Natural Resources and Environment

AGRICULTURE
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Royal Botanic Gardens Melbourne

PROJECT REPORT

Germination and growth response of salt tolerant native grasses from ephemeral wetlands in inland Victoria

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July 2001

Victoria The Place To Be

Agriculture Victoria - Werribee

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PROJECT REPORT

GERMINATION AND GROWTH RESPONSE OF SALT TOLERANT NATIVE GRASSES FROM EPHEMERAL WETLANDS IN INLAND VICTORIA

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Abstract

Germination and hydroponic growth trials were conducted on a number of native grass species to examine their growth characteristics and physiological responses to different levels of salinity. Germination, under a regime of 12 hours light and 12 hours dark at 25ºC, ranged from 0-19% to 0-54% for 17 and 164 after-ripening days respectively. Particularly poor germination (< 5%) was found for *Poa salacustris, Distichlis distichophylla* and *Puccinellia stricta* var. *perlaxa.* Excluding light significantly increased germination in one of two populations of each of *Agrostis adamsonii* and the *Puccinellia* sp. and in all three populations of *A. robusta* but decreased germination in both populations of *A. punicea.* Of three populations tested under saline conditions, *A. robusta* and the *Puccinellia* sp. gave better germination than *A. adamsonii* but all gave poor results at 200 and 300 mMol salt. Salt treatment (100, 200 and 300 mMol NaCl), depressed growth in all tested species. At least 50% of the plants survived the seven week growth trials; the worst being a population of *A. avenacea* and both populations of *A. punicea* at the 200 and 300 mMol treatments. Overall growth was superior in *A. adamsonii* and *A. robusta* but a high degree of salt tolerance was also noted in a further population of *A. avenacea* and in the slow growing *Puccinellia sp.* Significant increases in root length were observed for some of these populations as salt concentration increased. Relative water content and osmotic potential deceased in leaf tissue with increasing salt for most populations, in conjunction with increased uptake of sodium and chloride. Some evidence of osmotic adjustment was seen for some populations but salt exudation onto upper leaf surfaces appears to be a major salt tolerance mechanism.

Introduction:

With the support of the Australian Flora Foundation, laboratory and glasshouse work was undertaken during the year 2000, to investigate the germination and growing characteristics of a number of salt tolerant native grasses.

Observations during previous plant monitoring work indicated that the adaptation of native grasses to saline areas varied from slight (e.g. *Agrostis avenacea)* to high tolerance (e.g. *Danthonia eriantha)* to apparent salt dependence (e.g. *Agrostis adamsonii, Puccinellia stricta).* Salt tolerant Australian native plants (and grasses in particular) have received very little research attention. This project was undertaken to examine some of the growth differences between selected grasses and their underlying physiological characteristics, with a view to providing better knowledge of their cultural requirements.

Project Objectives:

1) To determine differences in dormancy, germination and seedling vigour for a number of salt tolerant native grass species.

2) To examine physiological responses and adaptation of these species to different levels of salinity on germination, seedling growth and vegetative growth.

3) To utilise the research findings in assisting the management of native species biodiversity at saline sites and the rehabilitation of species depleted sites.

Methods:

Seed Collection

Seed was collected from six native salt tolerant grass species (Table 1), on a range of sites with varying salinity (Table 2) in inland Western Victoria, during the summer of 1999/2000. The seed was used for germination studies; the species being:

Adamson's Blown-grass: *Agrostis adamsonii* Vickery
Salt Blowri-grass: *Agrostis robusta*[1] A.J.Brown and N.G.Walsh
Purple Blown-grass: *Agrostis punicea* var. *punicea*[1] A.J.Brown and N.G.Walsh
Australian Saltmarsh-grass: *Puccinellia stricta* (Hook.f.) C.Blom var. *perlaxa* Stapf. ex N.G.Walsh
Salt-lake Tussock-grass: *Poa salacustris* N.G.Walsh
Australian Salt-grass: *Distichlis distichophylla* (Labill.) Fassett

Adamson's Blown-grass and Purple Blown-grass (as *A. billardierei* var. *filifolia*) are listed under Schedule 2 of the Victorian 'Flora and Fauna Guarantee Act 1988' as 'Threatened Species' and Adamson's Blown-grass and Salt-lake Tussock-grass are listed as an 'Endangered' and a 'Vulnerable' species respectively under the National 'Environment Protection and Biodiversity Protection Act 1999'.

Mature inflorescences were harvested and stored in brown paper bags at room temperature until just prior the first germination study, when seed was separated and stored in screw-capped plastic vials. Seedlings of the *Agrostis* populations, one population of the *Puccinellia* and a combined population of the *Poa* were also used for to study growth response to salt. In addition, some earlier seed collections (summer of 1996/97) of Common Blown-grass (*Agrostis avenacea* J.F.Gmel) were used to produce seedlings for the growth trials.

Table 1 - Origin of seed used for germination and growth trials together with the soil salinity rating of the collection sites.

Site	Trial	Soil Salinity	Species
Dereel (D)	Germination, Growth	Moderate	*Agrostis adamsonii* (typical form)
St. Marnocks (ESN)	Germination, Growth	Very High	*Agrostis adamsonii* (robust form)
Skipton (MT)	Germination, Growth	Very High	*Agrostis robusta* (robust form)
Carranballac (CBS)	Germination, Growth	Severe	*Agrostis robusta* (typical form)
Lake Linlithgow (LIN)	Germination	Moderate	*Agrostis robusta* (typical form)
Lake Repose (LR)	Germination, Growth	Non-saline	*Agrostis punicea*
Bulart (SBL)	Germination, Growth	High	*Agrostis punicea*
West Mortlake (WM)	Growth	Non-saline	*Agrostis avenacea* (weeping form)
Ballyrogan (SHR)	Growth	Moderate	*Agrostis avenacea* (small erect form)
Skipton (MT)	Germination	Very High	*Puccinellia stricta* var. *perlaxa*
Lake Linlithgow (LIN)	Germination, Growth	High	*Puccinellia stricta* var. *perlaxa*
Lake Corangamite (C)	Germination	Slight	*Poa salacustris*
Lake Goldsmith (SY)	Germination	Slight	*Poa salacustris*
Lake Linlithgow (LIN)	Germination	Slight	*Poa salacustris*
Combined C, SY, LIN	Growth	Slight	*Poa salacustris*
St. Marnocks (ESN)	Germination	Very High	*Distichlis distichophylla*
Carranballac (CBS)	Germination	Severe	*Distichlis distichophylla*

Note: Electrical Conductivity (1:5 soil: water)[2]; Non-saline = <0.25 dS/m, Slight salt = 0.25-0.6 dS/m, Moderate salt = 0.6-1.4 dS/m, High salt = 1.4-3.3 dS/m, Very High salt = 3.3-7.7 dS/m, Severe salt = >7.7 dS/M

Dormancy Study

Seed samples were evaluated to study the rate of breaking dormancy. Three germination trials, using seed of different after-ripening age (17, 77 and 164 days after harvest) were carried out. The seeds were taken randomly from the bulk seed store and germination conducted in an incubator set at 25ºC temperature with a 12 hours light and 12 hours dark cycle. Germination was on milli-Q water saturated filter paper in closed petri dishes. The treatments of 25 seeds per petri dish were replicated 4 times in a randomised block design. Observation of germination was made every 2 to 3 days for the first 4 weeks, every week from 4 to 8 weeks and once a fortnight from 8 to 12 weeks. Seed was assessed as germinated and germinates removed when roots

[1]These species have been recently separated from A. *billardierei: A. robusta* formerly being A. *billardierei* var. *robusta* Vickery and A. *punicea* var. *punicea* formerly being A. *billardierei* var.filifolia Vickery (Brown and Walsh 2000).
[2] These salt ranges are adapted, slightly modified and expanded from those of Matters and Bozon: Class 1: 0.3-0.6 dS/m areas of low level salting, Class 2: 0.6-1.4 dS/m areas of moderate salting, Class 3: 1.4-3.5+ dS/m severely affected areas.

were about 3 mm long and coleoptiles visible. From the germination data collected over time, cumulative germination % and germination rate were calculated.

Effect of Light Conditions on Germination

At 164 days post harvest, an additional germination treatment of continuous darkness (except for a few minutes at each germinate count) was compared to the normal 12 hours light and 12 hours dark treatment. Incubation, observation and replicate conditions were the same as described above.

Effect of Salt on Germination

The populations of Adamson's Blown-grass, Salt Blown-grass and Australian Saltmarsh-grass which gave the highest germination in the earlier trials (i.e. D, MT and LIN respectively) were used to evaluate salt effects on germination. For each population, 25 seeds were placed on filter paper in petri dishes with varying levels of salt concentration (0, 100, 200 and 300 mMol) of NaCl and treatments were replicated 4 times in a randomised complete block design. Incubation was carried out at 25ºC in continuous darkness.

Table 2 - Soil characteristics of seed collection sites (summer sampling); pHw = pH in water:soil (1:5), pHc = pH in $CaCl_2$:soil (1:5), EC = electrical conductivity, Mois. = soil moisture (dry weight basis).

Species	Site	pHw	pHc	EC, dS/m	Mois. %	Texture
A. adamsonii	**D**	5.3	4.8	1.4	20	VFSCL
	ESN	8.2	8.0	3.9	84	SCL
A. robusta	**MT**	7.8	7.7	6.4	57	LC
	CBS	8.0	7.9	11.0	131	CL
	LIN	9.7	9.0	0.60	-	FSCL
A. punicea	**LR**	5.6	4.8	0.14	7	VFSC
	SBL	5.7	5.5	3.0	23	CL
A. avenacea	**SHR**	5.9	5.3	0.60	6	VFSCL
	WM	6.5	5.7	0.08	6	FSCL+
Puccinellia stricta	**MT**	7.8	7.7	6.4	57	LC
	LIN	9.6	9.2	2.5	-	FSCL+
Poa salacustris	**C**	8.6	8.2	0.33	-	LyS
	SY	8.8	8.0	0.46	16	LC
	LIN	8.8	8.3	0.35	-	LyCS
Distichlis distichophylla	**ESN**	8.2	8.0	3.9	84	SCL
	CBS	8.0	7.9	11.0	131	CL

textures: cl = clay loam, fscl = fine sandy clay loam, fscl+ = heavy fine sandy clay loam, lc = light clay, lycs = loamy coarse sand, lys = loamy sand, scl = sandy clay loam, vfsc = very fine sandy clay, vfscl = very fine sandy clay loam

Seedling Growth, Vegetative Growth and Physiological Study

It was originally planned that seedlings for the growth trials were to come from the germinates in the germination trials. However, the low germination in some populations required the propagation of seedlings in a sand-peat mixture in shallow trays under nursery glasshouse conditions instead. Additional seed from earlier collections (1996/97) of the *Agrostis* species were also used in case germination and seedling vigour proved to be better than the recent seed. As the recently collected seed gave good results, the resultant seedlings were used. Seedlings of relatively even size (approximately 3-4 cm shoot height) were selected from the nursery trays for the growth trials.

The growth trials were conducted in the same environment controlled glasshouse, under the same conditions (18 hr day/6 hr night cycle, 23-17ºC) except that the walls were whitewashed between the first and second trials. In order to examine all the populations of interest and due to insufficient bench space and equipment, two separate trials had to be conducted (Table 3). Population D of *Agrostis adamsonii* was used in both trials to allow statistical comparisons between all populations to be made. A second population of *Puccinellia stricta* (i.e. MT) was to be used in the second trial but because seedling growth was extremely poor it was discarded from further study. Due to the poor germination of *Poa salacustris* and *Distichlis distichophylla*, these species could not be used in the growth studies, although sufficient seedlings of *Poa* were grown in the nursery to allow for a non-replicated set of salt treatments to be applied.

Table 3 - Dates of setup, salt addition and harvest for the growth trials.

