SALT TOLERANCE in SOME TROPICAL TREE SPECIES

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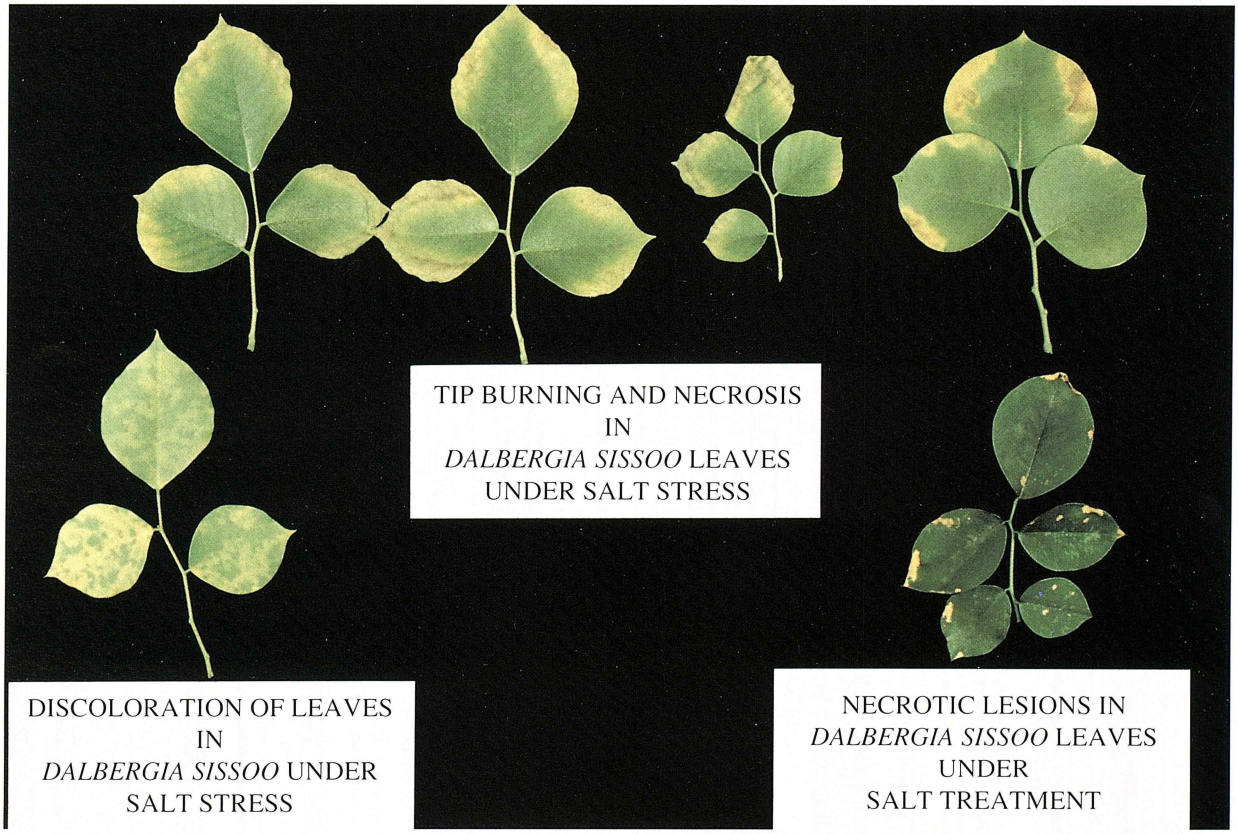

Leaf injuries in *Dalbergia sissoo* under salt treatment (S1) after 28 days.

Symptômes foliaires consécutifs à un traitement salin (S1) après 28 jours.

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ABSTRACT

SALT TOLERANCE IN SOME TROPICAL TREE SPECIES

Fast growing nitrogen fixing tree species are becoming increasingly important for biomass production on degraded salt affected land. Understanding of the physiology of salinity tolerance is important for the selection of tree species to withstand saline conditions. Studies on three tropical leguminous trees found that *Acacia nilotica* and *Prosopis juliflora,* are more salt tolerant than *Dalbergia sissoo.* Associated with this is the exclusion of Na^+ ions from the plant, and storage in the roots and stem and at lower levels, in the leaves. As a result *Acacia* the most tolerant species maintains a better K/Na ionic balance in its leaves.

