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GROWTH AND WATER RELATIONS OF TWO POPULUS
CLONES UNDER CHANGING LEVELS OF WATER STRESS

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Major professor

Donald Dickmann

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GROWTH AND WATER RELATIONS OF TWO *POPULUS* CLONES UNDER CHANGING LEVELS OF WATER STRESS

by

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ABSTRACT

GROWTH AND WATER RELATIONS OF TWO *POPULUS* CLONES UNDER CHANGING LEVELS OF WATER STRESS

by

Stefano Mazzoleni

Two *Populus* clones (cv. Tristis #1 and Eugenei) were grown in a climatic chamber to observe early patterns of growth and water relations in response to water deficiency and changing watering regimes. Height and weight growth, dry matter partitioning, leaf area production, transpiration rates and leaf water potential were measured during the experiment. Treatments significantly affected these parameters in both clones. The two varieties reacted in a similar way to a first stress period. One clone (cv. Eugenei) showed a great recovery capability in terms of growth once stress was interrupted. However, plants of this variety became very sensitive to water deficit and wilted during a second stress treatment. The other clone (cv. Tristis #1) followed a more conservative strategy and showed a better adaptation to water deficiency and to changing conditions of moisture availability.

ACKNOWLEDGEMENTS

I wish to thank Dr.Donald Dickmann, my major professor, and the other members of my commitee, Dr. Frank Dennis and Dr. Kurt Pregitzer, for their assistance and advice. I am also grateful to Dr. Phu V. Nguyen and to Connie Bobrovsky for their patient help in some of the lab analysis. I wish to thank Pat Pedersen for the help in the preparation of the graphs, Rosalie Martens for great assistance in the typing, Niro Higuchi, Mike Stine and Michael Gold for all the explanations about the computer use, and all my lab friends for their support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In natural environments plants are exposed to changing levels of water stress. The sensitivity to water stress varies according to species, physiological processes and ontogeny (Hsiao 1973, Kramer 1983). Plants control their water status by short- and long-term responses to the variable conditions of water deficiency (Hanson and Hitz 1982). These responses include anatomical, morphological, physiological and biochemical changes (Kramer 1983).

Many studies have been conducted to determine the effects of environmental factors and plant water relations. Most studies with tree species have produced information about short term plant responses to water stress, such as diurnal trends of transpiration, water potential and photosynthesis relative to certain environmental variables, e.g., soil water potential, air temperature and irradiance either under field conditions (Anderson 1982, Barker 1973, Cline and Campbell 1976, Graham and Running 1984, Federer 1977, Keller 1976, Marshall and Waring 1984, Nelson and Michael 1982, O'Connor and Dickmann 1985, Pallardy and Kozlowski 1979a - 1981, Running 1976, Teskey et al.1984, Tobiessen and Kana 1974, Whitehead et al.1984) or controlled conditions (Blake and Ferrel 1977, Edwards and

Robertson 1976, Eubanks 1971, Kaufmann 1977, Kelliher et al.1980, Kelliher and Tauer 1980, Lopushinsky 1969, Lopushinsky and Klock 1974, Pallardy and Kozlowsky 1979b, Regher et al.1975, Untrsheutz et al.1974, Zavitkovski and Ferrel 1968).

Fewer studies are available in which growth was analyzed and long term adaptation to water deficency assessed. For example, effects upon osmotic adjustement and partitioning between the root system and above-ground parts can change the plant responses to the same conditions of stress (Morgan 1984, Hsiao 1973, Kramer 1983). Most of the studies including growth analysis have been conducted under controlled conditions, such as greenhouses or growth chambers (Jarvis and Jarvis 1963, Kelliher et al.1980, Kelliher and Tauer 1980, Markhart 1985, Pallardy and Kozlowsky 1979c). Many authors have emphasized that results obtained in controlled conditions may not be applicable to field situations. Field-grown plants seem to develop a greater resistance to water stress; e.g., Jordan and Ritchie (1971) reported that stomata of greenhouse-grown cotton closed at a leaf water potential of -16 bars while those of field-grown plants did not close even at -27 bars. In the case of poplars (_Populus_ _deltoides_) in controlled conditions, Regeher et al. (1975) found a sharp, 50% decline in stomatal conductance at -8 bars of leaf water potential and a reduction of transpiration to almost 0 at -10 to -11 bars. In field conditions, Federer (1977) reported stomatal closure occurred at -17 bars in _Populus_ _grandidentata_ and

Populus tremuloides while Tobiessen and Kana (1974) reported closure at -30 and -60 bars for the same two species respectively. Nelson and Ehlers (1984) compared the same two hybrid Populus clones used in this study (NC-5260, 'Tristis #1' and NC-5326, 'Eugenei') when grown in growth chamber, greenhouse and field conditions. They found significant differences among growth environments in terms of photosynthetic rates and stomatal resistances. An explanation for these differences could be the lack of sufficent time to adapt to water stress when it occurs very rapidly, such as in plants grown in pots where root system are restricted (Gardner et al.1985). Ontogenetical differences also should be considered; often field studies use mature trees while greenhouse and growth chamber experiments are mostly performed with seedlings or saplings. Parker (1956) stressed this point, distinguishing the establishment phase, characterized by shallow roots exposed to rapid and severe dryness, from the mature stage when deep roots alleviate the effects of a very severe drought.

When we consider the seedling stage, we also should take into account the type of watering regimes that the plants experience. In fact, in controlled experiments the conditions are maintained largely more constant than in natural environments; e.g., sometimes plants are grown at various levels of osmotic stress obtained by different concentrations of polyethylene glycol (for poplar studies: Edwards and Robertson 1976, Eubanks 1971). However, at the seedling stage when trees are becoming established, it is not only the absolute value of water deficiency that can be tolerated, but the kind of reaction to changing water levels that is more important. In a generally dry environment characterized by brief periods of good watering, a capability of rapid utilization of the available water should be an advantage. On the other hand, this response can be dangerous if the reaction during the favorable period implies loss of the resistance mechanisms to the deficency status which will occuragain. An example of this kind of problem can be the breaking of dormancy in spring as soon as good climatic conditions appear: this response can give a plant a competitive advantage in initiating nutrient uptake before other plants become active, but at the same time too much promptness can expose new tissues to cold damage in environments where late freezes occur.

To consider the problem of drought responses in plants, growth patterns must be analyzed in changing conditions. Hsiao (1973) and Kramer (1983) discuss the problem of growth adjustments during and after stress. However, very few experiments have investigated developmental reactions to interruption of stress (Acevedoet al.1971, Gates 1955, Green et al.1971, Kemper 1961) and none to my knowledge with tree species.

The present experiments was established to observe the early growth patterns and water relations of young rooted cuttings of <u>Populus</u> under conditions of water deficency and their reactions to interruption of stress. The two clones Eugenei and Tristis #1 were chosen because of their physiological and morphological diversity (Isebrands et al.1983, Michael 1984, Nelson and Ehlers 1984) and silvicultural interest (Dickmann and Stuart 1983, Hansen 1983). Tristis #1 (hybrid between*P.tristis* and *P.balsamifera*) is included in the section Tacamahaca and Eugenei (*P.*x*euramericana*, i.e. *P.deltoides*x*P.nigra*) is part of the section Aigeiros. Trees of the former section, known as balsam poplars, are considered adaptable to dry conditions and cold resistant and hybrids of the latter section, because of their fast growth rates, are the most important group of cultivated poplar clones (Dickmann and Stuart 1983).