Trial	Setup	Salt addition	Harvest	Species	Population
1	10th Aug	24th Aug	5- 10th Oct	*Agrostis adamsonii*	ESN
					D
				Agrostis robusta	MT
					CBS
				Agrostis punicea	SBL
					LR
2	18th Oct	6th Nov	18-19th Dec	*Agrostis adamsonii*	D
				Puccinellia stricta var. *perlaxa*	LIN
				Agrostis avenacea	SHR
					WM
				Poa salacustris	combined

Seedlings were suspended in a series of 15L non-transparent (dark green) plastic tubs containing aerated Hoagland's solution. This was done by wrapping a small piece of sponge-foam around the junction of root and stem and lodging each in a hole cut through the lids of the tubs. The lid of each tub held eight plants. Treatments were applied by the addition of sodium chloride to the tubs to provide salt concentrations of 0, 100, 200 and 300 mMol. These salt concentrations can be expressed as follows;

100 mMol NaCl = 5,840 mg/L (EC measures 10.67 dS/m in solution or 1.97 dS/m in soil)
200 mMol NaCl = 11,680 mg/L (EC measures about 20 dS/m in solution or 3.94 dS/m in soil)
300 mMol NaCl = 17,520 mg/L (EC measures about 29 dS/m in solution or 5.91 dS/m in soil)

At transference from the nursery[3], the seedlings were initially suspended in water only, with Hoagland's solution being gradually added at 1/4, 1/2 and full strength over a two to three week period. When the solution was at full strength, the salt treatments were gradually applied at an average of 1/10 per day for 10 days. Weekly growth measurements were commenced from the onset of salt additions.

Seedlings that died within the first two weeks of the growth trials (before maximum salt strength was achieved) were treated as missing values for the purpose of statistical analysis. Seedlings or plants were considered to be dead when no green leaf or part leaf remained. Seedlings dying after two weeks were regarded as being salt affected and were given zero values for growth measurements (e.g. tiller number, shoot height).

The trials were set up in a design similar to split plots in randomised blocks (Appendices 1 and 2). In each of four blocks or benches, six (trial 1) or four (trial 2) pairs of tubs were randomly allocated to the four salt treatments (0, 100, 200 and 300 mMol NaCl). Each tub contained two plots (half-tubs) and the six (trial 1) or four (trial 2) plant entries (populations) were randomly allocated to the plots. Each plot contained four seedlings of the same population.

Overall shoot height (highest point of hand gathered shoots but discarding dead leaves) and tiller number were measured for each plant at weekly intervals. Just before harvest, one typical, fully expanded leaf was taken at pre-dawn from each plot and used to measure osmotic potential, relative water content and osmotic adjustment. At seven weeks from the onset of salt application, each individual plant was harvested, shoots and roots separated and shoot height and root length measured. Shoot and root samples were rapidly washed and rinsed in deionised water (three successive rinses), dried at 60ºC and biomass calculated. The four shoots and four roots per plot were separately composited and analysed for total sodium, potassium, magnesium, calcium, chloride, phosphorus and sulphur.

Statistical Treatment

Germination results were reduced to 4 week data blocks and analysed by analysis of variance (ANOVA) using the Genstat 5 package (Release 3. 1, Lawes Agricultural Trust, Rothamstead Experimental Station).

Weekly growth measurements, physiological measurements, plant tissue nutrient concentrations and harvest results were analysed by the Residual Maximum Likelihood (REML) method of Genstat 5. 1, using population D as the common element across the two trials. As a consequence of using REML (where all other population

[3] To assist the initial growth of seedlings for the first trial, they were transferred from the nursery to 2L aerated tubs (smaller versions of the trial tubs) of nutrient solution in a growth chamber and grown on for about 3 weeks, before being transferred to the trial tubs. Nutrient solution was gradually added to prevent any shock to growth from transferral to the 2L tubs.

results are compared to the means for D across trials), some adjusted means were slightly negative. After examination of residual errors, some measurements (shoot and root weights, tiller numbers and root:shoot length) were log transformed and re-evaluated.

Mean weekly growth rate of shoot height and tiller production rate were calculated for the total trial period. In order to negate the effects of inherent seedling size and growth rate differences between populations and just examine salt tolerance, mean results of each harvest measurement were also expressed in terms of their relativity to the control treatment.

Results and Discussion:

Germination Trials

DORMANCY

Results of the dormancy trials are shown in Table 4. Significant differences in germination with increasing after-ripening time was found for two out of three *Agrostis robusta* populations (MT and CBS) and one out of two *A. punicea* populations (SBL) under a 12 hour light and 12 dark regime at 25ºC. These three populations also gave the highest germination percentages for all populations in these trials. No significant differences were found for the remaining *A. robusta* and *A. punicea* populations. Germination of *Puccinellia, Poa* and *Distichlis* under these conditions was extremely poor. *Distichlis* was not included in the first dormancy trial as it wasn't ready to harvest until mid January, by which time the trial was underway. A significant decrease with after-ripening time was found for the ESN population of *A. adamsonii* but no difference was found for the D population. Germination for both *A. adamsonii* populations was not encouraging.

Table 4 - Seed germination (%) at 12 weeks as affected by dormancy; 17, 77 and 164 days from seed harvest (light conditions: 12 hrs light, 12 hrs dark).
Values in the same column that share the same letter are not significantly different (LSD= 10.8).

Treatment	***A. adamsonii***		***A. robusta***			***A. punicea***		***Puccinellia***		***Poa***	***Distichlis***
	D	ESN	MT	CBS	LIN	LR	SBL	MT	LIN	C	ESN
17 days	2 a	19 b	7 a	4 a	6 a	16 a	5 a	0 a	1 a	0 a	-
77 days	0 a	9 ab	20 b	41 b	4 a	10 a	11 a	3 a	0 a	1 a	1 a
164 day	6 a	7 a	54 c	34 b	13 a	19 a	25 b	1 a	0 a	0 a	0 a

Note: Germination was nil for all treatments and times for the other *Poa* and *Distichlis* populations.

LIGHT EFFECTS

The exclusion of light, significantly increased germination for one population of *A. adamsonii* (D), all populations of *A. robusta* and one population of *Puccinellia* (LIN) and in each case, displayed dramatic differences (eg. from *6%* to 75% for D) (Table 5). Maximum germination was obtained within four weeks for each of these populations. Again the *Poa, Distichlis* and the remaining *Puccinellia* (MT) populations performed poorly. There was no effect of continuous darkness on ESN *(A. adamsonii)* and there was a significant decrease in germination for both the *A. punicea* populations. However, under conditions of 12 hours light, *A. punicea* showed a significantly delayed germination up to at least the 12 weeks of the trials.

Table 5 - Seed germination (%) at 4, 8 and 12 weeks as affected by hours of light; 12L+12D=12 hrs light and 12 hours dark, 24D=24 hrs dark (dormancy conditions: approx. 24 weeks from seed harvest)

Values in the same column and for the same time period that share the same letter are not significantly different (LSD= 10.1).

Treatment	***A. adamsonii***		***A. robusta***			***A. punicea***		***Puccinellia***		***Poa***	***Distichlis***
4 weeks	**D**	**ESN**	**MT**	**CBS**	**LIN**	**LR**	**SBL**	**MT**	**LIN**	**C**	**ESN**
12L+12D	6 a	6 a	53 a	34 a	13 a	1 a	11 a	1 a	0 a	0	0
24D	75 b	10 a	89 *b*	71 *b*	48 *b*	3 a	2 a	6 a	39 *b*	4	0
8 weeks	**D**	**ESN**	**MT**	**CBS**	**LIN**	**LR**	**SBL**	**MT**	**LIN**	**C**	**ESN**
12L+12D	6 a	7 a	54 a	34 a	13 a	13 a	18 b	1 a	0 a	0	0
24D	75 b	14 a	90 b	71 b	48 b	5 a	4 a	7 a	39 b	4	4
12 weeks	**D**	**ESN**	**MT**	**CBS**	**LIN**	**LR**	**SBL**	**MT**	**LIN**	**C**	**ESN**
12L+12D	6a	7a	54 a	34 a	13 a	19 b	25 b	1 a	0 a	0	0
24D	75 b	14 a	90 b	71 b	48 b	6 a	7 a	7 a	39 b	4	8

Note: Germination was nil for all treatments and times for the other *Poa* and *Distichlis* populations. For these species, only one replicate (of 25 seeds) was established for the 24D treatment (therefore one germinate = 4% and two germinates = 8%.

SPECIES DIFFERENCES

The results of the dormancy and dark trials indicate considerable variability in the germination requirements both within and between species. *Agrostis robusta* has obviously performed best of all species under the conditions of both the 12 hours light and nil light treatments, with the latter giving a 35-37% improvement in germination for all populations. Nevertheless, there remains a 40-41% range in germination across the *A. robusta* populations. Whether, the poorer performing LIN population has less viable seed or greater dormancy, cannot be ascertained from the current work. Site conditions that support the growth of this population include; a much lower salinity (slight salt), a higher pH (extremely alkaline) and a lighter texture (i.e. less water holding capacity), compared to the other sites (Table 2). Whether adaptation to these conditions has had an effect on seed characteristics is unknown.

The lack of good germination under dark conditions in the ESN population of *A. adamsonii is* in direct contrast to the D population which yielded 75% germination. Site conditions between the populations are different in terms of pH (strongly acid at D, moderately alkaline at ESN) and salinity (moderate at D, very high at ESN). Another condition at ESN is that it almost always has a covering of surface water compared to the more periodic nature of surface water at D. In addition, ESN has a thick surface covering of *Distichlis distichophylla* mat which does not exist at D. Other stimuli for germination may be required at ESN, such as a pre-drying event and/or a higher germination temperature or fluctuating temperature (reflecting that germination only occurs when the site experiences a short drying out period), storage under moist conditions (reflecting loss of viability if seed is allowed to dry out) or long-term storage in dark or reduced light conditions (reflecting seed burial in the *Distichlis* mat). These conditions could not be tested for within the resources of the current project. Of particular interest is the decreased germination of ESN seed with increasing after-ripening time. Previous work (James and Brown 1997) with *A. adamsonii* seed from these sites and germinated under temperature controlled glasshouse conditions in a seed raising mix (with a light covering of sand), gave percent germination values of 63 and 90.5 for D at 2 months and 14 months after-ripening time respectively compared to 92 and 72.5 for ESN. Although these germinations were much higher than the current trials, the same trend for ESN is evident.

Agrostis punicea, although not showing high germination in any of the trials, has displayed very different responses to the other *Agrostis* spp. tested. Germination improved with time after sowing and the species performed better in the light and dark cycle than in continuous dark. Again, one site (SBL) gave better results than the other (LR) and may be related to site conditions (Table 2); the former having a higher salt level but not drying out as much in the summer, than the latter.

Variation in germination response between and within species of *Agrostis* is not uncommon. Work with *A. gigantea R*oth. has shown that freshly harvested seed required both light and alternating temperatures for best germination while older seed germinated well at a constant temperature in the dark (Williams 1973). Varying light and temperature requirements for optimum germination has been found for cultivars of the turf species; A. *stolonifera* L. and *A. capillaris* L (Toole and Koch 1977).

Improvement in germination of one *Puccinellia population* (LIN) was achieved with the continuous dark treatment and achieved similar results to *Agrostis robusta* from the same site (but in an adjacent less salty area). *Puccinellia* from MT did not germinate well under any tested conditions, despite *A. robusta* performing well

from this site. It is obvious from this result that the required conditions for breaking dormancy are as much related to primary genetic character as to site adaptation.

Distichlis and *Poa* were not replicated in the continuous dark treatment, due to lack of seed. However, over all the trials (450 seeds for *Distichlis* and 975 seeds for *Poa),* only 3 seeds of *Distichlis* (all from ESN) germinated, of which 2 were in the continuous dark treatment at 8 and 12 weeks and 1 was at 12 weeks in the 2nd dormancy trial. On closer examination, much of the *Distichlis* seed was found to be shrivelled (92.5% and 98.5% for ESN and CBS respectively) and unlikely to be viable. Only 2 seeds of *Poa* (both from C) germinated throughout the trials, of which 1 was at 2 weeks in the continuous dark treatment and 1 was at 4 weeks in the 2d dormancy trial. Both of these species have a stoloniferous or rhizomatous growth habit and therefore do not need to rely as much on viable or non-dormant seed dispersal compared to tussock forming species. However, other environmental conditions probably also play a part in germination success. For example, it has been shown in North America, that germination in *Distichlis spicata* of greater than 80% resulted from a fluctuating temperature regime (27.5ºC for 8 hrs and 16.5-23ºC for 16 hrs) (Sabo *et aL* 1979). In Japan, *Poa crassinervis* Honda. required more than 20 days storage at 30ºC to break dormancy (Watanabe *et al.* 1996).