Key words : SALT TOLERANCE ; SODIUM ; ION EXCHANGE CAPACITY ; SELECTION CRITERIA.

RÉSUMÉ

TOLÉRANCE A LA SALINITÉ DE QUELQUES ESPÈCES D'ARBRES TROPICAUX

Les espèces à croissance rapide, fixatrices d'azote, prennent de plus en plus d'importance pour la production de la biomasse sur les sols salés dégradés. Comprendre la physiologie de la tolérance à la salinité est important pour le choix des espèces ligneuses capables de supporter la salinité. Des études entreprises sur trois légumineuses tropicales ont montré que *Acacia nilotica* et *Prosopis juliflora* sont plus tolérantes à la salinité que *Dalbergia sissoo.* De plus, on note le rejet par la plante des ions de Na^+ et leur stockage dans les racines et la tige et, à un niveau moins élevé, dans les feuilles. On en conclut qu'*Acacia*, qui est l'espèce la plus tolérante, maintient un meilleur équilibre en K/Na dans les feuilles.

Mots-clés : TOLÉRANCE AU SEL ; SODIUM ; CAPACITÉ D'ÉCHANGE IONIQUE ; CRITERE DE SÉLECTION.

RESUMEN

TOLERANCIA A LA SALINIDAD DE ALGUNAS ESPECIES DE ARBOLES TROPICALES

Las especies de crecimiento rápido, que presentan la particularidad de fijar el nitrógeno, toman cada día mayor importancia por lo que respecta a la producción de biomasa en los suelos salados degradados. Es de suma importancia comprender la fisiología de la tolerancia a la salinidad para la selección de las especies madereras capaces de soportar cierto grado de salinidad. Diversos estudios emprendidos mediante tres leguminosas tropicales, han permitido demostrar que *Acacia nilotica* y *Prosopis juliflora* presentan mayor tolerancia a la salinidad que *Dalbergia sissoo.* Además, se pone de manifiesto el rechazo por la planta de los iones de sodio y su acumulación en las raíces y el tallo y, a un nivel menos elevado, en las hojas. Se llega a la conclusión por la cual *Acacia,* que corresponde a la especie de major tolerancia a la sal, mantiene el mejor equilibrio en K/Na en las hojas.

Términos clave : TOLERANCIA A LA SAL ; SODIO ; CAPACIDAD DE INTERCAMBIO IONICO ; CRITERIO DE SELECCION.

Salinity affects about 340 million hectares of land in the world, of which nearly one third are in the south and southeast Asia. Plants in saline areas suffer varying degrees of physiological damage. Salinity affects plants via : Water relations ; Nutrition ; Carbohydrate production and Use. These effects differ from species to species and are modified by other environmental conditions. The effects on nutrition may be caused directly by excessive uptake and accumulation of a toxic ion in the tissue or by an imbalance in the uptake and metabolism of other ions. GREENWAY and MUNNS (1980) have reviewed the effects of excess Na^+ and Cl^- ions on plant growth and metabolism. Research on plant physiological response to salinity in crops has been reviewed by TURNER and PASSIOURA (1986). YADAV (1980) and EL-LAKANY (1986) have made observations on the growth and tolerance of important tree species. It is important to understand the physiological effects of salinity and plant tolerance mechanisms to select and possibly breed better salt tolerant genotypes. This paper deals with the salt tolerance and the ionic regulation shown by the seedlings of *Acacia nilotica, Prosopis juliflora* and *Dalbergia sissoo,* three important leguminous tree species in India.

MATERIAL AND METHODS

Three salt treatments and a control (C) were imposed on 15 cm tall plants growing in sterile sand contained in plastic pots. A mixture of ions present in saline soils (RICHARDS, 1954) was used to impose three salinity levels in the seedlings. The lowest salt treatment (S1) contained 26.4 mM sodium (Na^+), 22.4 mM chloride (Cl^-), 6.1 mM sulphate (SO_4^-), 3.0 mM calcium (Ca^{++}), 2.0 mM magnesium (Mg^{++}) and 2.0 mM bicarbonate (HCO_3^-) per litre. The S2 salt treatment contained twice and S3 four times these concentrations. Initially the salt solution was applied in equal increments every two days till the treatment salinity was reached, thereafter the pots were irrigated daily with the appropriate salt solution until harvested at 28 days. A randomised block design (3 species × 4 treatments × 6 replicates) was used. During and at the end of the experiment measurements were made of fresh and dry weights. Concentrations of Na^+, K^+, Mg^{++}, Ca^{++} and Cl^- in the leaves, stems and roots were determined in an acid digest extract.