MATERIALS AND METHODS

Unrooted hardwood cuttings of two poplar clones (_P_. _tristis_ x _P_. _balsamifera_ cv.Tristis #1 and _P_. x _euramericana_ cv. Eugenei) were soaked in water for 24 hours and then planted in pots (18 cm diameter, 20 cm height) filled with a sandy-loam soil. The plants were grown in a climatic chamber where temperature ranged from 28 °C during a 18 hour day to 15 °C at night. Incandescent lamps determined the total photoperiodic length, but maximum light intensity was obtained gradually by activating two groups of cool fluorescent tubes (they were turned on and off 1 and 2 hours after and before the beginning and the end of the artificial day). The plants were maintained at maximum light intensity for 14 hours per day (photon flux density of 300±30 Microeinsteins/m^2/sec). During the experiment the plants were fertilized three times with a 15-30-15 N-P-K commercial water soluble fertilizer. All the cuttings were well watered for 30 days, then they were grouped in homogeneous height groups and the experiment was arranged according to a block design. The total length of the experiment was 73 days.

Three treatments were applied and samples were collected three times during the experiment. The watering regimes were established in such a way that plants in treatment 1 were brought to field capacity once a day (300ml per pot), while during the stress period plants in treatments 2 and 3 received water to half of field capacity every three days. The experiment is schematically represented in Figure 1.

Soil water content was measured through the experiment by weight loss of samples dried in an oven at 75°C for four days. Soil organic matter content at the end of the experiment was estimated by the Walkley-Black method (Nelson and Sommers 1965). Height, leaf water potential, stomatal conductance, leaf area and biomass partitioning were measured. Sampling was based on five replications of each treatment per clone, but some extra plants were grown in the same conditions to frequently check some variables, such as water potential, without having to destructively sample the experimental units. Leaf water potential in bars was measured by a PMS pressure chamber (Boyer 1969). Stomatal conductance was estimated by measuring transpiration on the abaxial leaf surface with a Li-Cor LI-65 autoporometer equipped with a Kanemasu type sensor (Kanemasu et al.1969, Morrow and Slatyer 1971). Leaf area measurements were made by a Li-Cor LI-3000 area meter. For the biomass analysis plants were removed from the soil, the roots washed by hand to avoid fine root losses, all the parts dried in an oven at 75°C for four days, and then weighed.

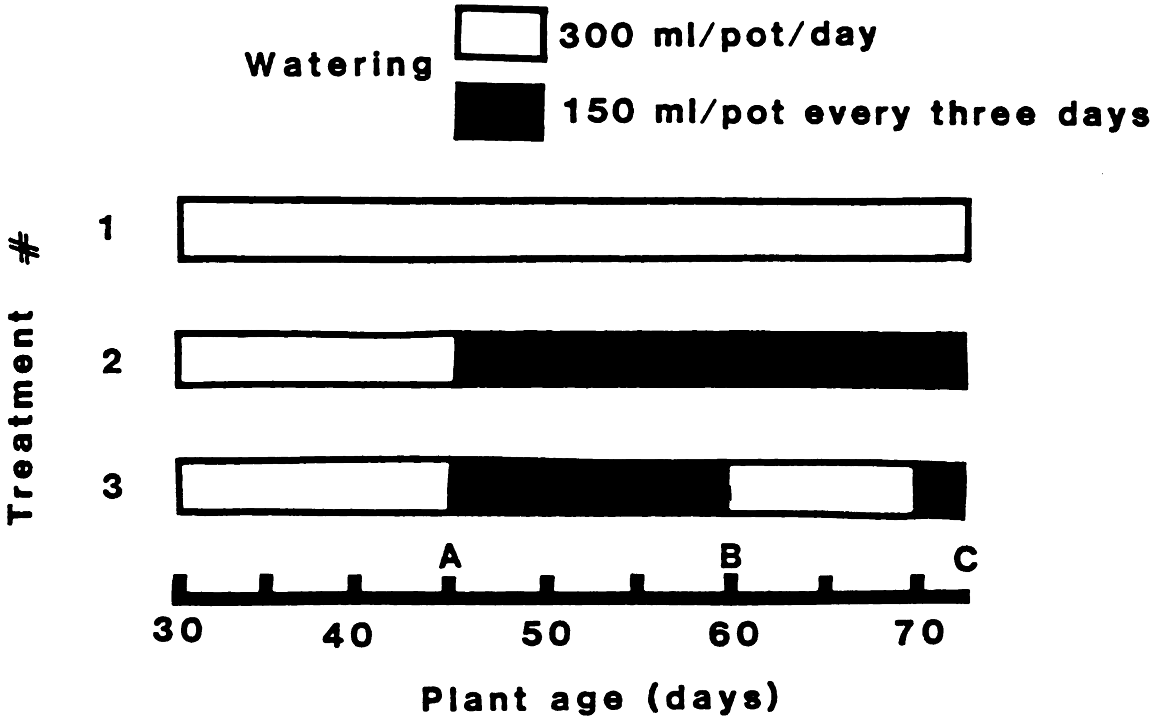

Figure 1. Schematic representation of the watering treatments in the experiment. Letters indicate sampling days.

RESULTS

Water relations - The stomatal conductance and leaf water potential of the cuttings before the stress treatment began (45 days old) are shown in Figure 2. No difference in water potential was found between the two clones, but Eugenei showed a slightly higher conductance than Tristis #1. Stomatal conductance did not vary significantly according to leaf position in both clones. Figure 3 depicts the soil water content during a watering cycle once the stress treatment began. It is clear that the plants under stress were exposed not only to a lower level of available moisture, but also to more variable conditions. This watering procedure was preferred to a more homogeneous one, i.e., watering every day in the deficiency treatment, but with a smaller amount of water, in order to reflect more natural conditions, where changing stress levels are the norm.

The first reduction in water supply caused a significant reduction of stomatal conductance in both clones (Figure 4a). The reduced transpiration somewhat balanced the lower water level in the soil, so leaf water water potential decreased only slightly relative to the control (Figure 4b).

The water status of the plants during this experiment was not constant because of the changing of soil water

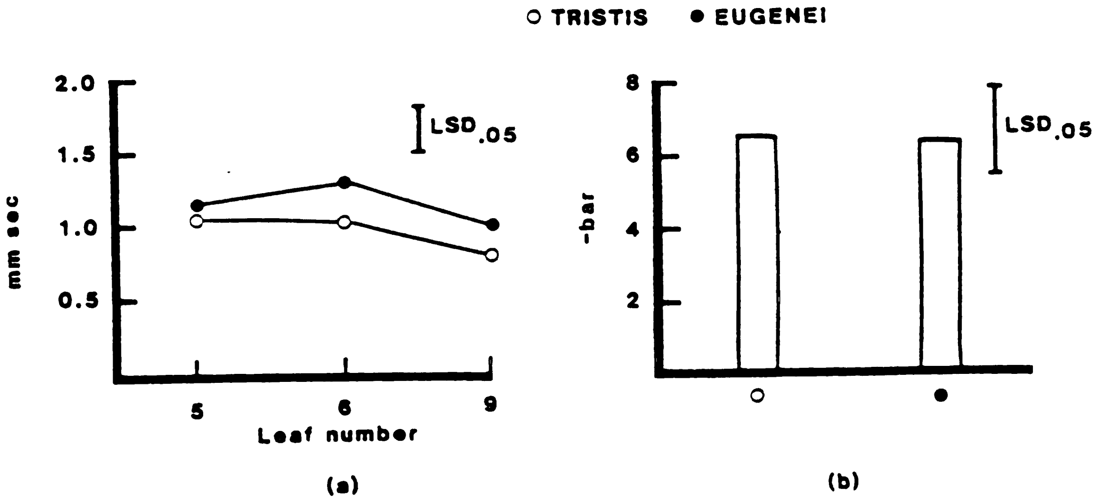

Figure 2. Water relations of two *Populus* clones after 45 days of full watering.