SALINITY

Germination under saline conditions gave significant reductions for each population tested (Table 6). In particular, germination in *Agrostis adamsonii* (D) was reduced to only 9% (18% of the control) at 100 mMol NaCl and no seeds germinated at higher salt levels. *Agrostis robusta* (MT) gave significantly better germination in the nil and 100 mMol treatments than *A. adamsonii* and still achieved more than 50% germination in the latter (74% of the control). *Puccinellia* (LIN) seed did not germinate as well as either *Agrostis* species in the control, but still achieved a 20% germination at 100 mMol (54% of the control). A small percentage of both *A. robusta* and *Puccinellia* seed still germinated at the highest salt level of 300 mMol. These results indicate that germination for all three species is inhibited by elevated soil salt levels and requires leaching autumn or winter rains before conditions are most favourable for the establishment of new seedlings. Experiments with *Puccinellia distans* (L.) Parl. and *P. lemmoni* (Vasey) Scribn. also showed reduced germination (less than 50% of controls) when watered with 75% sea water solution (Harivandi *et al.* 1982). In the same experiment, salt treated *Agrostis stolonifera* only produced 1 % germination of the control.

Table 6 - Seed germination (%) at 4 weeks as affected by salinity level (germination conditions: 24 hrs dark, approx. 46 weeks from seed harvest)
values in the same column that share the same letter are not significantly different (LSD= 11.6).

Treatment	*Agrostis adamsonii*	*Agrostis robusta*	*Puccinellia stricta* var. *perlaxa*
	D	**MT**	**LIN**
0 mMol salt	51 b	72 c	39 c
100 mMol salt	9 a	53 b	21 b
200 mMol salt	*0 a*	6 *a*	7 *a*
300 mMol salt	0 *a*	*1 a*	2 *a*

Growth Trials

SEEDLING AND PLANT SURVIVAL

Seedlings dying prior to (missing) or post (dead) installation of the full strength salt treatments are recorded in Table 7. More than 99% of seedlings were successfully established in the growth trials. Despite the very high salt concentrations of some salt treatments, only 6% of plants overall, died as a result of salt. Deaths were largely at the 200 mMol and 300 mMol salt treatments in the *Agrostis punicea* populations and in SHR of *A. avenacea.* Most 'missing' seedlings were undersize and probably died as a result of a restrictive root system that failed to reach the nutrient solution, although some may have died from the early salt additions (e.g. LR and SHR at 100 mMol).

Table 7 - Number and percent of missing seedlings and plant deaths during the trials.

Population	Treatment mM NaCl	Species	Missing seedlings		Dead plants	
			Number	*Percent*	*Number*	*Percent*
MT	0	*A. robusta*	*1*	*6*		
CBS	300	*A. robusta*			*1*	*6*
SBL	300	*A. punicea*			3	19
SBL	200	*A. punicea*			3	19
SBL	100	*A. punicea*			*1*	*6*
LR	300	*A. punicea*			*7*	*44*
LR	200	*A. punicea*			*6*	38
LR	100	*A. punicea*	2	12		
LR	0	*A. punicea*	*1*	*6*		
D	0	*A. adamsonii*	2	12		
SHR	300	*A. avenacea*			8	50
SHR	200	*A. avenacea*			*7*	*44*
SHR	100	*A. avenacea*	*1*	*6*	*1*	*6*
WM	200	*A. avenacea*	*1*	*6*		
WM	0	*A. avenacea*	*1*	*6*		
Poa	300	*P. salacustris*			1	21
Total			**9**	**1**	**38**	**6**

GROWTH RATE

Figures 1-4 and 6-9 show production over time, for each salt treatment, in plant height and tiller number, respectively. Mean weekly growth rates as affected by salt treatment are plotted in Figures 5 and 10. Table 8 provides the mean data and significant differences between treatments for each population.

For the nil salt treatment, the *Agrostis* species showed a similar rate of growth in shoot height, although the *A. robusta* populations and *D (A. adamsonii)* had significantly higher growth rates (5.2-5.8 cm/week) than both *A. punicea* (4.2-4.3 cm/week). Growth rate for MT *(A. robusta)* (5.8 cm/week) was also significantly higher than ESN *(A. adamsonii)* and the *A. avenacea* populations (4.5-4.7 cm/week). The *Puccinellia* population displayed a much slower rate of growth (1.3 cm/week) than all the *Agrostis* populations. However, *Puccinellia,* along with WM (A. *avenacea),* had significantly higher tiller production rate (6.1-6.3 tillers/week) than all other populations (2.6-4.6 tillers/week). Within *A. punicea,* tiller production rate for SBL (4.4 tillers/week) was significantly higher than for LR (2.6 tillers/week).

At 100 mMol salt, the *A. adamsonii* and *A. robusta* populations had significantly higher growth rates for shoot height (36-4.2 cm/week) than all other species (1.0-2.6 cm/week). *Puccinellia* again had the lowest growth rate, but not significantly different from SHR (*A. avenacea*) and SBL (*A. punicea*). CBS (*A. robusta)* was the only population to maintain tiller production rate, compared to the control, although results for the other *A. robusta* (MT) and for both *A. adamsonii* populations were not significantly reduced. *Puccinellia,* D (A.*adamsonii)* and CBS (*A. robusta)* had significantly higher tiller production rates (3.6-3.7 tillers/week) than SHR (*A. avenacea*) and the *A. punicea* populations (1.0- 1.8 tillers/week).

At 200 mMol salt, growth rates for height were significantly separated into three groups; SHR (*A. avenacea*) at -2.0 cm/week, *Puccinellia, A. punicea* and WM (*A. avenacea)* at 0.2-1.1 cm/week and *A. adamsonii* and *A. robusta* at 2.3-3.6 cm/week. Two significantly different groups were found for tiller production rate; SHR (A. *avenacea*) and *A. punicea* at -0.2- 1.0 tillers/week and the remaining populations at 2.4-3.1 tillers/week.

Table 8 - Mean weekly growth rate in shoot height and tiller production for each salt treatment.

Height Growth Rate, cm/week						Tiller Production Rate, tillers/week					
A. adamsonii		S0	S1	S2	S3	*A. adamsonii*		S0	S1	S2	S3
ESN	S0	4.71				ESN	S0	3.60			
	S1	*	3.67				S1	ns	2.71		
	S2	*	*	2.34			*S2*	ns	ns	2.77	
	S3	*	*	*	1.35		*S3*	*	ns	ns	1.99
A. adamsonii		S0	SI	S2	S3	*A. adamsonii*		S0	SI	S2	S3
D	S0	*	5.34				D	SO	4.62		
	S1	*	3.93				S1	ns	3.66		
	S2	*	*	2.73			*S2*	*	ns	3.06	
	S3	*	*	*	1.43		*S3*	*	*	ns	2.15
A. robusta		S0	S1	S2	S3	*A. robusta*		S0	S1	S2	S3
MT	C	5.76				MT	S0	3.73			
	S1	ns	4.24				S1	ns	2.88		
	S2	*	ns	3.59			*S2*	ns	ns	2.48	
	S3	*	*	*	1.63		*S3*	*	ns	ns	1.75
A. robusta		S0	S1	S2	S3	*A. robusta*	S0	S1	S2	S3	
CBS	S0	5.19				CBS	S0	3.73			
	S1	*	4.12				SI	ns	3.67		
	S2	*	*	2.94			*S2*	*	ns	2.44	
	S3	*	*	*	1.49		*S3*	*	*	*	1.06
A. punicea		S0	S1	S2	S3	*A. punicea*		S0	S1	S2	S3
LR	S0	4.17				LR	S0	2.55			
	S1	*	2.32				S1	*		1.16	
	S2	*	*	0.43			*S2*	*	ns	0.10	
	S3	*	*	ns	-0.33		*S3*	*	ns	ns	0.05
A. punicea		S0	S1	S2	S3	*A. punicea*	S0	S1	S2	S3	
SBL	S0	4.29				SBL	S0	4.43			
	S1	*	1.81				S1	*	1.79		
	S2	*	*	0.83			*S2*	*	ns	0.96	
	S3	*	*	*	-0.68		*S3*	*	*	ns	0.01
Puccinellia		S0	S1	S2	S3	*Puccinellia*		S0-	SI	S2	S3
LIN	S0	1.30				LIN	S0	6.10			
	S1	ns	1.00				S1	*		3.58	
	S2	*	ns	0.18			*S2*	*	ns	2.85	
	S3	*	*	ns	0.02		*S3*	*	*	ns	2.23
A. avenacea		S0	S1	S2	S3	*A. avenacea*		S0	S1	S2	S3
SHR	S0	4.54				SHR	S0	3.41			
	S1	*	1.71				SI	*		0.96	
	S2	*	*	-2.03			*S2*	*	ns	-0.18	
	S3	*	*	ns	-2.77		*S3*	*	ns	ns	-0.26
A. avenacea		S0	S1	S2	S3	*A. avenacea*		S0	S1	S2	S3
WM	S0	4.72				WM	S0	6.28			
	S1	*	2.58				S1	*		2.87	
	S2	*	*	*1.11*		S2	*	ns	2.62		
	S3	*	*	*	-0.18		S3	*	*	*	1.12

Salt treatments: S0=nil, S1=100mMol, S2=200 mMol, S3 =300 mMol.
* significant where t prob. of pairwise differences <0.05. ns =nonsignificant.

Significant groupings of populations for height growth rates at 300 mMol salt were the same as for 200 mMol, although the rates were all lower (-2.8, -0.7-0.0 and I.4-1.6 cm/week respectively). Groupings for tiller production rates were also similar to 200 mMol salt but CBS (*A. robusta*) and WM (*A. avenacea*) were not significantly different to the *A. punicea* populations. Tiller production rates were lower overall for 300 mMol compared to 200 mMol salt, but only significantly so for CBS (*A. robusta*) and WM (*A. avenacea*).

For most populations, the effect of the 100 mMol salt treatment is most apparent at about the 3 week stage (i.e. 1 week after full strength application of the treatment) but at the higher salt treatments, the effect is noticeable at 2 weeks.

HARVEST

Appendix 3 provides the results on statistical analysis of growth measurements at the time of harvest. For populations where deaths occurred, it should be noted that measurements for relative water content, osmotic potential and nutrient concentrations were carried out on the remaining live plants and no adjustment for the dead plants could be made.

All species showed a level of salinity tolerance, with at least some plants in each population surviving even at the highest salt treatment. In this respect, all species and populations could be defined as halophytes, albeit, with differing levels of salt tolerance. None of the populations displayed a requirement for salt. This result was similar to that obtained in a New Zealand study of halophytes (including *Puccinellia stricta* and *Lachnagrostis filiformis* (G.Forst.) Trin. syn. *Agrostis avenacea*) from a salt marsh (Partridge and Wilson 1987). Dead leaves and salt deposits toward the base of leaf blades were observed in all populations at the 100, 200 and 300 mMol salt levels. Salt accumulation on leaves was noticeably higher with increasing salt treatment and did not appear to be influenced by population, except that WM (*A. avenacea*) seemed to have less accumulation at the 100 and 200 mMol levels, than all other populations.

All species and populations displayed decreased shoot height (Fig. 11), tiller number (Fig. 12) and shoot weight and shoot density (Figs. 13 and 14) with increasing salinity, when compared to the control treatment. However, differences in tiller number for *Agrostis adamsonii* and *A. robusta* were either, non-significant (ESN and MT) or only significant at the highest salt level (D and CBS). Likewise, shoot density (expressed here as weight/unit height) differences were only significant for *A. robusta* at the highest salt level and were non-significant throughout for LR (*A. punicea*).

Root weight generally decreased significantly from the control with increasing salinity (Fig. 15). However, root weight differences for *A. robusta* were either non-significant, or only significant at the highest salt level (MT and CBS respectively). In addition, root weight was not significantly different between salt treatments for the LR population of *A. punicea*.

Root length (Figure 16) significantly increased at the 200 mMol salt level compared to the control for *A. adamsonii* (ESN and D), but not at 300 mMol. Significant increase in root length also occurred from 100 mMol to 200 mMol for WM (*A. avenacea*) and MT (*A. robusta*) but only after an initial decrease from the control. These increases, in response to salinity, appeared to be accompanied by a thinning of the roots. A greater root surface area would probably provide for greater water uptake and if so, would constitute one mechanism for salt tolerance. In contrast to these populations, root length in SHR (*A. avenacea*), LR and SBL (*A. punicea*) displayed significant decrease with increasing salt. The remaining populations did not show significant differences in root length.