RESULTS AND DISCUSSION

The total dry weight for all three species was reduced by increasing salinity (fig. 1, p. 64). The S1 treatment caused a reduction of about 20 % in all species with *Dalbergia* showing the least response. Changes in shoot and root dry weights (fig. 2 and 3, p. 64) varied between species, *Acacia* showed a small reduction of 5 % in root dry weight but 21 % reduction in the shoot. In *Prosopis* the root dry weight increased by a massive 50 % while the shoot decreased by 32 %. *Dalbergia* in contrast showed the greatest effect on root dry weight (20 % reduction) and least effect on shoot with a 10 % reduction. At salinity S2 total dry weight was reduced by 25 % in *Acacia* and about 40 % for *Prosopis* and *Dalbergia.* In terms of root and shoot the pattern was similar to S1 but *Acacia* and *Prosopis* both had slightly greater root dry weights (10 and 4 % respectively) than control plants. Shoot dry weights decrease, with *Acacia* showing the least 35 % reduction compared to 50 % and 43 % for *Prosopis* and *Dalbergia* respectively. At the highest salinity S3 *Dalbergia* was severely affected with a reduction of 71 % in total dry weight made up by a reduction of 54 % in root and 82 % in shoot dry weight. *Acacia* and *Prosopis* were less affected showing total dry weight reductions of 44 % and 52 % respectively. Both maintained high root dry weights with reductions of only 10 % in *Prosopis* and 22 % in *Acacia.*

From this it appears that *Acacia* and *Prosopis* are relatively well adapted to the salinities imposed. Part of this adaptation may be seen as the maintenance and actual increase in root biomass as a response to salinity. In contrast the response of *Dalbergia* to salinity level S1 was a greater reduction of root biomass than shoot biomass, root biomass thereafter showed a steady decline. This tolerance ranking is supported by the indices of tolerance, the ratio of relative growth rate of a treatment to that of the control and allows comparison of the responses of different species that have different growth rates under unstressed conditions (SHAH *et al.,* 1990). *Acacia* and *Prosopis* show similar values dropping to 0.8 in treatment S3, while *Dalbergia* steadily falls reaching values of 0.75 at S2 and 0.35 at S3 (fig. 4, p. 64).

The tissue concentration of Mg^{++}, Ca^{++} and Cl^- (data not shown) had little variation between treatments with no clear trends. Sodium showed significant differences between treatments, species and tissues (see table p. 65). In the control plants *Dalbergia* showed the lowest concentrations − only 7.6 and 9.8 micrograms/gm dry weight in stem and roots respectively. In contrast, *Acacia* showed high concentration in roots (31.5 micrograms/gm) and lower levels in leaves and stem. In *Prosopis* similar concentrations are seen in the stem and roots and roughly half the concentration in the leaves. In all three species the concentration of Na^+ in the leaves is similar 11.9 to 17.4 micrograms/gm. *Acacia* in S1 and S2 treatments show only small increases in stem and leaf concentration while the root concentration increases three fold. At the highest salinity, the leaf concentration of Na^+ is remarkably low only 2.9 times that of the control plants, while the stem and roots show increases of 8.1 and 7.1 times respectively. In terms of concentration there is a gradient of increase from leaves to stem to roots. In *Prosopis* a different pattern emerges in treatments S1 and S2 where the leaves and stem show an increase of 2 to 3 times that of control Na^+, while the roots show a 2.2 fold increase in S1 and 3.8 times in S2. In the highest salt treatment S3 the leaves show a 11.9 times increase whereas stem and root show 7.3 and 8.1

fold increase respectively. *Dalbergia* tissues show (except S1 leaves) similar patterns of Na^+ concentration in S1 and S2, the concentration gradient decreasing from stem and roots to leaves – the reverse of the pattern seen in the control plants. However in S3 plants this is again reversed with Na^+ concentration increasing from roots to stem to leaves, the latter having a massive 17.6 times increase to 305.4 micrograms/gm.