(a) - Stomatal conductance according to leaf position (1=apical leaf). Each point represents an average of 4 samples.

(b) - Leaf water potential measured on the 8th leaf. Values are averages of ten replications.

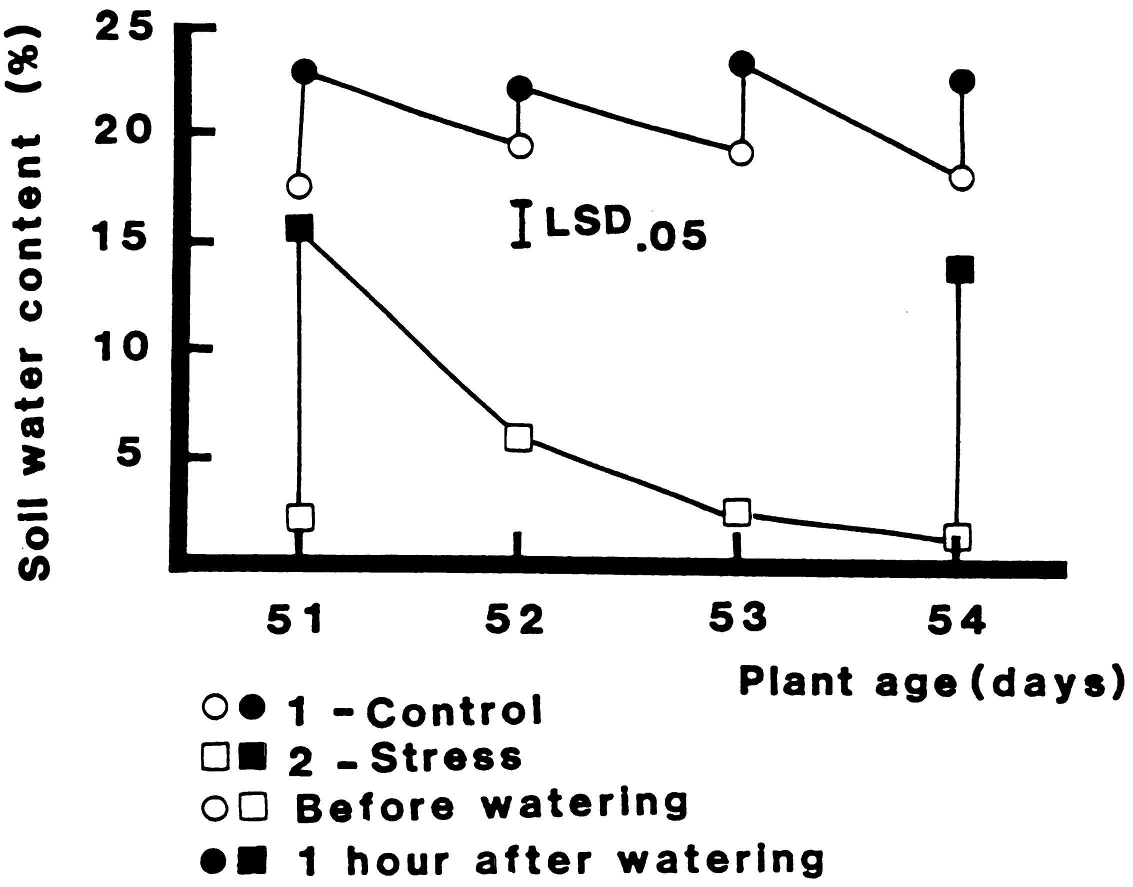

Figure 3. Effect of watering treatments on gravimetric soil water content (g water/g dry soil). Each point represents an average of 4 samples.

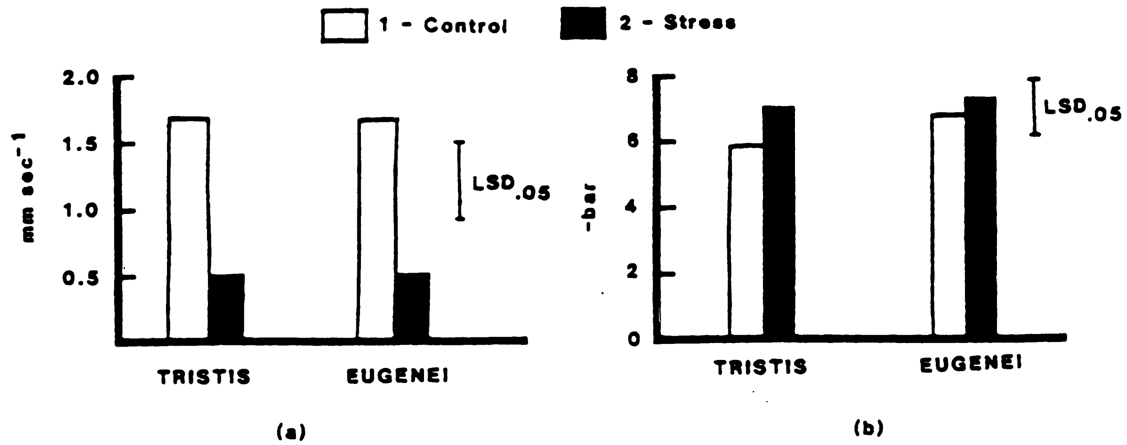

Figure 4. Effect of water treatments on stomatal conductance (a) and leaf water potential (b) in two *Populus* clones. Values are averages of five replications. Measurements made on the 8th leaf 1 hour after watering. Plants were 54 days old.

content (Figure 3). Figure 5 shows stomatal conductance and leaf water potential before and after watering in the two clones. These data were based on only two replications in order to limit destructive sampling before the end of the experiment, consequently their statistical significance was limited, but they still show some interesting points.

The stressed plants of both clones reacted to watering in a similar way. After watering stomatal conductance increased and the higher leaf water potentials indicated that the plants improved their water status. The maintainance of a better water status and, at the same time, higher transpiration indicates a better adaptation of Tristis #1 to the stressed conditions.

The two clones differed in the reaction to watering of the plants under control conditions. Both transpiration and leaf water potential of Tristis #1 did not seem to be affected by watering, whereas Eugenei stomatal conductance increased after watering, causing a relative reduction of leaf water potential.