Fig. 1 **Increase in plant height over time for salt treatment of 0 mMol.**

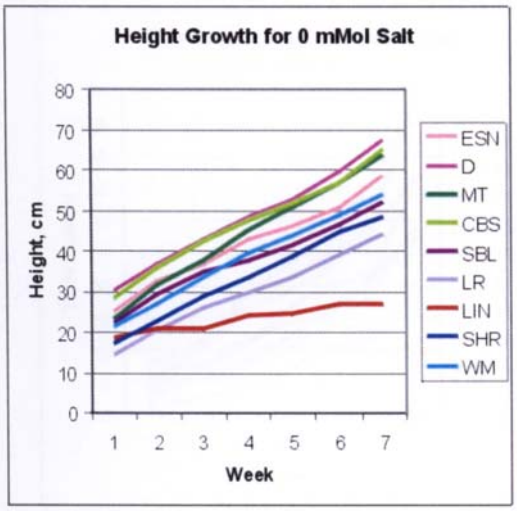


Fig. 2 **Increase in plant height over time for salt treatment of 100 mMol.**

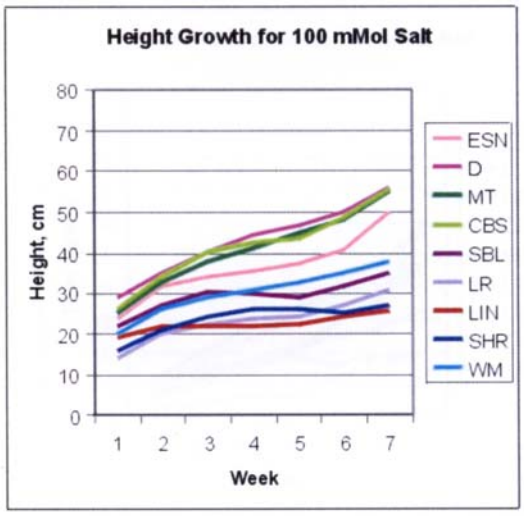


Fig. 3 **Increase in plant height over time for salt treatment of 200 mMol.**

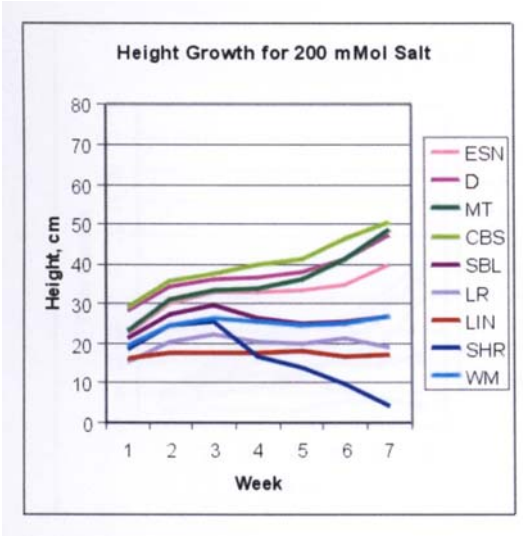


Fig. 4 **Increase in plant height over time for salt treatment of 300 mMol.**

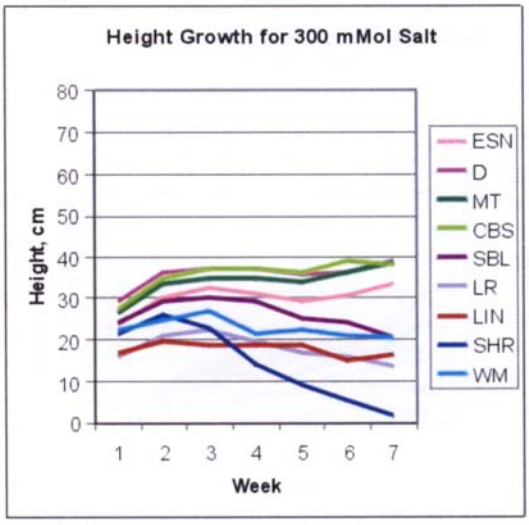


Fig. 5 **Average growth rate of shoot height for each salt treatment**

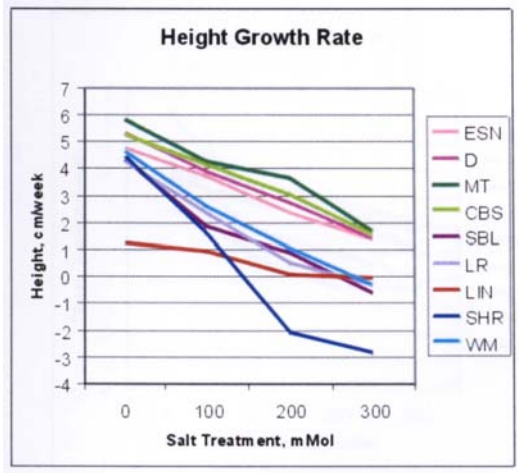


Fig. 6 **Increase in tiller number over time for salt treatment of 0 mMol.**

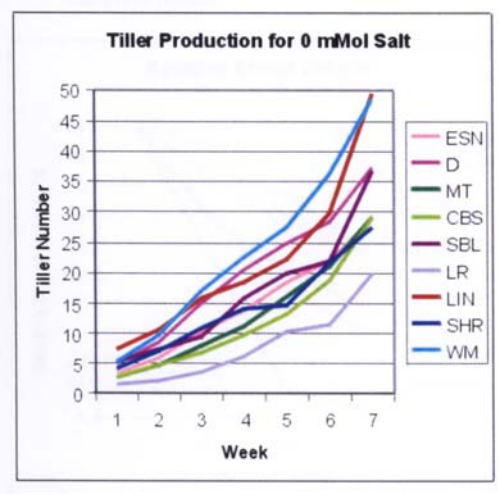


Fig. 7 **Increase in tiller number over time for salt treatment of 100 mMol.**

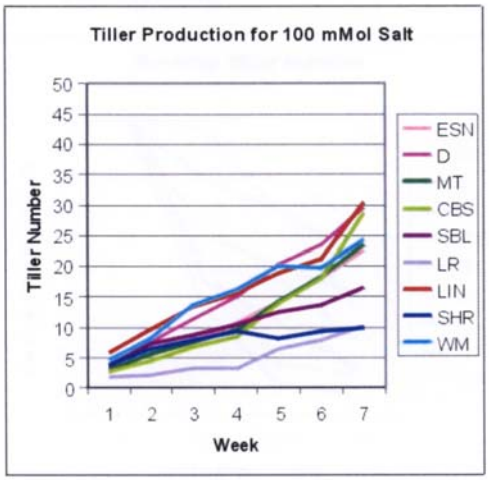


Fig. 8 **Increase in tiller number over time for salt treatment of 200 mMol.**

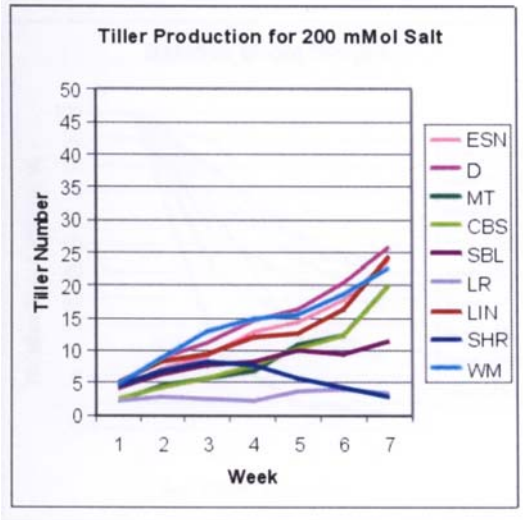


Fig. 9 **Increase in tiller number over time for salt treatment of 300 mMol.**

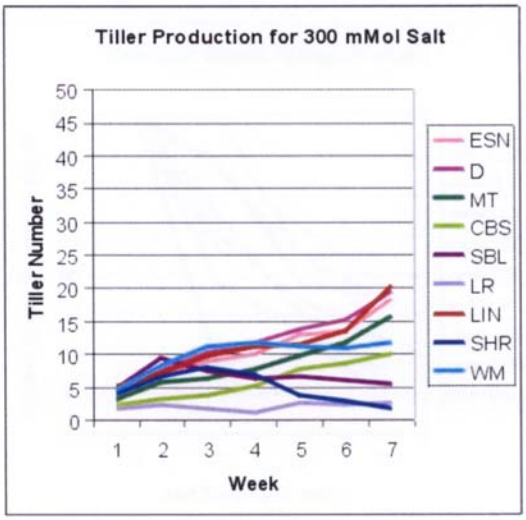


Fig. 10 **Average tiller production rate for each salt treatment**

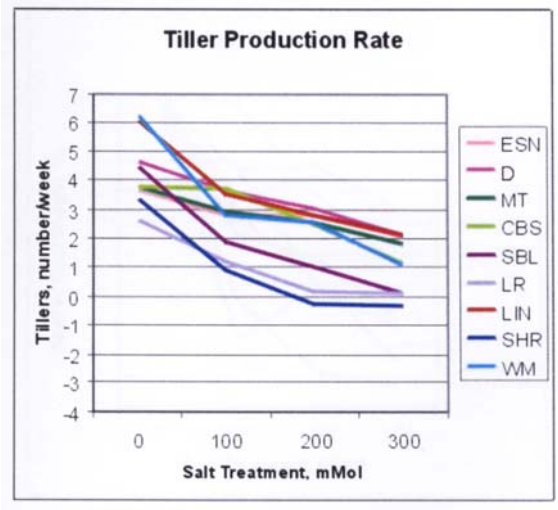


Fig. 11 Shoot height relative to the control (0 mMol salt) treatment.

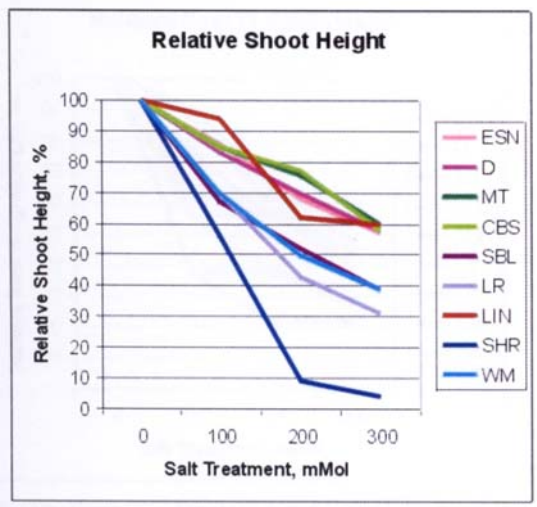


Fig. 12 Tiller number relative to the control (0 mMol salt) treatment.

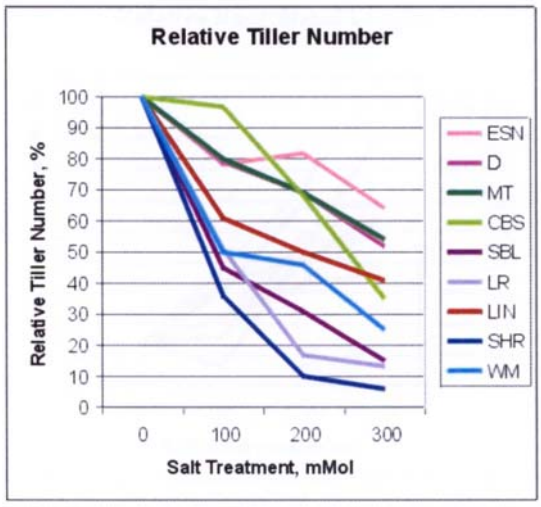


Fig. 13 Shoot weight relative to the control (0 mMol salt) treatment.

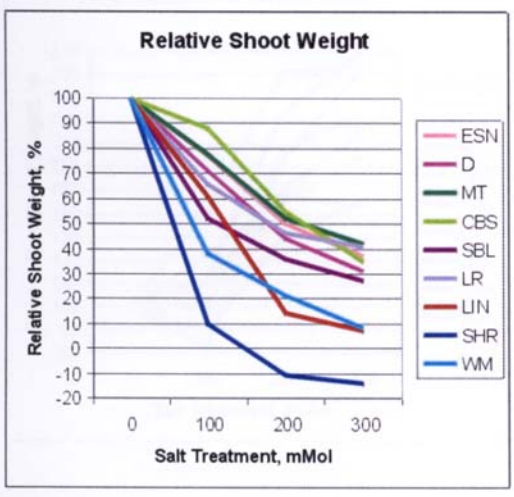


Fig. 14 Shoot density relative to the control (0 mMol salt) treatment.

