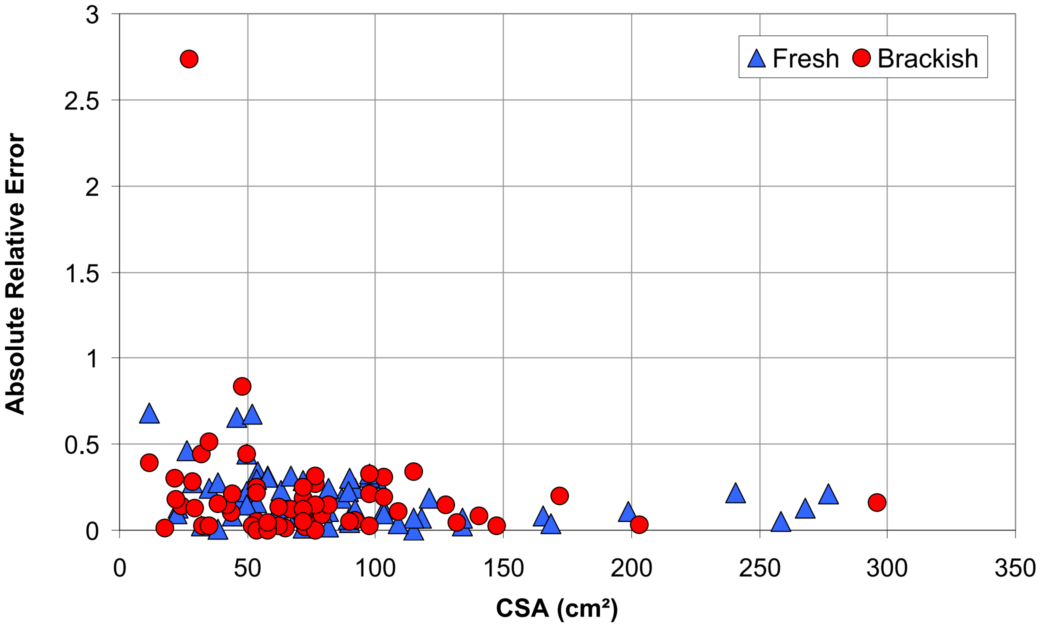
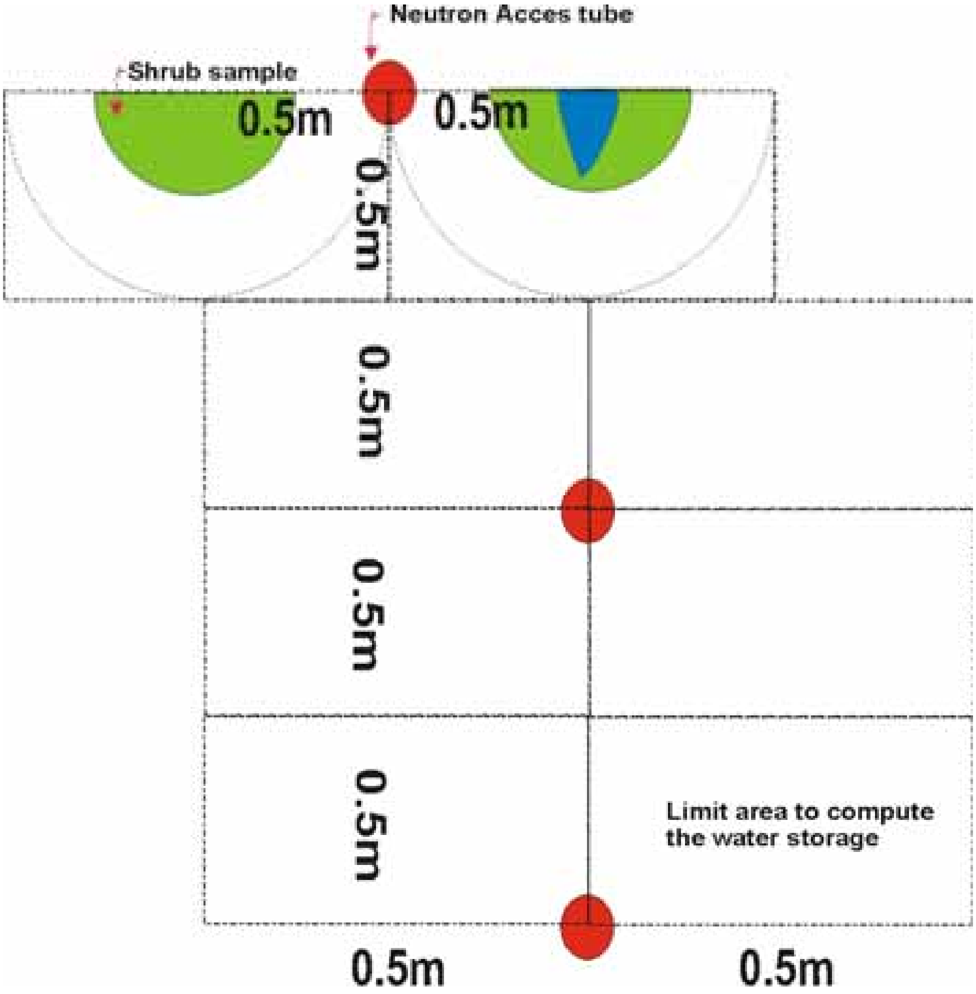


Fig. 4. Absolute Relative Error in the estimation of above ground trunk dry biomass per shrub as function of the Cross sectional Area (CSA) separated by water quality application.

Annex 7. Scheme for the calculation of ΔS



Annex 8. Pictures of the experiment

Photo 1. Experimental plot with *Acacia saligna* before pruning.

Neutron Probe access tube
Minirhizotron access tube
Dike-like structure
Pipe from the Drip Irrigation System
5 and 7. Measurements shrubs (*Acacia saligna)*
6. Buffer shrub (*Acacia saligna)*