Though the concentration of Na^+ *per se* has very different physiological effects in the different tissues this great divergence between the Na^+ distribution of the species in different treatments is of great significance in terms of its actual tissue and cellular location, method of transport and concentration, and the physiological effects. These are subjects of ongoing work.

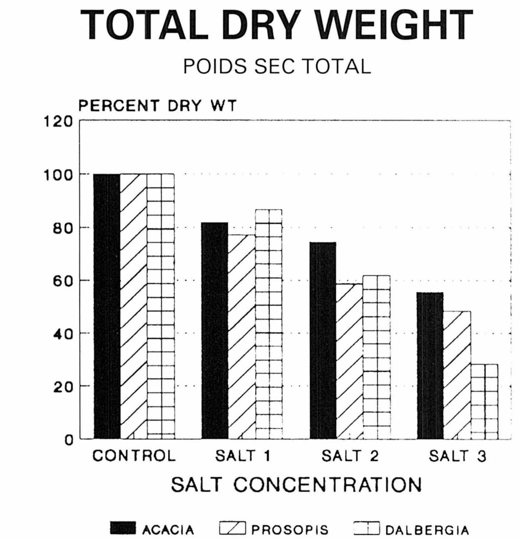

Fig. 1. Total dry wt as percent of the control after 28 days of salt treatment in the three species.

Poids sec total (en % du témoin) après 28 jours de traitement chez les trois espèces à trois niveaux de salinité différents.

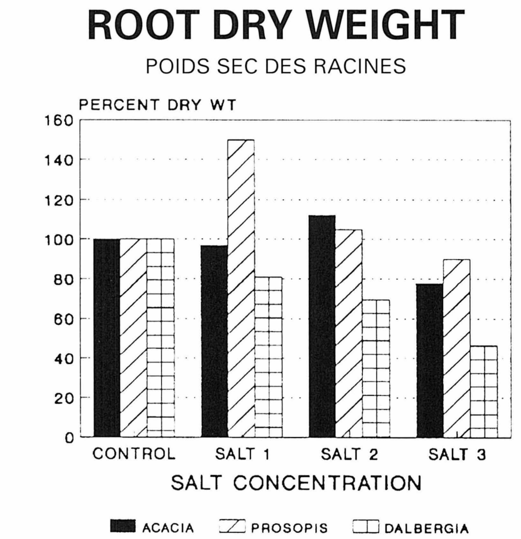

Fig. 2. Root dry wt as compared to the control after 28 days of salt treatment in the three species.

Poids sec total de la racine comparé au témoin après 28 jours de traitement chez les trois espèces, à trois niveaux de salinité différents.

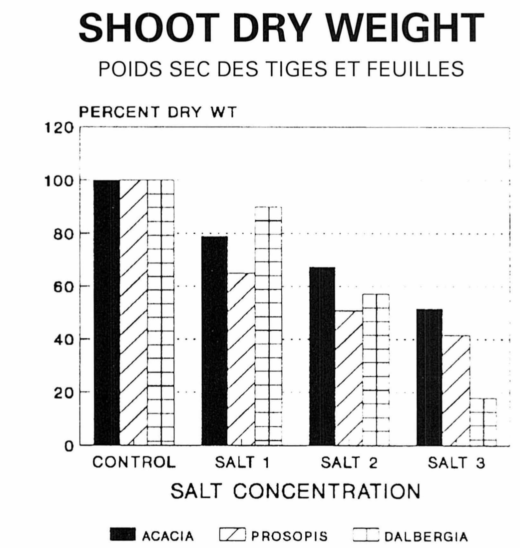

Fig. 3. Dry shoot wt compared to the control after 28 days of salt treatment in the three species.

Poids sec total des tiges et des feuilles comparé au témoin après 28 jours de traitement chez les trois espèces, à trois niveaux de salinité différents.

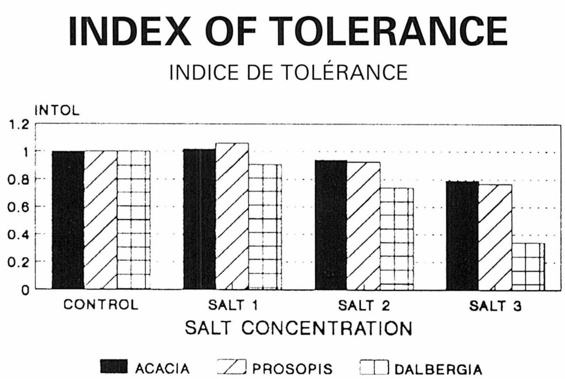

Fig. 4. Ratio of the relative growth rate of control and treatments in the three species.