In treatment 3 the plants were watered again like the control after a period of stress, and then stressed once more at the end of the experiment (Figure 1). During the interruption of stress both clones recovered and their water status was not different from the control. When the new stress occurred, Eugenei had completely lost resistance to water deficiency and the water potential of the newly formed leaves decreased to the wilting point, whereas Tristis #1

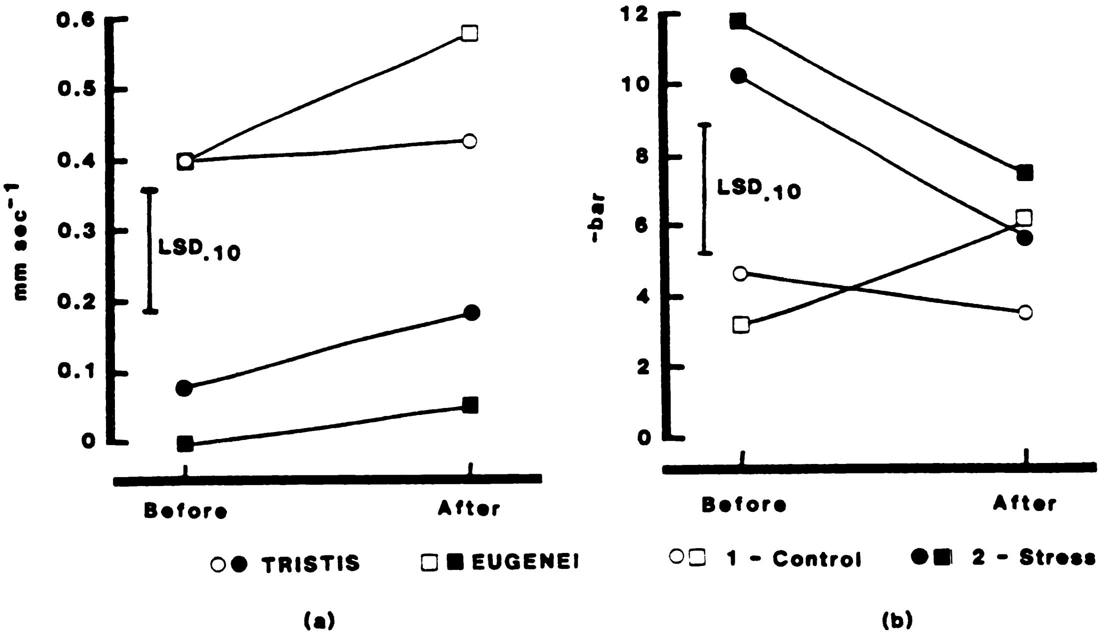

Figure 5. Stomatal conductance (a) and leaf water potential (b) before and 1 hour after watering according to water treatment in two <u>Populus</u> clones . Each point is an average of two values. Measurements made on the 7h and 8th leaves. Plants were 68 days old.

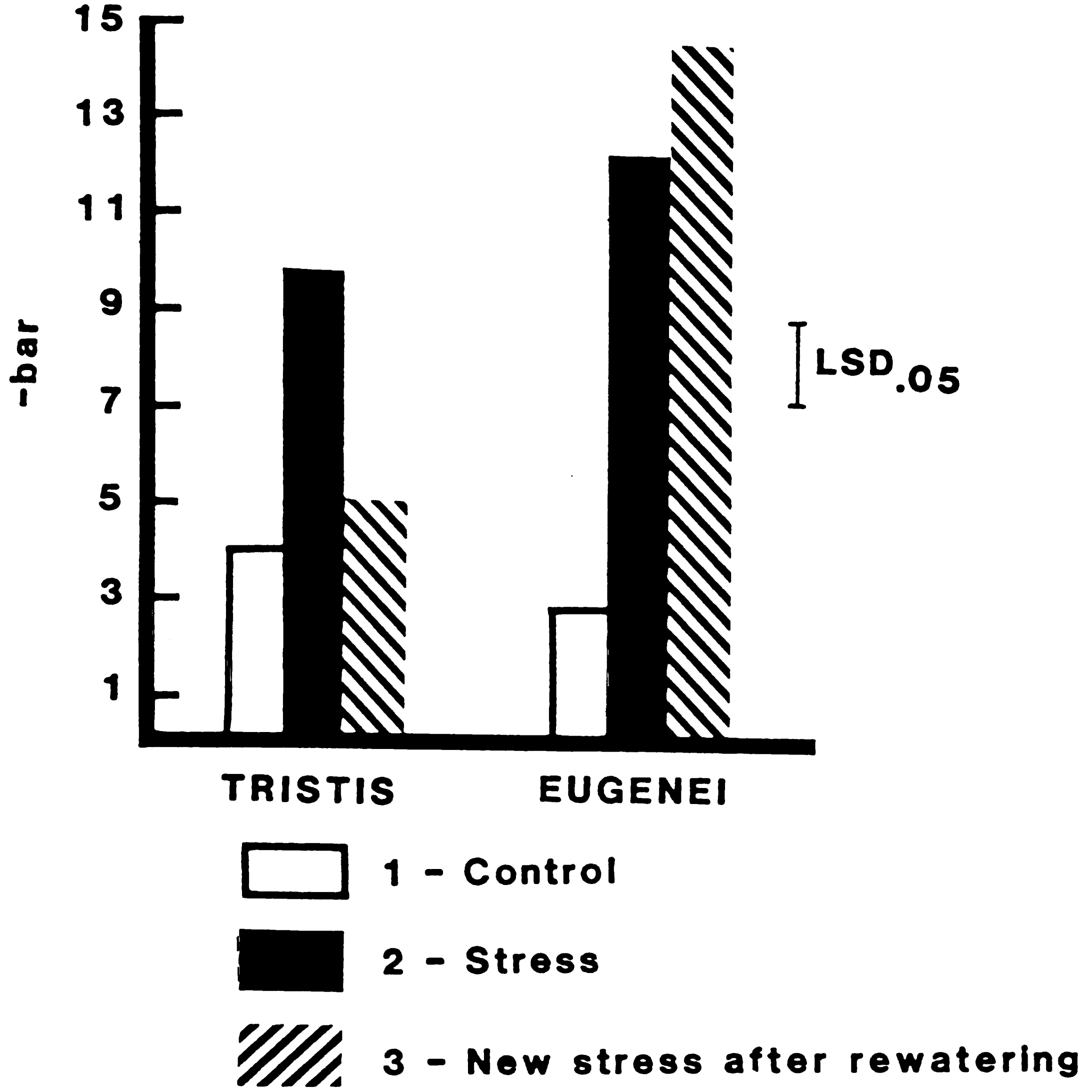

Figure 6. Leaf water potential in two <u>Populus</u> clones according to watering regimes. Each point is the average of five replications. Measurements made before watering on the 8th leaf. Plants were 73 days old.

maintained a high potential not significantly different from the control (Figure 6).

Under optimal conditions treatment 1), Eugenei had a slightly higher leaf water potential (-3 bars) than Tristis #1 (-4 bars), otherwise, under continuous stress, Tristis #1 maintained a better water status than Eugenei (-10 versus -12 bars), (cf. Figure 5). The difference between the two clones in the third treatment was quite dramatic. In Eugenei the low leaf water potential, about -14 bars, produced wilted plants, whereas in Tristis #1 a potential of -5 bars can be considered still in the range recorded for plants under full watering (treatment 1).

<u>Growth</u> <u>and</u> <u>development</u> - The watering regimes influenced the development of the seedlings in a very significant way. Height growth patterns in the two clones according to the different treatments is shown in Figure 7. The treatment effect is evident, but differences between clones were found only in treatment 3. In fact, when stress was interrupted, Eugenei showed a stronger new flush of growth than Tristis #1. This capability of recovery also is more evident when plant weight is considered (Figure 8). The recovery after stress interruption was much greater in Eugenei than Tristis #1, but the two clones did not differ in weight under full watering or under continuous stress (treatments 1 and 2).