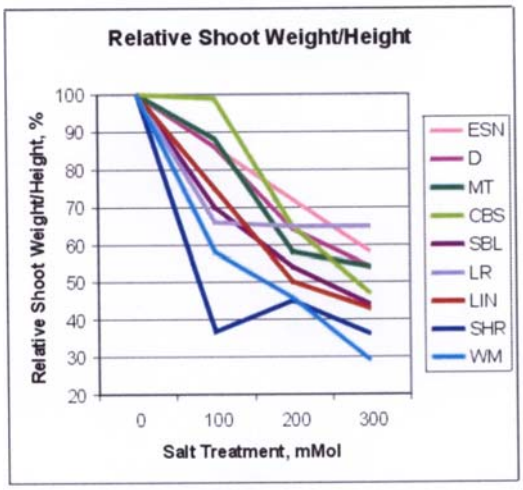


Fig. 15 Root weight relative to the control (0 mMol salt) treatment.

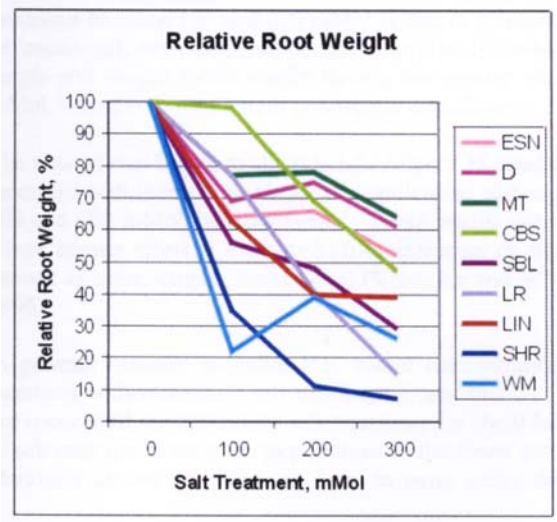


Fig. 16 Root length relative to the control (0 mMol salt) treatment.

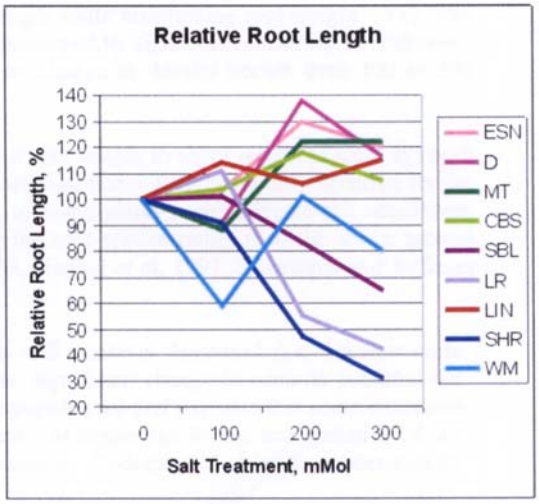


Fig. 17 Root density relative to the control (0 mMol salt) treatment.

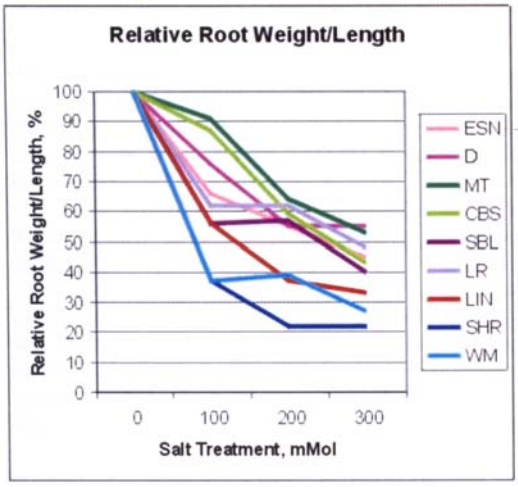


Fig. 18 Root length:Shoot height relative to the control (0 mMol salt) treatment.

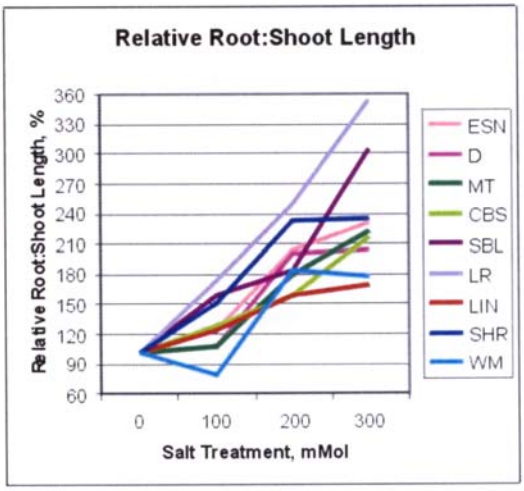
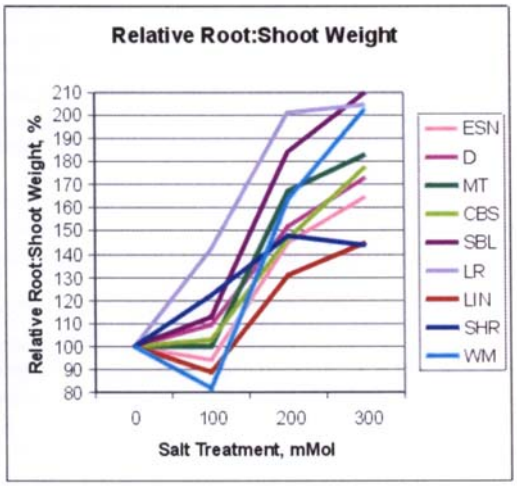


Fig. 19 Root:Shoot weight relative to the control (0 mMol salt) treatment.



Decreased root density (expressed here as weight/unit length) is apparent for all populations (Figure 17) but its causal parameter varies for each population and salt level. For example, decreased root density for *A. adamsonii* between 0 and 100 mMol is due to decreased root weight while maintaining root length, whereas density decreases between 100 and 200 mMol is due to increased root length while maintaining root weight. For WM (*A. avenacea*), decreased root density from 0 to 100 mMol is accompanied by significant decreases in both root length and weight (with weight having the greater effect) but no change in density occurs from 100 to 200 mMol, where both root length and weight significantly increase.

The ratio of root length to shoot height (Figure 18) and the ratio of root weight to shoot weight (Figure 19) both increased with increasing salt for all populations, although for most, significant differences only occurred for the 200 and 300 mMol salt treatments. These results are common to many plants under adverse salt conditions, where greater effort is expended on maintaining or stimulating the root system rather than the above ground growth as a mechanism for survival (Venables and Wilkins 1978, Kenkel et al. 1991, Srivastava and Jefferies 1996).

In general, osmotic potential (i.e. solute concentration) of the cell contents decreased (i.e. became more negative) with increasing salt treatment (Appendix 3). However, significant change in osmotic potential did not occur until the 200 mMol salt treatment for about half of the populations and suggests that some exclusion of salt may occur for these populations at the lower salt treatment. At higher salt levels, accumulation of salt obviously assists the plants to draw in extra water through osmosis. Sodium and chloride concentrations

(where there was sufficient plant material for analyses) significantly increased in both shoots and roots for all populations with increasing salt treatment, except for root sodium in ESN (A. *adamsonii*) (Appendix 3). Populations showing the highest root:shoot sodiums at 200 mMol NaCl were LIN *(Puccinellia),* CBS (*A. robusta*) and D (A. *adamsonii*) at 2.5, 2.3 and 1.7 respectively (Appendix 3), and are also highly salt tolerant populations. Salt tolerant clones of *Festuca rubra* L. and *Agrostis stolonifera* have been shown to restrict sodium accumulation in shoots while non-tolerant clones have equal root and shoot sodium concentrations (Hannon and Barber 1972). In the current study, MT (*A. robusta*), SBL and LR (*A. punicea*) and WM (*A. avenacea*) all had root:shoot sodiums of near 1.0 (range 0.7-1.3) and indicate that other mechanisms apart from salt exclusion and restricted translocation are employed for salt tolerance. Low root:shoot sodiums of less than 0.5 were found, not only in the less tolerant SHR (*A. avenacea*), but also in the highly tolerant ESN (*A. adamsonii*).

Relative water content decreased (and presumably cell hydration) with increasing salt for all species but changes were not significant for WM (*A. avenacea*) and only significant at 300 mMol for SHR (*A. avenacea*), *A. punicea* (LR and SBL) and MT (*A. robusta*) (Appendix 3). The remaining populations did not show significant change in relative water content until 200 mMol salt. Significant evidence for osmotic adjustment was found in all but three populations (LR - *A. punicea,* SHR - *A. avenacea,* LIN - *Puccinellia stricta)* but due to the high variability associated with the measurements that lead to this calculation (particularly osmotic potential), this condition was variable across the treatments (Appendix 3). Osmotic or partial osmotic adjustment appears to be one mechanism for enhancing survival in most of these populations.

Cation concentrations showed significant changes for some species and treatments but they were not consistent. Potassium and magnesium tended to decrease in the shoots as sodium increased with increasing salt treatment, except for D (*A. adamsonii*) and WM (*A. avenacea*) where concentrations increased (Appendix 3). Potassium was largely unchanged in root tissues but did significantly decrease in *A. punicea* and increase in *Puccinellia* (LIN), while magnesium significantly increased in a few populations (I), MT - *A. robusta* and LIN). Calcium also decreased in shoots of D and LIN but increased in the poorly performing LR (*A. punicea*) and SHR (*A. avenacea*) populations (Appendix 3). Root calcium increased for *Puccinellia* only (Appendix 3). These changes in cations with salt treatment probably reflect a combination of preferential uptake, osmotic adjustment, translocation and pre-mature ageing but it was not within the scope of this study to differentiate between these causal effects.

Other nutrient changes with increasing salt were minimal. Significant decrease in sulphur occurred for shoots of *A. robusta* and phosphorus decreased in WM (*A. avenacea)* (Appendix 3). Increased phosphorus in D and LR and increased sulphur in LIN was found for root tissue (Appendix 3).

POPULATION DIFFERENCES

Agrostis adamsonii (ESN and D)
Despite the observed growth differences in the field between these two populations, they performed equally well under the conditions of these trials (Figs. 1-19). In comparing the D population in the first trial to the ESN population (Table 9 for D and Appendix 3 for ESN), plant height in the former tended to be slightly greater throughout the trial but growth rate of height and tiller production was not significantly different at any salt level (statistics not provided). Uptake of sodium, chloride and potassium into the shoots was not significantly different, but D had significantly higher root sodium and lower root potassium at the 200 mMol salt level.

Seasonal effects on growth were apparent when comparing the D populations of the first trial (late winter - mid spring) with the second trial (mid spring - early summer). Significant differences between the populations were measured in a range of parameters (Table 9). In particular, shoot height and its growth rate significantly increased for both the nil and 200 mMol salt treatments (results for the 100 and 300 mMol treatments are not shown here). This result is likely to be due to increased day length and light intensity (despite the whitewashed glasshouse), stimulating more rapid growth and hastening maturity. Some of the plants in the second trial were starting to flower at harvest. In addition to shoot height, shoot weight and weight/tiller significantly increased in the second trial but for the nil treatment only. In contrast, root length and root length:shoot height decreased in the second trial but for the 200 mMol salt treatment only. Shoot potassium and K:Na significantly decreased and, probably as a consequence, osmotic potential increased in the second trial for the nil treatment. In the 200 mMol salt treatment, shoot sodium significantly decreased while root sodium increased. The more rapid growth of the second trial appears to outstrip the plants pace at translocating potassium and sodium from roots to shoots. In Trial 1 plants, potassium is lower in the shoots of the 200 mMol salt treated plants, compared to the control. The reverse is found for Trial 2 plants. Apart from this case, higher potassium in the 200 mMol salt treatment compared to the control is only found in population WM (*A. avenacea)* of Trial 2 and suggests light stimulated effects here as well.

Illustration 1 - 0 mMol NaCI: A. *adamsonii* (ESN), A. *robusta* (MT), A. *punicea* (SBL)

Illustration 2 - 100 m Mol NaCI: A. *adamsonii* (ESN), A. *robusta* (MT), A. *punicea* (SBL)

Illustration 3 - 200 mMol NaCI: A. *adamsonii* (ESN), A. *robusta* (MT), A. *punicea* (SBL)

Illustration 4 - 300 mMol NaCI: A. *adamsonii* (ESN), A. *robusta* (MT), A. *punicea* (SBL)

Table 9 - Mean results for *Agrostis adamsonii* (D) for 0 mMol NaCl (S0) and 200 mMol (S2) treatments in Trials 1 and 2; values in the same row that share the same letter are not significant (where t prob. of pairwise difference <0.05).