Pourcentage du taux de croissance par rapport au témoin et aux traitements chez les trois espèces.

Concentration of Sodium and Potassium in leaf, stem and root

in Micromoles/gram dry wt

	LEAF		STEM		ROOT	
	Na	K	Na	K	Na	K
ACACIA						
C	11.95a	33.95a	13.05a	25.13a	31.52a	30.03a
S1	15.22a	45.19b	15.34a	44.75b	90.22b	53.62b
S2	18.48a	39.06c	21.74a	37.25bc	96.74b	28.63a
S3	34.78a	37.99d	105.44b	33.27c	225.00c	54.22b
PROSOPIS						
C	16.30a	60.01a	35.87a	42.95a	34.78a	25.73a
S1	41.30ab	57.82a	80.44b	41.04a	77.17b	24.35a
S2	48.92b	51.75b	106.53b	36.66b	130.43c	23.65a
S3	193.48c	44.84c	263.05c	30.58c	271.74d	17.55a
DALBERGIA						
C	17.40a	45.96a	7.61a	22.86a	9.79a	23.69a
S1	16.30a	46.42a	36.96b	22.38a	61.96b	19.41b
S2	25.00a	41.83b	48.91b	20.22a	57.02b	17.06bc
S3	305.44b	37.34c	128.26c	22.04a	92.40c	16.44c

Means with the same letter in a column are not different at 0.05 significance level by the Scheffe's multiple range test.

Effect of salt treatment S 3 on *Prosopis juliflora* after 28 days of treatment.

Effet du traitement S 3 sur Prosopis juliflora *après 28 jours.*

Also of relevance is the K^+ concentration of the tissue and the K/Na ratio in relation to the plant response to the salinity treatments. Table below shows a general decrease in K^+ levels with increasing salinity, apart from *Acacia* which showed significant increases in K^+ at the lowest and highest salinity treatment. A marked treatment effect is shown in the leaf K/Na ratio. This ranged in the control plants from 2.7 in *Dalbergia* to 3.7 in *Prosopis*. The ratio tended to decrease as leaf Na^+ levels rise and K^+ levels fall. At S3 *Acacia* maintains a ratio of 1.1 while that of *Prosopis* and *Dalbergia* falls to 0.2 and 0.1 respectively. Again the physiological effects are not clear but the importance of K^+ in many plant processes is well documented (PITMAN, 1988).

In these initial experiments we show very different responses to salinity between the three species in terms of growth, and Na^+, K^+ uptake and distribution. LAUCHLI (1984) has described the legume response to salt tolerance by 'salt exclusion'. BERSTEIN (1975) has related the salt tolerance of woody species to the differential transport of Na^+ and Cl^- ions to the shoots. The other form of avoidance of the toxic ions is by compartmentation whereby toxic ions are accumulated in less sensitive parts such as the stem in *radiata* pine (SANDS and CLARKE, 1977), or at the cell level in the vacuoles (JESCHKE, 1984). The regulation of sodium movement into the plant, its retention in the basal parts and restricted translocation to the apical (growing) portion, appears to play an important role in salt tolerance which has also been suggested by LAUCHLI and WIENEKE (1979).

From our results we see *Acacia* well adapted to salinity in terms of salt exclusion from the plant and also from the leaves while at the same time foliar K^+ levels are maintained. It is perhaps significant that this species was able to produce the highest total and shoot dry weight in the two most severe treatments. *Prosopis* showed less ability to exclude Na^+ from the plant and the leaves and relatively little decrease in root dry weight. *Dalbergia* is the most sensitive of the species with a low index of tolerance and productivity, especially at the highest salinity, in which treatment a dramatic increase in leaf Na^+ occured. The species are now being examined in relation to the exclusion and partitioning mechanisms involved and the effects of the accumulation of Na^+ and K^+ in different tissues in terms of their effects on cell activity, water potential, respiration and carbon fixation. ■