This capability for recovery in Eugenei did not correspond to a balanced growth in terms of biomass partitioning. Figure 9 shows the weight increase of leaves

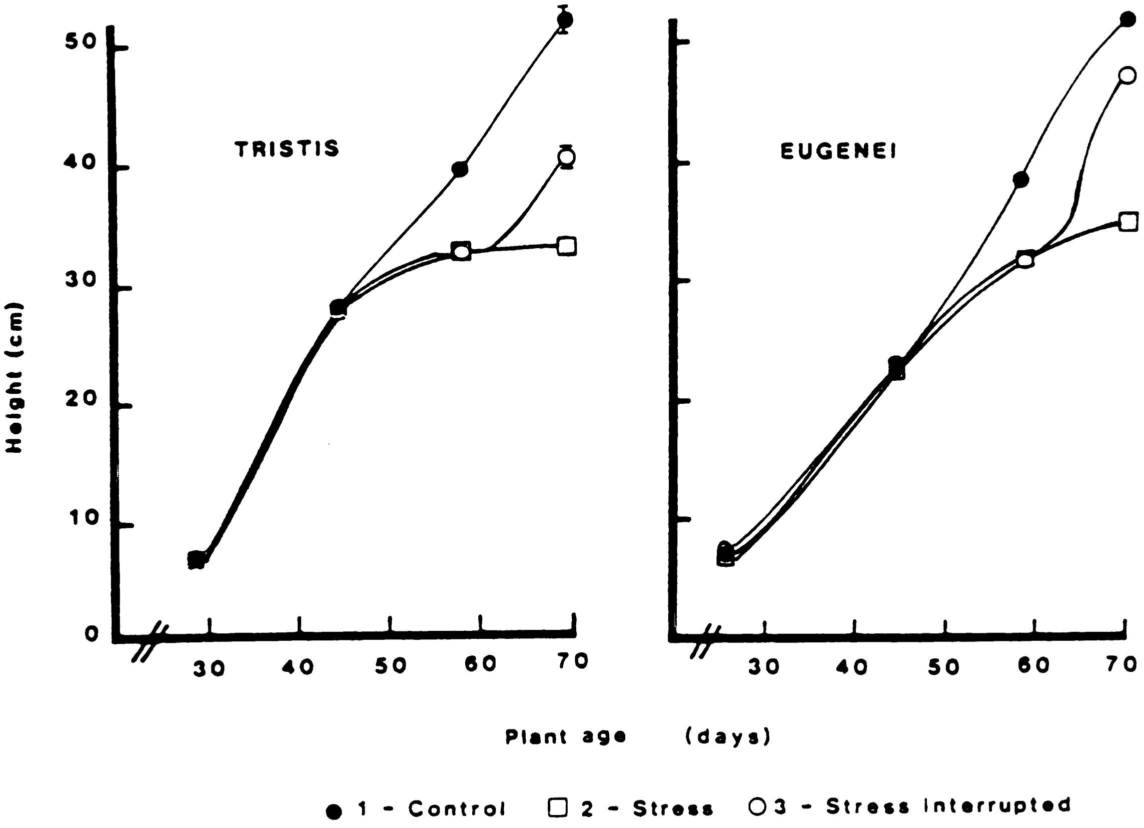

Figure 7. Shoot height growth of two *Populus* clones according to three watering regimes. Values are the average of five replications. Bars denote standard error of the means; where absent bars fall within symbols.

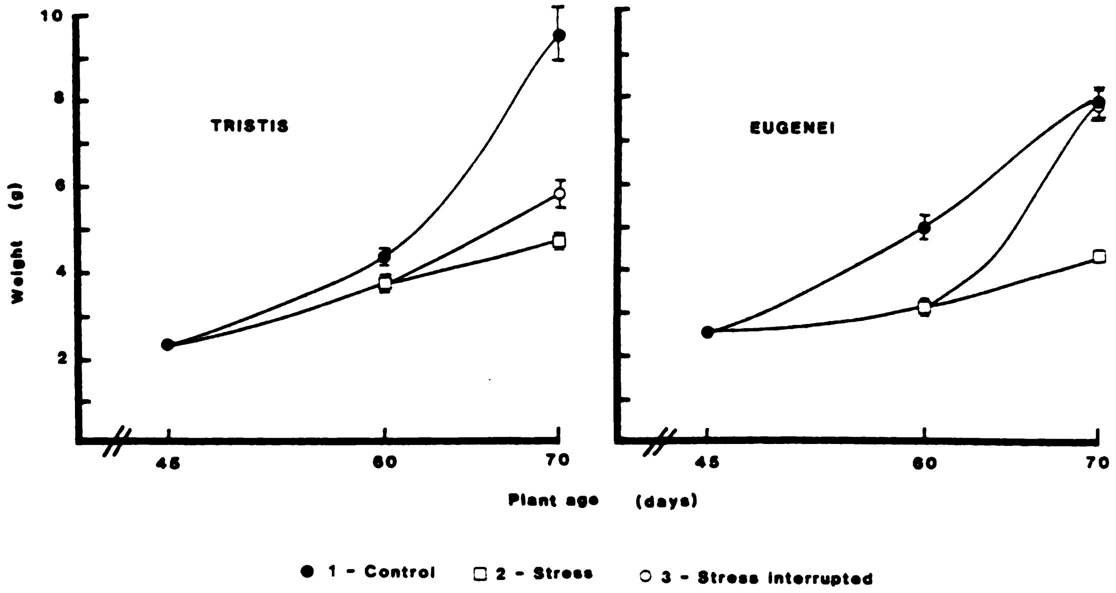

Figure 8. Dry weight growth of two *Populus* clones according to three watering regimes. Values are the average of five replications. Bars denote standard error of the means; where absent bars fall within symbols.