Measure	Trial 1		Trial 2	
	S0	S2	S0	S2
Shoot Height, cm.	58.7 *b*	41.0 *a*	76.9 *c*	53.9 *b*
Height Growth Rate, cm/week	4.27 *b*	1.86 *a*	6.45 *c*	3.59 *b*
Shoot Weight, g	5.41 *b*	2.51 *a*	7.80 *c*	3.34 *a*
Shoot Density, g/cm	0.090 *ab*	0.062 *a*	0. 100 *b*	0.061 *a*
Tiller Number	36.7 *b*	25.8 *a*	38.2 *b*	25.8 *a*
Tiller Production Rate, no./week	4.44 *bc*	2.94 *a*	4.83 *c*	3.18 *ab*
Weight/Tiller, g	0.15 *b*	0.10 *a*	0.21 *c*	0. 13 *ab*
Root Length, cm	42.1 *a*	65.1 *c*	43.8 *ab*	53.5 *b*
Root Weight, g	0.59 *a*	0.42 *a*	0.60 *a*	0.47 *a*
Root Density, g/cm.	0.014 *b*	0.006 *a*	0.014 *b*	0.009 *a*
Root Lgt:Shoot Hgt	0.72 *ab*	1.62 *c*	0.58 *a*	1.04 *b*
Root Wgt: Shoot Wgt	0.11 *ab*	0.19 *b*	0.09 *a*	0. 16 *ab*
Relative Water Content, %	100.8 *b*	91.5 *a*	97.0 *ab*	91.7 *a*
Osmotic Potential	-22.6 *b*	-28.1 *b*	-16.7 *a*	-24.1 *b*
Osmotic Adjustment	0.00 *a*	3.43 *a*	0.00 *a*	5.94 *a*
Shoot Sodium, %	0.06 *a*	1.94 *c*	0.09 *a*	1.39 *b*
Shoot Potassium, %	5.73 *c*	4.48 *b*	1.27 *a*	4.12 *b*
Shoot K:Na	101.0 *b*	2.3 *a*	20.1 *a*	3.1 *a*
Shoot Chloride, %	0.94 *a*	3.66 *b*	0.73 *a*	2.90 *b*
Root Sodium, %	0.08 *a*	1.63 *a*	0.08 *a*	3.70 *b*
Root Potassium, %	5.19 *a*	3.41 *a*	3.36 *a*	6.10 *a*
Root K:Na	66.6 *b*	3.7 *a*	48.9 *b*	2.1 *a*
Root Chloride, %	0.45 *a*	3.34 *b*	0.42 *a*	2.73 *b*

Agrostis robusta (MT, CBS)

Shoot height, tiller number and growth rate were very similar for these two populations throughout the trial at each salt level (Figs. 1-5). In addition, shoot and root weights and root lengths at harvest were also similar. Comparison of the two populations for relative tiller number (Fig. 12), relative root weight (Fig. 14), relative shoot density (Fig. 15) and relative root length (Fig. 16) indicate that the CBS population was largely unaffected by salt at the 100 mMol level, whereas MT was showing a decreasing trend in these parameters (80%, 77%, 88% and 88% of the control, respectively). This slightly greater tolerance of CBS to salt is understandable, given the higher site salinity environment in which the population was found. However, at 300 mMol salt, MT shows less relative reduction than CBS for tiller number (54% to 34% respectively) and root weight (64% and 47% respectively) and greater relative root length (122% and 107% respectively). Relative shoot weight and height were very similar between populations over all salt treatments.

Osmotic potential, relative water content and osmotic adjustment were not significantly different between populations. MT did have significantly higher shoot sodium and root chloride at the 200 mMol salt level compared to CBS. Less accumulation of sodium and chloride have been found in a salt-tolerant clone of *A. stolonifera* compared to a salt-senstitive clone (Hodson *et al. 1985)* and again supports CBS as being, at least slightly, more salt-tolerant than MT.

Agrostis punicea (LR, SBL)

Shoot height (Figs. 1-4) and tiller number (Figs. 6-9) were always higher in SBL compared to LR throughout the trial, but only consistently significant in the 0 mMol treatment. This result suggests a genetic difference in these characteristics. When treated with 100, 200 and 300 mMol salt, shoot height and tiller number were almost always significantly higher in SBL up to week 4. From weeks *5* to *7*, shoot height in SBL was only significantly higher than LR for the highest salt treatment and tiller number did not show any significant differences (apart from the nil treatment). Growth rate in shoot height was similar between the populations regardless of salt treatment (Fig. 5). Overall tiller production rate was slightly higher in SBL than in LR with tiller production ceasing at 300 mMol and 200 mMol for SBL and LR respectively (Fig. 10) and tiller die-back occurring from week *2*. The greater salt tolerance displayed by SBL is consistent with this population deriving from a saline environment compared to LR from a non-saline one.

Illustration 5 – General view of growing trial set

Illustration 6 - 0, 100, 200, 300 mMol NaCI: *Poa salacustris*

Illustration 7 - 0 mMol NaCl: *A. adamsonii* (D), *Puccinellia stricta* (LIN), *A. avenacea* (SHR and WM)

Illustration 8- 200 mMol NaCl: *A. adamsonii* (D), *Puccinellia stricta* (LIN), *A. avenacea* (SHR and WM)

At harvest, shoot and root weights and root lengths were lower in all LR plots compared to SBL. However, relative shoot weight (Fig. 13) was about 10% higher in all salt treated LR compared to SBL, as was relative root weight (Fig. 15) for 100 mMol salt. In contrast, relative root weight at 300 mMol and relative root length (Fig. 16) at both 200 mMol and 300 mMol were lower for LR and confirms the greater intolerance of this population to increasing salt, particularly in its root system. Relative water content was critically low (<70%) at 300 mMol salt in the LR population and osmotic adjustment was only discernible between 200 mMol and 300 mMol and the control for SBL. In addition, shoot sodium was significantly higher and shoot and root K:Na were significantly lower in LR than in SBL. These results all reflect the greater salt tolerance of SBL compared to LR (Hodson *et al.* 1985).

Agrostis avenacea (SHR, WM)

Large differences in growth characteristics were measured between the populations of this species. Shoot height differences between the weaker SHR and the stronger WM populations were apparent from week 4 for the salt treatments and particularly at the 200 mMol and 300 mMol levels. Growth rate difference was also noticeable from the 200 mMol salt level. However, height and growth rate for the two populations were not significantly different at the nil salt level. Tiller numbers and tiller production rate were lower in SHR throughout the trial and at all salt treatments, including the control; suggesting an inherent difference in this characteristic. Also, SHR displayed considerable tiller die-back at the higher salt levels, from about week 3; which was not apparent in WM. The SHR population appears to have some salt tolerance at the 100 mMol level, which represents about three times the salt concentration of the site it was collected from, but struggles to survive at higher salinities. In contrast, the WM population maintains reasonable height and tiller numbers, even at 300 mMol salt and indicates a considerable degree of inherent adaptability.

At harvest, WM showed a significant increase in root length and weight at the 200 mMol salt level compared to the 100 mMol treatment, denoting a response to the imposed stress. At 300 mMol, root length and weight decrease but not significantly so from 200 mMol. The SHR population does not show this response.

Some decrease in relative water content was seen in SHR (i.e. in the remaining green leaves) but there was no significant change in osmotic adjustment. In contrast, there was no significant change in relative water content for WM and some osmotic adjustment is evident. Sodium and chloride concentrations were significantly lower and potassium and K:Na significantly higher in the shoots of WM compared to SHR. The shoot potassium in 200 mMol salt treated WM plants was significantly higher than the control; the increased uptake appearing to be a mechanism to control solute concentration of sodium while maintaining cell turgor.

Despite SHR deriving from a saline environment, it did not perform as well as WM from a non-saline site. Generally it has been found that grass populations growing in saline environments have greater salt tolerance than those growing on non-saline sites (Ahmad *et al.* 1981, Wu 1981, Partridge and Wilson 1987, Kik 1989). However, studies with *A. stolonifera* have shown that populations from non-saline environments can have similar (Ashraf 1986) or greater (Kik *et aL* 1987, Kik 1989) genetic variability in terms of salt tolerance, compared to populations from saline sites. Evidence also shows strong selection within field populations of *A. stolonifera* and other grasses to adjust the level of salt tolerance response at each point of a salinity gradient (Venables and Wilkins 1978).

The results obtained in the second trial for both populations, did not show as good salt tolerance as that obtained elsewhere. For example, a New Zealand coastal salt-marsh study obtained maximum growth for *Lachnagrostis filiformis* (syn. *Agrostis avenacea)* at 0.9% NaCl salt solution concentration (equiv. to 150 mMol) and half maximum growth at 2.5% NaCl (equiv. to 430 mMol) (Partridge and Wilson 1987), whereas SHR and WM was reduced to half growth at approximately 55 and 75 mMol NaCl respectively. However, this study was conducted with plants taken from the field, rather than with plants grown from seed, and may imply that natural selection has provided the greater degree of salt tolerance.

OBSERVATIONS OF *POA SALACUSTRIS*

Similar effects of increasing salt on growth rate and harvest was found for *Poa salacustris* (Table 10) as was found for the other studied species: shoot height growth rate decreased from 3.2 cm/week at nil salt to no growth at 300 mMol salt and tiller production decreased from 11/week to 1.3/week; 300 mMol salt treated plants were only 36%, 22% 11% and 23% of nil salt plants for shoot height, tiller number, shoot weight and root weight respectively (much of the decrease occurring from nil to 100 mMol); root length at the highest salt level only decreased by 20% from the control. In terms of shoot height growth rate and harvest shoot height, *Poa* showed a similar response to salinity as did WM (*A. avenacea*) and *A. punicea* except for a lower growth rate in the nil salt treatment. Relative shoot and root weight reduction with salinity was similar to WM. Tiller number was very high at 0 mMol salt, being at least twice that of the highest result for other populations (LIN and WM). A proliferation of short rhizomes was also evident. Tiller number rapidly reduced with salt addition (eg. 35% of the control at 100 mMol). Only one plant died; at the 300 mMol salt level.

Illustration 9 - 0, 100, 200, 300 mMol NaCl:
Agrostis adamsonii (D)

Illustration 10 - 0, 100, 200, 300 mMol NaCl:
Puccinellia stricta var. *perlaxa* (LIN)

Illustration 11 - 0, 100, 200, 300 mMol NaCl:
Agrostis avenacea (SHR)

Illustration 12 - 0, 100, 200, 300 mMol NaCl:
Agrostis avenacea (SHR)

Table 10 - Mean growth, harvest, physiological and nutrient tissue concentration results for four plants/un-replicated treatment of *Poa salacustris*.

Measurement	0 mMol	100 mMol	200 mMol	300 mMol
Growth rate: Shoot height, cm/week	3.2	2.1	1.4	0.0
Growth rate: Tiller number, tillers/week	11.0	3.5	2.3	1.3
Harvest: Shoot height, cm	42.8	31.5	27.0	15.5
Harvest: Tiller number	88.0	31.3	20.8	19.0
Harvest: Root length, cm	30.5	32.8	26.5	24.3
Harvest: Root length:Shoot height	0.71	1.04	0.98	1.57
Harvest: Shoot weight, g	10.53	2.55	2.15	1.13
Harvest: Weight/tiller, g	0.12	0.08	0.10	0.06
Harvest: Shoot density (wgt/hgt), g/cm	0.25	0.08	0.08	0.07
Harvest: Root weight, g	0.60	0.16	0.17	0.14
Harvest: Root density (wgt/lgt), g/cm	0.020	0.005	0.006	0.006
Harvest: Root:Shoot weight	0.057	0.062	0.079	0.124
Harvest: Total biomass, g	11.13	2.71	2.32	1.27
Relative Water Content, %	88.5	90.5	98.9	72.8
Osmotic Potential, bars	-21.04	-22.30	-26.50	-29.80
Osmotic Adjustment, bars	0.00	-1.60	-7.83	-2.44
Shoot Sodium, %	0.08		3.00	
Root Sodium, %	0.09		1.60	
Root:Shoot Sodium	1.13		0.53	
Shoot Potassium, %	5.10		2.70	
Root Potassium, %	4.20		3.60	
Shoot K:Na	63.8		0.90	
Root K:Na	46.7		2.25	
Shoot Chloride, %	0.79		5.30	
Root Chloride, %	0.46		na	
Root:Shoot Chloride	0.58		na	
Shoot Na:CI	0.10		0.57	
Root Na:CI	0.20		na	
Shoot Magnesium, %	0.16		0.10	
Root Magnesium, %	0.09		0.10	
Shoot Calcium, %	0.37		0.24	
Root Calcium, %	0.25		0.15	
Shoot Phosphorus, %	0.87		0.76	
Root Phosphorus, %	0.78		0.82	
Shoot Sulphur, %	0.38		0.30	
Root Sulphur, %	0.63		0.54	

While osmotic potential decreased with increasing salt, relative water content appears to increase to 200 mMol salt before showing a 26% reduction at 300 mMol. Consequently, some osmotic adjustment is evident at 200 mMol salt. However, without replication, the significance of these differences cannot be ascertained.