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TOLÉRANCE A LA SALINITÉ DE QUELQUES ESPÈCES D'ARBRES TROPICAUX

S. SINGH et F. B. THOMPSON
Contribution volontaire au Xe Congrès Forestier Mondial

Il y a dans le monde environ 340 millions d'hectares de terres salées, dont un tiers en Asie du Sud et du Sud-Est. La salinité du sol a des conséquences sur la physiologie de l'arbre, sa nutrition, etc, qui varient selon les espèces et les autres conditions de milieu. Il est utile de comprendre l'effet physiologique de la salinité et les mécanismes de la tolérance pour pouvoir ensuite sélectionner des génotypes résistants. Cette contribution concerne la tolérance de semis d'*Acacia nilotica,* de *Prosopis juliflora* et de *Dalbergia sissoo.*

MATÉRIEL ET MÉTHODE

Des plants de 15 cm de haut, élevés en pots de plastique dans du sable stérile, ont subi quatre niveaux de salinité : Témoins, S1 (26,4 mM de Na^+, 22,4 mM de Cl^-, 6,1 mM de SO_4^{--}, 3,0 mM de Ca^{++}, 2,0 mM de Mg^{++} et 2,0 mM de HCO_3^- par litre), S2 (concentration double) et S3 (triple) ; l'essai a duré 28 jours, puis les plants ont été récoltés, pesés (poids sec et poids frais) et analysés (concentration de Na^+, K^+, Mg^{++}, Ca^{++} et Cl^- dans les feuilles, les tiges et les racines).

Quatre traitements, trois espèces, six répétitions.

RÉSULTATS ET DISCUSSION

Pour toutes les espèces, l'augmentation de la salinité ralentit la croissance de 20 % (S1), 40 % (S2), 70 % (S3). Mais les effets sur les parties aériennes et les feuilles sont différents : au niveau S1, la masse de racines a augmenté de 50 % *(Prosopis)* alors que celle des tiges diminuait de 32 % par rapport au témoin. Pour *Acacia,* la différence de croissance des racines par rapport au témoin était de − 5 % (S1) et de + 10 % (S2). Cela révèle une adaptation de *Prosopis* et *Acacia* à certains niveaux de salinité. *Dalbergia* accusait une plus forte réduction de croissance.

La concentration des ions Mg^{++}, Ca^{++} et Cl^- dans les tissus varie peu selon les traitements. Celle de Na^+, en revanche, augmente beaucoup ; elle peut aller, pour le traitement S3, dans les feuilles, jusqu'à 12 fois *(Prosopis)* et même 17 fois *(Dalbergia)* la concentration du traitement-témoin.

L'augmentation est moins forte chez *Acacia* (3 fois dans les feuilles, 7 fois dans les racines). La concentration de K^+ diminue quand la salinité augmente, sauf chez les *Acacia.* Le ratio K/Na varie beaucoup plus chez *Dalbergia* et *Prosopis* que chez *Acacia* (cf. tableau ci-dessous).

Cette expérience montre que *Dalbergia, Prosopis* et *Acacia* réagissent très différemment à l'augmentation de la salinité. Dans le traitement-témoin, *Acacia* présente une teneur en Na^+ plus élevée dans ses racines que dans les parties aériennes, ce qui n'est pas le cas ni des *Prosopis,* ni du *Dalbergia,* dont la teneur la plus élevée en Na^+ se trouve, pour le premier, dans la tige et, pour le second, dans les feuilles. Lorsque la salinité augmente dans le sol, la concentration en Na^+ augmente uniformément pour le *Prosopis* dans les racines, les tiges et les feuilles. Il en va différemment chez *Acacia,* où elle reste concentrée dans les racines (niveau S1 et S2) et dans la tige (S3) mais augmente modérément dans les feuilles. Il en est de même chez le *Prosopis,* où la concentration d'ions Na^+ dans les feuilles n'atteint un niveau élevé que dans le traitement S3. *Acacia nilotica* apparaît ainsi comme l'espèce la mieux adaptée à la salinité.

Pourcentage de sodium dans les feuilles, tiges et racines selon le traitement appliqué

	S1			S2			S3		
	R	T	f	R	T	f	R	T	f
ACACIA	2,9	1,2	1,3	3,1	1,7	1,5	7,1	8,1	2,9
PROSOPIS	2,2	2,2	2,5	3,8	3,0	3,0	7,8	7,3	11,9
DALBERGIA	6,3	4,9	0,9	5,8	6,4	1,4	9,4	16,9	17,6