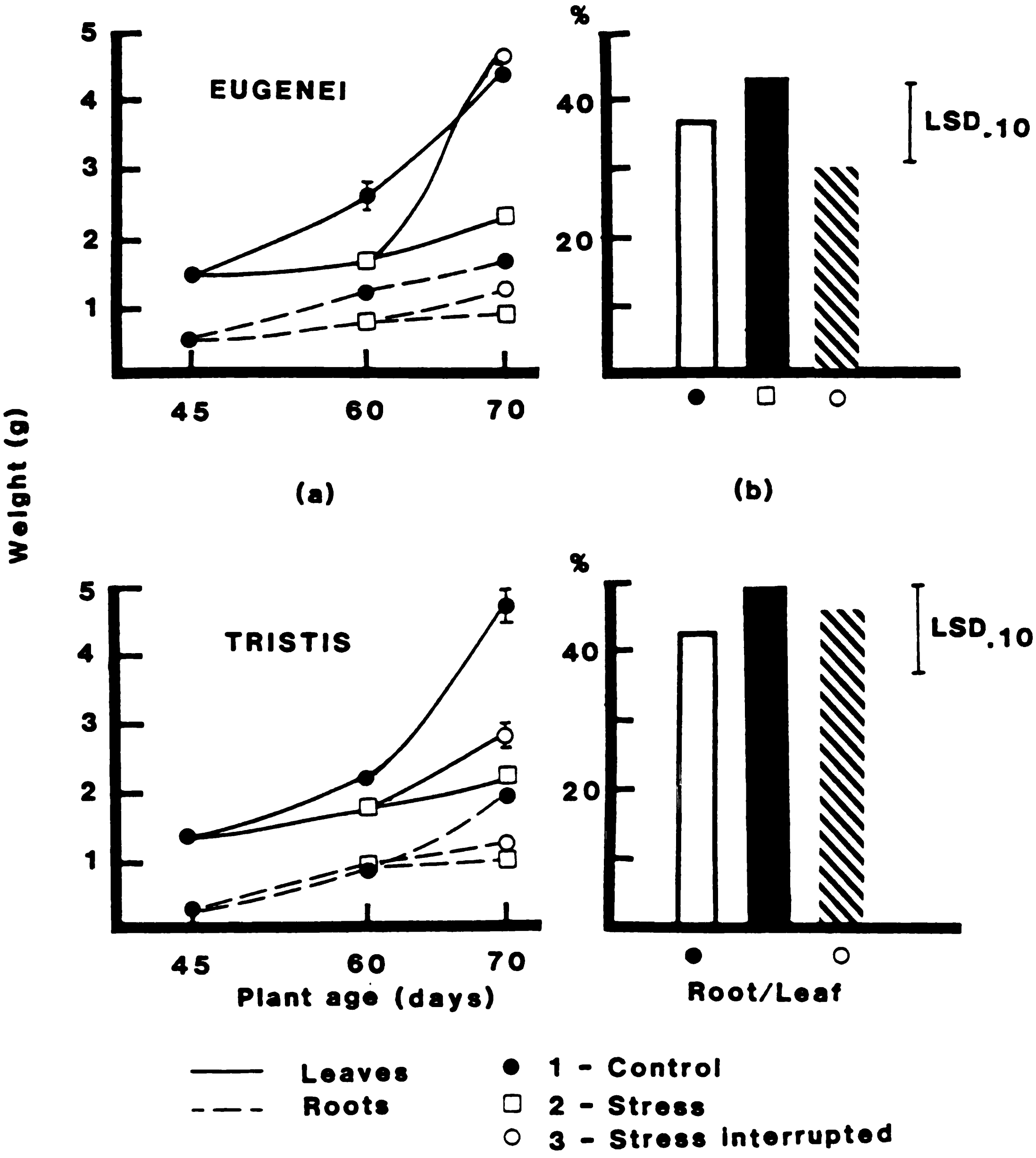

Figure 9. Leaf and root weight growth (a) and root/leaf weight ratios (b) of two Populus clones according to three watering regimes. Values are the average of five replications. In (a) bars denote standard error of the mean; where absent bars fall within symbols.

and roots and relative root/leaf ratios at the end of the experiment. Compared to the control, in both clones the stressed plants increased their relative allocation of biomass to the root system, as shown by the larger root/leaf ratios (treatment 2 versus 1). Tristis #1 generally showed a tendency toward a larger root/leaf ratio than Eugenei in all the treatments, but the differences were not significant, except for treatment 3 where stress was interrupted. It is clear that the new flush of growth after interruption of stress in Eugenei mainly was allocated above-ground. The increased growth of the shoot was not balanced by an equivalent reaction at the root level and this caused the final root/leaf ratio to be very low in this third treatment. Conversely, the interruption of stress in Tristis #1 did not cause an unbalanced growth and these plants maintained a relatively large root/leaf ratio. This result partially explains the very different sensitivity in terms of water status shown by the two clones when stressed a second time (Figure 6).

Figure 10 reports measurements of soil organic matter content at the end of the experiment. The higher values found for the soil in pots where plants were under water deficiency (treatment 2) are indicative of greater root-turnover and/or exudation in stressed conditions.

Tables 1, 2 and 3 summarizes the comparison between the clones relatively to growth parameters.

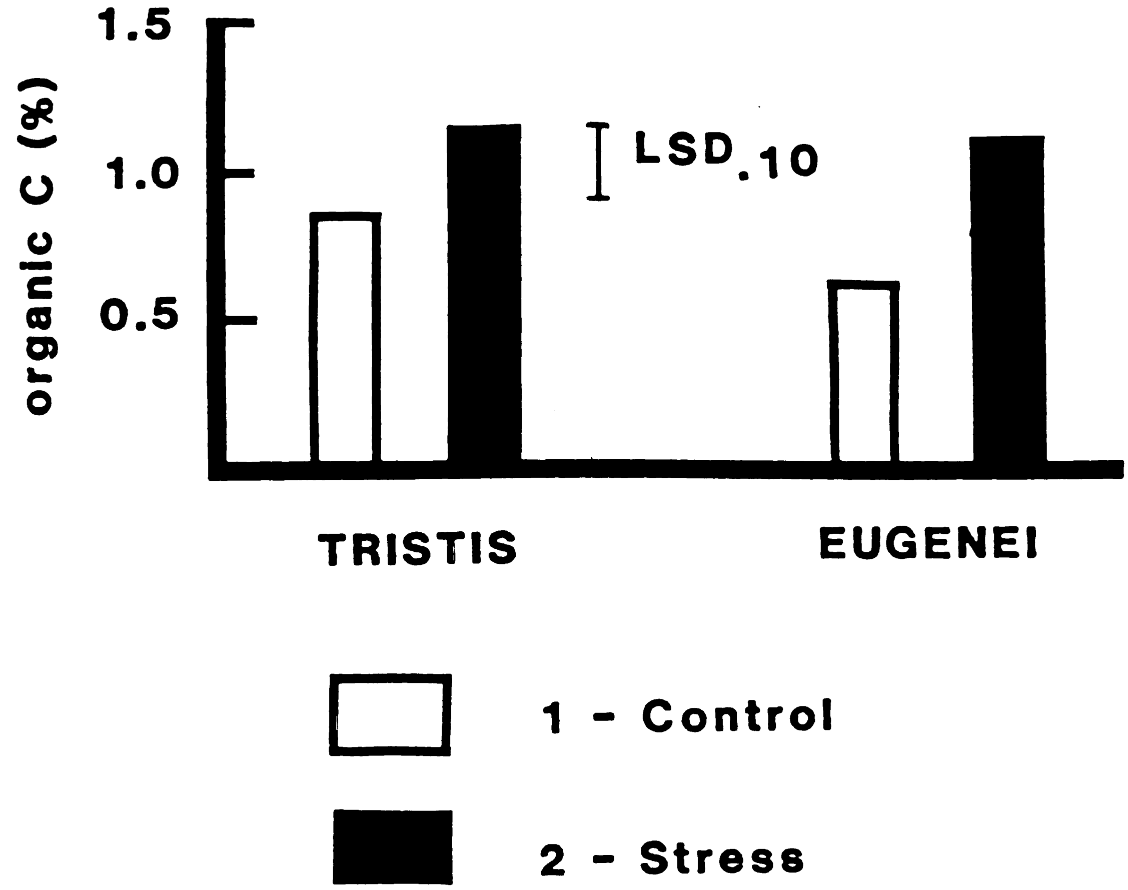

Figure 10. Organic carbon content of the soil according to watering treatment and clone. Each value represents an average of three replications.

Table 1. Comparison of growth parameters in two *Populus* clones maintained under full watering for 73 days. Values are averages of five replications. Asterisks indicate significance level of the difference of the means (* .05 - ** .01).

	EUGENEI	TRISTIS #1	
Height (cm)	52.6	52.4	n.s.
Dry weight (g)			
Total	7.88	9.46	n.s.
Leaves	4.35	4.85	n.s.
Stem	1.91	2.67	**
Roots	1.62	2.09	*
Leaf area (cm^2)	804	788	n.s.
Root/shoot ratio	0.26	0.28	n.s.
Root/Leaf ratio	0.37	0.43	n.s.

Table 2. Comparison of growth parameters in two *Populus* clones maintained under full watering for 45 days and then under stress for 28 days. Values are averages of five replications.

	EUGENEI	TRISTIS	
Height (cm)	35	33.2	n.s.
Dry weight			
Total	4.34	4.64	n.s.
Leaves	2.31	2.21	n.s.
Stem	1.04	1.35	n.s.
Roots	0.99	1.08	n.s.
Leaf area (cm^2)	414	391	n.s.
Root/Shoot ratio	0.29	0.30	n.s.
Root/Leaf ratio	0.43	0.49	n.s.