Increased concentrations in sodium (shoots and roots) and chloride (shoots) was seen in the comparison of the nil and 200 mMol salt treatments with decreased potassium, calcium and sulphur (shoots and roots) and magnesium (shoots). No large change occurred for phosphorus. These trends were also evident in the majority of other populations.

Even though growth was markedly reduced (half maximum growth occurring at 60 mMol NaCl), *Poa salacustris* displayed only one death out of sixteen plants (or one in twelve salt treated plants) and that at 300 mMol NaCl (Table7). In comparison, a New Zealand salt-marsh species; *Poa laevis*, has shown half maximum growth at 1.0% NaCl (equiv. to 170 mMol NaCl) and deaths occurring from 1.6% NaCl (equiv. to 270 mMol NaCl) (Partridge and Wilson 1987). Although naturally growing near salt lakes, *Poa salacustris* does not occur where soils are any more than very slightly saline. The only Australian *Poa* known to tolerate saline conditions is the small annual; *P. fax*. Likewise, in a New Zealand study of sand dune plant species, *Poa pusilla* (a rhizomic species) was less tolerant of salt than the wheat that represented the glycophytic control (Sykes and Wilson 1989). However, salt tolerant accessions of *P. alpina* (Acharya et al. 1992) and *P. pratensis* (Horst and Taylor 1983) have been sourced and suggests that some selection of *P. salacustris* may also be possible.

Cultural Requirements and Site Rehabilitation

Germination requirements are varied, not only between the species studied but between populations within species. Breaking of dormancy for *Agrostis adamsonii*, *A. robusta* and *Puccinellia stricta* var. *perlaxa* is adversely affected by light and suggests that seed should be stored in dark conditions prior to sowing. The period of dark storage required is unknown. In contrast, *A. punicea* germination is dependent on light conditions. In addition, *A. punicea* displays delayed germination after sowing compared to almost immediate germination of the other species (most within 1-2 weeks).

Germination is adversely affected by salt for at least the species tested here (*A. adamsonii*, *A. robusta* and *Puccinellia stricta*) and suggests that field sowings would be more successful after leaching winter rains than during autumn (particularly relatively dry autumns). *Agrostis robusta* and *Puccinellia* are likely to be more useful than *A. adamsonii* where soil salt levels are high. Practically no information on suitable germination conditions for *Poa salacustris* and *Distichlis distichophylla* were obtained from the current study. Improved germination for these species and for some of the *Agrostis* spp. and *Puccinellia* may result from a fluctuating temperature regime but this is still to be tested. Long-term viability of seed was not studied, but four year old seed of all of the *Agrostis* species were successfully germinated under nursery glasshouse conditions.

Growth rate and plant vigour were particularly impressive for *A. adamsonii* and *A. robusta*, even at the highest salt treatment and would be particularly useful where rapid establishment and ground cover is required. Field monitoring studies suggest that tussocks of these species will persist for at least three seasons, provided site conditions remain moist (A.J. Brown, pers. comm).

Agrostis punicea is not a vigorous species but it could still be used in low to moderately saline land. It is a most attractive grass, with its pinkish-purple, relatively large and diffuse inflorescences. Some genetic diversity, between populations was evident in their varying response to saline conditions and suggests that some selection for suitable strains may be necessary.

Agrostis avenacea displayed considerable genetic diversity and obviously further study of this taxon is warranted in this regard. In particular, the adaptability of the WM population from a non-saline situation to saline conditions was remarkable and although not as tolerant as *A. robusta* and *A. adamsonii*, it nevertheless displayed good growth rates and tiller numbers. The SHR population would be useful for slightly saline sites.

Puccinellia appears to have a much slower growth rate than the *Agrostis* species and is likely to be a longer-term coloniser of saline land. Although salt tolerance characteristics displayed in the current trial were variable (e.g. reasonable maintenance of relative shoot height and root length and good tiller production but sharp decrease in shoot and root weights), field observations are that *Puccinellia* inhabits the most saline portions of the landscape at any site (eg. LIN). It may be that salt tolerance in *Puccinellia* increases with age. A comparison of half maximum growth between *Puccinellia stricta* var. *stricta* plants transferred to salt solutions from a salt-marsh (Partridge and Wilson 1987), to the seed raised plants in the current trial are; 2.1% NaCl (equiv. to 360 mMol NaCl) and 125 mMol NaCl respectively. Other work has shown that *Puccinellia* spp., as well as being highly salt tolerant, are also highly tolerant of waterlogged or anaerobic conditions (Cooper 1982, Huckle et al. 2000).

The place of *Poa salacustri*s is still uncertain without further study. In the field, it is found on the upper beach margins of salt lakes where soil salt concentrations are relatively low. Indications from the current study suggest that it has a reasonably high salt tolerance, at least, once established. It may not tolerate the waterlogged conditions that often accompany saline conditions. It has a prolific rhizomatous root system and would be useful in soil binding situations.

All of the tested species have potential for use in rehabilitating saline soils and, for the purpose of preserving or enhancing native plant biodiversity, would be preferred over introduced exotics. However, the results of this study show that their potential use is varied in relation to the severity of salting requiring redress and the rate of colonisation needed. Some species (eg. *Puccinellia*, *Poa* and *Distichlis* spp.) and populations (eg. ESN *Agrostis adamsonii*) need further work to determine their germination requirements and all species would benefit from a better understanding of their soil moisture requirements, including tolerance to drought (either periodic or long-term). Establishment under field conditions and management of established communities is the obvious next phase of work required. None of the species tested displayed a salt requirement, despite many of them only occurring in saline situations in the field. One conclusion from this result would be that they have been out-competed by other more vigorous species in non-saline sites. If this is so, adequate management of exotic invading species (eg. *Plantain* spp.) on saline sites would be vital to the success of re-establishment attempts.

Acknowledgments:
German Spangenberg and his team (particularly Clinton Le Page and Ulrich John) at the Plant Biotechnology Centre, Agriculture Victoria, Department of Natural Resources and Environment are warmly acknowledged for their provision of controlled temperature glasshouse facilities, equipment and chemicals for the growth trials. Their advice and encouragement throughout the trial period was extremely helpful. Thanks are also due to John Reynolds of Agriculture Victoria for biometric services and to the nursery staff at the Royal Botanic Gardens Melbourne for provision of glasshouse facilities and ongoing maintenance of seedlings produced for the study. The State Chemistry Laboratory, Agriculture Victoria provided the chemical analysis of plant tissue.

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APPENDIX 1: DESIGN FOR 1st SALINITY TOLERANCE TRIAL

Block one		**Block two**		**Block three**		**Block four**	
S2	S1	S0	S1	S0	S1	S2	S3
6 3	2 5	4 2	5 4	6 5	6 4	5 3	4 3
5 4	1 3	6 1	3 1	2 4	3 1	6 2	5 1
1 3	6 4	5 3	2 6	1 3	3 2	4 1	6 2
S0	S3	S2	S3	S3	S2	S0	S1
4 6	3 1	5 3	3 1	4 6	3 4	6 4	2 4
3 2	5 6	4 1	5 6	1 3	6 2	2 5	6 5
1 5	4 2	2 6	4 2	5 2	5 1	1 3	1 3

1. Each block (replicate) was located on a separate bench in the glasshouse but aligned as shown

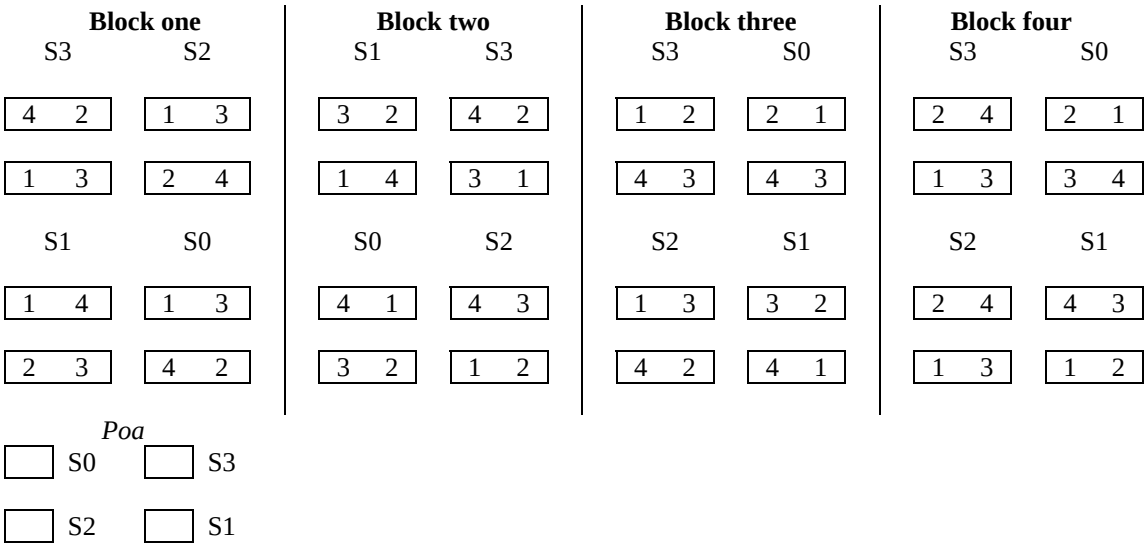
2. Treatments: S0 = control (no salt), S1 = 100 mM salt, S2 = 200 mM salt, S3 = 300 mM salt (randomised within blocks)

3. Each rectangle represents a single undivided tub (contains nutrient solution), made up of two squares to represent two plots

4. Nos. 1, 2, 3, 4, 5 and 6 are separate plant populations (randomised within treatments): 1 = *Agrostis adamsonii* (ESN), 2 = *A. adamsonii* (D), 3 = *A. robusta* (MT), 4 = *A. robusta* (CBS), 5 = *A. punicea* (SBL), 6 = *A. punicea* (LR).

5. Each plot contains 4 plants (plants are held at the shoot/root junction by foam in holes drilled through the lids of tubs)

APPENDIX 2: DESIGN FOR 2nd SALINITY TOLERANCE TRIAL



1. Each block (replicate) was located on a separate bench in the glasshouse but aligned as shown

2. Treatments: S0 = control (no salt), S1 = 100 mM salt, S2 = 200 mM salt, S3 = 300 mM salt (randomised within blocks)

3. Each rectangle represents a single undivided tub (contains nutrient solution), made up of two squares to represent two plots

4. Nos. 1, 2, 3 and 4 are separate plant populations (randomised within treatments): 1 = *Agrostis adamsonii* (D), 2 = *Puccinellia stricta* var. *perlaxa* (LIN), 3 = *A. avenacea* (SHR), 4 = *A. avenacea* (WM).

5. Each plot contains 4 plants (plants are held at the shoot/root junction by foam in holes drilled through the lids of tubs)

6. Four extra tubs (one per salt treatment); each of four plants of *Poa salacustris* were situated on bench one for observation and measurement.

APPENDIX 3: MEAN VALUES FOR HARVEST RESULTS AND SIGNIFICANT DIFFERENCES BETWEEN SALT TREATMENTS (treatments as for Appendix 1)

[#]data log transformed before analysis, though means presented are non-log transformed, * significant where t prob. of pairwise differences <0.05, ns = non significant.