Table 3. Comparison of growth parameters in two *Populus* clones maintained under full watering for 45 days, under stress for 15 days and then under full watering again for other 10 days. Values are averages of five replications. Asterisks indicate significance level of the difference of the means (* .10 - ** .05 - *** .01).

	EUGENEI	TRISTIS #1	
Height (cm)	47.4	40.2	**
Dry weight (g)			
Total	7.86	5.83	**
Leaves	4.56	2.89	***
Stem	1.91	1.57	n.s.
Roots	1.39	1.37	n.s.
Leaf area (cm^2)	855	515	***
Root/Shoot ratio	0.21	0.30	n.s.
Root/Leaf ratio	0.30	0.46	*

Leaf area - Total leaf area growth (Figure 11) was strongly affected by the watering treatment. Eugenei generally showed a tendency toward larger leaf area than Tristis #1, but the difference between the two clones was not significant, except for treatment 3, where stress was interrupted. The rate of leaf expansion and the formation of new leaves in stressed plants were greatly reduced and, at the end of the experiment, these plants had a leaf surface of less than 50% of the control in both clones. Leaf abscission occurred only in Eugenei in treatment 2, the shedding regarding the basal part of the abscised stems. Table 4 shows the amount of abscised leaf area in the stress treatment for the sample plants.

The reaction to rewatering, already shown as height and weight recovery, was really dramatic in terms of leaf expansion in Eugenei. In fact, in this clone the plants in treatment 3 gained a larger total leaf area than the control itslef. This difference was not significant, but at least is is an indication of the large allocation of resources to the leaves that occurred in this clone once stress was interrupted.

The distribution of leaf area according to position on the stem is shown in Figure 12. Tristis #1 presents a more homogeneous distribution along the stem and in this clone the difference among treatments consisted mainly in diversity in the total amount of leaf area. Very differently, Eugenei showed a more irregular distribution and an amazing concentration of area in few large leaves in

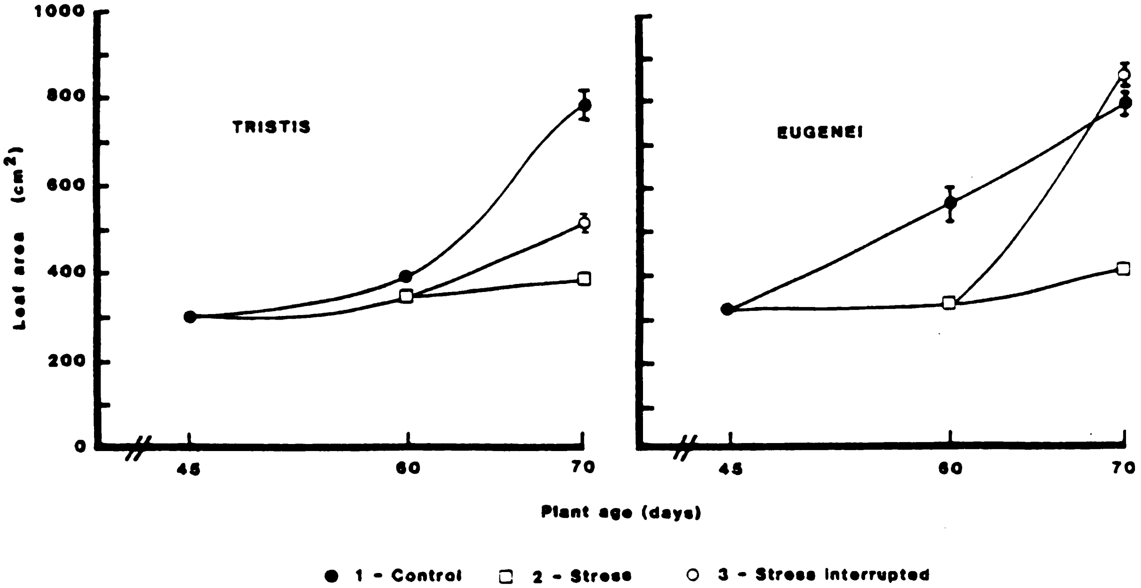

Figure 11. Leaf area growth of two <u>Populus</u> clones according to three watering regimes. Values are the average of five replications. Bars denote standard error of the mean; where absent bars fall within symbols.

Table 4. Total leaf area and area of abscised leaves in two *Populus* clones maintained under full watering for 45 days and then under stress for 28 days. Values are averages of five replications. Different letters in each column indicate significant difference between the clones(.05).

	Total leaf area (cm2)	Area of abscised leaves (cm2)	% of total produced leaf area that shedded
EUGENEI	413 a	50 a	10.6 a
TRISTIS	390 a	0 b	0 b

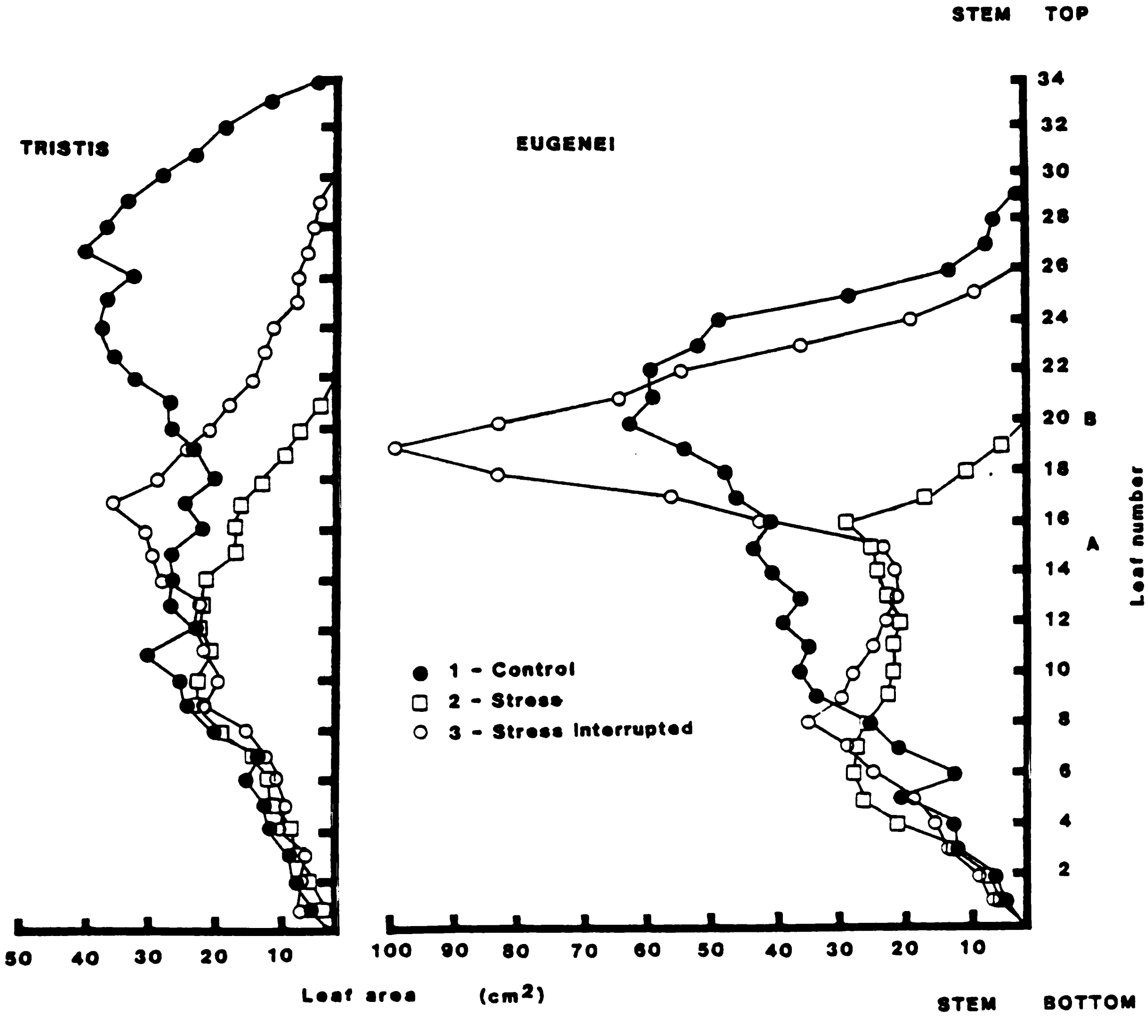

Figure 12. Leaf area distribution on the stem in two Populus clones according to watering regimes. Values are the average of two measurements from the plants with higher and lower total leaf area in each treatment. Plant age was 73 days. Letters indicate number of leaves present on the seedlings: (A) when stress began in treatment 2 and 3, and (B) when stress was interrupted in treatment 3.

the latter stages of treatment 3. These large leaves were also very fleshy and as a consequence were more sensitive to further stress. When the first period of stress began the plants had an average of 15 leaves, but the stress reduced the rate of expansion of the immature leaves (last 5 - 6 formed leaves, number 9 to 15 on the stem) and caused a reduction of formation of new leaves (final numer about 31 for treatment 1 compared to 20 for treatment 2 in both clones). When the stressed plants were rewatered like the control, leaves 16 to 21 in Eugenei enlarged in an impressive way. These leaves were formed under stress, but expanded more than the control leaves when water became available. Whereas flexibility in the development of the last six formed leaves was shown, leaves already mature did not change size when watering changed (see leaf numbers from about 10 to 15 in treatment 3 versus 2).

DISCUSSION

Populus clones have been reported to show differences in early patterns of shoot growth, root elongation and leaf area growth (Pallardy and Kozlowsky 1979, Isebrand et al. 1983). The plants of the two clones used in this study did not show significant differences in growth parameters, under full watering and continuous stress (treatments 1 and 2). However, Tristis #1 generally had a higher allocation of dry weight to the stem and to the root system than Eugenei and showed a better maintainance of water balance, whereas Eugenei showed a tendency to higher leaf area production and lower root/shoot and root/leaf weight ratios (Tables 1 and 2). These results are in agreement with Isebrands et al. (1983), who reported the same two clones to have similar early growth rate, but differences between them appeared later in the season. The same authors reported that Eugenei maintained high growth rate and continued leaf production for a longer period than Tristis #1, whereas Tristis #1 continued root growth after above-ground growth stopped, gaining a root/shoot ratio about three times greater than that of Eugenei.

In the present experiment the watering treatments had a significant effect on the growth and water relations of both clones. Under stress height, weight, and leaf area growth were greatly affected.

Growth at the whole plant level is a complex phenomenum and depends on the balance between several plant processes and characteristics, mainly available leaf area, photosynthesis and respiration rates (Kramer and Kozlowski 1979), losses by root turn-over and exudation (Smucker 1984). Under conditions of water deficiency the growth rates decrease because of the effect of the reduced water potential on these physiological processes (Hsiao 1973).

Total leaf area is significantly related to water conditions at both the single plant and stand levels (Grier and Running 1977). In conditions of water deficiency leaf growth is one of the first physiological processes to be affected. Boyer (1970a - 1968) found that, as leaf water potential decreased, leaf enlargement was inhibited very severely before photosynthesis and respiration were affected. In poplars Kelliher et al. (1980) and Kelliher and Tauer (1980) reported a large reduction of leaf area expansion and increased leaf shedding in moderately and severely stressed plants. This work shows similar results, but leaf abscission was found only in Eugenei in treatment 2. It is interesting that in the stress treatment the final total leaf area did not differ between the two clones, but it was obtained by two different strategies, Tristis #1 being more conservative than Eugenei; in fact, as shown in Table 4, Eugenei had a smaller reduction of leaf area production and, in order to maintain the water balance, shed the "surplus" leaves in the lower crown.

Reduction in available photosynthetic surface is probably the most important factor affecting the overall growth rate (Watson 1952), however, variation in net photosynthetic rates per unit area have been reported in water stressed plants (Boyer 1970a, 1970b, 1971 in corn, soybean and sunflower - Regeher et al. 1975 in poplar - Zavitokovski and Ferrel 1968 in Douglas fir - Sung and Krieg 1979 in sorghum and cotton).

A comparison between the photosynthetic activity of these two clones has been extensively made by Michael (1984), Isebrands et al. (1983), and Nelson and Ehlers (1984), but not under water stress. In the present experiment photosynthetic rate was not measured.

Smucker (1984) discussed the problem of carbon losses from plant root systems by exudation and root turn-over, and how these losses are enhanced in stress environments. In this experiment the root systems of the stressed plants (treatment 2) were darker in colour than the control (treatment 1) and this with the results reported in Table 4 are indicative of increased root decomposition and exudation under stress.

The two clones reacted very differently in terms of recovery after stress was interrupted. The greater resumption of growth in Eugenei compared to Tristis #1 (Figure 7 and 8) is especially significant. The flexibility of development showed (Figure 12) by the last 5 - 6 leaves, formed under stress, but yet able to expand when water was available again, reflects the leaf developmental pattern in poplar. In this species full anatomical and physiological maturity has been found to occur at a leaf plastocron index of 6 in young plants (Pieters 1974, Isebrand and Larson 1973).

The great leaf enlargement shown by Eugenei after stress interruption (Figure 11 and 12) resembles that observed by Bassman and Dickmann (1982) on artificially defoliated poplar cuttings, where new leaves produced after defoliation were larger than new leaves on control plants.

The great diversity of sensitivity of the two clones to a new stress after a rewatering period (Eugenei wilted while Tristis #1 maintained a good water balance) compared to the absence of significant differences under continuous stress conditions (Figure 6) shows the value of the present experimental approach.

Isebrands et al. (1983) underline the importance of the integration of physiological methods with growth analysis. The results of this study, such as the unbalanced growth of Eugenei after stress interruption, or the generally larger root/leaf ratios in Tristis #1, and their consequences on the capability of maintainance of a sufficient water status, clearly support their statement.

As already said in the introduction, the two clones used in the experiment are representative of two main sections of the genus <u>Populus</u> Tacamahaca for Tristis #1 and Aigeiros in the case of Eugenei. Aigeiros hybrids have largely been used in forest plantations, especially in North

America, whereas Tacanahaca hybrids have only recently been used to any extent, mainly in Europe (Dickmann and Stuart 1983). Tristis #1 has been used in short rotation management trials (Ek and Dawson 1976).

The results of this study suggest that for application in silvicultural conditions, where a relative control of the environment is possible (e.g. irrigation), obviously a clone achieving a higher growth rate and higher above-ground allocation of biomass, such a Eugenei, is preferred. But in the case of plantations in marginal zones, where changing moisture conditions are likely to occur, a more conservative strategy like shown by Tristis #1 is to be preferred because of the risk reduction.

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