Agrostis adamsonii (ESN)

Shoot Height, cm		S0	S1	S2	S3
	S0	58.4			
	S1	*	50.0		
	S2	*	*	39.6	
	S3	*	*	ns	33.5

Root Length, cm		S0	S1	S2	S3
	S0	49.2			
	S1	ns	50.9		
	S2	*	*	64.1	
	S3	ns	ns	ns	59.1

Shoot Sodium, %		S0	S2
	S0	0.03	
	S2	*	1.59

Root Sodium, %		S0	S2
	S0	0.20	
	S2	ns	0.63

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	5.28			
	S1	ns	4.06		
	S2	*	ns	2.65	
	S3	*	*	ns	1.93

Root Weight, g[#]		S0	S1	S2	S3
	S0	0.73			
	S1	*	0.47		
	S2	*	ns	0.48	
	S3	*	ns	ns	0.38

Shoot Potassium, %		S0	S2
	S0	5.19	
	S2	*	3.29

Root Potassium, %		S0	S2
	S0	5.88	
	S2	ns	4.23

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.093			
	S1	ns	0.080		
	S2	*	ns	0.067	
	S3	*	*	ns	0.054

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.015			
	S1	*	0.010		
	S2	*	ns	0.008	
	S3	*	ns	ns	0.007

Shoot K:Na		S0	S2
	S0	123.5	
	S2	*	-6.6

Root K:Na		S0	S2
	S0	67.6	
	S2	*	7.4

Tiller Number#		S0	S1	S2	S3
	S0	28.8			
	S1	ns	22.5		
	S2	ns	ns	23.7	
	S3	ns	ns	ns	18.4

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	0.94			
	S1	ns	1.17		
	S2	*	*	1.91	
	S3	*	*	ns	2.17

Shoot Chloride, %		S0	S2
	S0	1.03	
	S2	*	4.13

Root Chloride, %		S0	S2
	S0	0.50	
	S2	*	4.19

Shoot Na:Cl		S0	S2
	S0	0.055	
	S2	*	0.402

Root Na:Cl*		S0	S2
	S0	0.180	
	S2	ns	0.133

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.190			
	S1	ns	0.169		
	S2	*	*	0.113	
	S3	*	*	ns	0.096

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.16			
	S1	ns	0.15		
	S2	*	*	0.24	
	S3	*	*	ns	0.27

Root:Shoot Na		S0	S2
	S0	2.114	
	S2	*	0.494

Root:Shoot K		S0	S2
	S0	1.212	
	S2	ns	1.243

Root:Shoot Cl		S0	S2
	S0	0.517	
	S2	*	1.033

Total Biomass, g		S0	S1	S2	S3
	S0	6.00			
	S1	*	4.52		
	S2	*	*	3.11	
	S3	*	*	ns	2.29

Relative Water, %		S0	S1	S2	S3
	S0	99.0			
	S1	ns	96.3		
	S2	*	*	87.1	
	S3	*	*	ns	80.3

Shoot Calcium, %		S0	S2
	S0	0.3	
	S2	ns	0.21

Root Calcium, %		S0	S2
	S0	0.21	
	S2	ns	0.20

Shoot Magnesium, %		S0	S2
	S0	0.16	
	S2	*	0.11

Root Magnesium, %		S0	S2
	S0	0.16	
	S2	ns	0.16

Shoot Phosphorus, %		S0	S2
	S0	0.78	
	S2	ns	0.75

Root Phosphorus, %		S0	S2
	S0	0.77	
	S2	ns	1.44

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-18.0			
	S1	*	-23.3		
	S2	*	*	-31.9	
	S3	*	*	ns	-29.2

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	0.14			
	S1	ns	4.75		
	S1	*	ns	9.35	
	S3	ns	ns	ns	4.63

Shoot Sulphur, %		S0	S2
	S0	0.39	
	S2	ns	0.40

Root Sulphur, %		S0	S2
	S0	0.77	
	S2	ns	0.80

Agrostis adamsonii (D)

Shoot Height, cm		S0	S1	S2	S3
	S0	67.6			
	S1	*	56.2		
	S2	*	*	47.4	
	S3	*	*	ns	39.3

Root Length, cm		S0	S1	S2	S3
	S0	42.9			
	S1	ns	38.9		
	S2	*	*	59.3	
	S3	ns	*	*	49.7

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	6.60			
	S1	ns	4.68		
	S2	*	ns	2.93	
	S3	*	*	ns	2.04

Root Weight, g[#]		S0	S1	S2	S3
	S0	0.59			
	S1	*	0.41		
	S2	*	ns	0.44	
	S3	*	ns	ns	0.36

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.095			
	S1	ns	0.082		
	S2	*	ns	0.062	
	S3	*	*	ns	0.051

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.014			
	S1	*	0.011		
	S2	*	ns	0.008	
	S3	*	ns	ns	0.008

Tiller Number#		S0	S1	S2	S3
	S0	37.4			
	S1	ns	29.5		
	S2	ns	ns	25.8	
	S3	*	*	ns	19.5

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	0.965			
	S1	ns	0.70		
	S2	*	*	1.30	
	S3	*	*	ns	2.17

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.179			
	S1	ns	0.157		
	S2	*	*	0.114	
	S3	*	*	ns	0.106

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.11			
	S1	ns	0.12		
	S2	*	*	0.16	
	S3	*	*	ns	0.18

Total Biomass, g		S0	S1	S2	S3
	S0	7.18			
	S1	*	5.09		
	S2	*	*	3.38	
	S3	*	*	*	2.40

Relative Water, %		S0	S1	S2	S3
	S0	98.9			
	S1	ns	96.4		
	S2	*	ns	91.6	
	S3	*	*	ns	88.2

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-19.6			
	S1	*	-22.0		
	S2	*	*	-26.1	
	S3	*	*	ns	-28.0

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	0.00			
	S1	ns	1.96		
	S1	*	ns	4.69	
	S3	*	ns	ns	5.05

Shoot Sodium, %		S0	S2
	S0	0.08	
	S2	*	1.65

Root Sodium, %		S0	S2
	S0	0.08	
	S2	*	2.64

Shoot Potassium, %		S0	S2
	S0	3.48	
	S2	*	4.30

Root Potassium, %		S0	S2
	S0	4.18	
	S2	ns	4.64

Shoot K:Na		S0	S2
	S0	60.7	
	S2	*	2.7

Root K:Na		S0	S2
	S0	58.0	
	S2	*	2.9

Shoot Chloride, %		S0	S2
	S0	0.84	
	S2	*	3.30

Root Chloride, %		S0	S2
	S0	0.43	
	S2	*	2.99

Shoot Na:Cl		S0	S2
	S0	0.092	
	S2	*	0.50

Root Na:Cl*		S0	S2
	S0	0.193	
	S2	*	0.926

Root:Shoot Na		S0	S2
	S0	1.242	
	S2	*	1.712

Root:Shoot K		S0	S2
	S0	1.738	
	S2	ns	1.080

Root:Shoot Cl		S0	S2
	S0	0.514	
	S2	*	0.938

Shoot Calcium, %		S0	S2
	S0	0.35	
	S2	ns	0.26

Root Calcium, %		S0	S2
	S0	0.20	
	S2	ns	0.24

Shoot Magnesium, %		S0	S2
	S0	0.13	
	S2	*	0.09

Root Magnesium, %		S0	S2
	S0	0.11	
	S2	*	0.17

Shoot Phosphorus, %		S0	S2
	S0	0.88	
	S2	ns	0.92

Root Phosphorus, %		S0	S2
	S0	0.84	
	S2	*	2.39

Shoot Sulphur, %		S0	S2
	S0	0.35	
	S2	ns	0.33

Root Sulphur, %		S0	S2
	S0	0.57	
	S2	ns	0.76

Agrostis robusta (MT)

Shoot Height, cm		S0	S1	S2	S3
	S0	64.1			
	S1	*	55.1		
	S2	*	ns	49.0	
	S3	*	*	*	38.8

Root Length, cm		S0	S1	S2	S3
	S0	36.5			
	S1	ns	32.2		
	S2	ns	*	44.3	
	S3	ns	*	ns	44.3

Shoot Sodium, %		S0	S2
	S0	0.04	
	S2	*	2.28

Root Sodium, %		S0	S2
	S0	0.19	
	S2	*	2.38

Shoot Weight,g#		S0	S1	S2	S3
	S0	3.26			
	S1	ns	2.55		
	S2	*	*	1.71	
	S3	*	*	ns	1.36

Root Weight, g#		S0	S1	S2	S3
	S0	0.38			
	S1	ns	0.29		
	S2	ns	ns	0.29	
	S3	ns	ns	ns	0.24

Shoot Potassium, %		S0	S2
	S0	4.24	
	S2	*	2.82

Root Potassium, %		S0	S2
	S0	4.66	
	S2	ns	3.98

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.049			
	S1	ns	0.043		
	S2	ns	ns	0.028	
	S3	*	ns	ns	0.027

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.010			
	S1	ns	0.009		
	S2	*	ns	0.007	
	S3	*	*	ns	0.005

Shoot K:Na		S0	S2
	S0	79.8	
	S2	*	-8.2

Root K:Na		S0	S2
	S0	47.3	
	S2	*	-0.07

Tiller Number#		S0	S1	S2	S3
	S0	29.2			
	S1	ns	23.5		
	S2	ns	ns	20.2	
	S3	ns	ns	ns	15.8

Root:Shoot Length#		S0	S1	S2	S3
	S0	0.62			
	S1	ns	0.67		
	S2	*	*	1.12	
	S3	*	*	ns	1.40

Shoot Chloride, %		S0	S2
	S0	0.87	
	S2	*	3.88

Root Chloride, %		S0	S2
	S0	0.44	
	S2	*	4.29

Shoot Na:Cl		S0	S2
	S0	0.079	
	S2	*	0.586

Root Na:Cl*		S0	S2
	S0	0.181	
	S2	*	0.500

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.105			
	S1	ns	0.115		
	S2	*	*	0.068	
	S3	ns	*	ns	0.072

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.15			
	S1	ns	0.15		
	S2	*	*	0.25	
	S3	*	*	ns	0.27

Root:Shoot Na		S0	S2
	S0	1.453	
	S2	*	1.052

Root:Shoot K		S0	S2
	S0	1.155	
	S2	ns	1.304

Root:Shoot Cl		S0	S2
	S0	0.629	
	S2	*	1.141

Total Biomass, g		S0	S1	S2	S3
	S0	3.63			
	S1	ns	2.83		
	S2	*	ns	2.00	
	S3	*	*	ns	1.58

Relative Water, %		S0	S1	S2	S3
	S0	98.7			
	S1	ns	97.0		
	S2	ns	ns	92.6	
	S3	*	*	ns	86.5

Shoot Calcium, %		S0	S2
	S0	0.36	
	S2	ns	0.29

Root Calcium, %		S0	S2
	S0	0.22	
	S2	ns	0.24

Shoot Magnesium, %		S0	S2
	S0	0.15	
	S2	*	0.10

Root Magnesium, %		S0	S2
	S0	0.14	
	S2	ns	1.14

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-20.0			
	S1	*	-26.7		
	S2	*	*	-31.9	
	S3	*	ns	ns	-31.3

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	0.14			
	S1	*	6.04		
	S1	*	ns	9.41	
	S3	*	ns	ns	6.79

Shoot Phosphorus, %		S0	S2
	S0	0.82	
	S2	ns	0.74

Root Phosphorus, %		S0	S2
	S0	0.59	
	S2	*	2.39

Shoot Sulphur, %		S0	S2
	S0	0.51	
	S2	*	0.43

Root Sulphur, %		S0	S2
	S0	0.47	
	S2	ns	0.43

Agrostis robusta (CBS)

Shoot Height, cm		S0	S1	S2	S3
	S0	65.3			
	S1	*	55.5		
	S2	*	ns	50.3	
	S3	*	*	*	38.2

Root Length, cm		S0	S1	S2	S3
	S0	42.6			
	S1	ns	44.2		
	S2	ns	ns	50.2	
	S3	ns	ns	ns	45.7

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	3.10			
	S1	ns	2.74		
	S2	*	*	1.71	
	S3	*	*	*	1.09

Root Weight, g[#]		S0	S1	S2	S3
	S0	0.44			
	S1	ns	0.43		
	S2	ns	ns	0.31	
	S3	*	*	ns	0.21

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.046			
	S1	ns	0.045		
	S2	ns	ns	0.030	
	S3	*	*	ns	0.022

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.011			
	S1	ns	0.009		
	S2	*	ns	0.006	
	S3	*	*	ns	0.005

Tiller Number#		S0	S1	S2	S3
	S0	29.2			
	S1	ns	28.7		
	S2	ns	ns	20.0	
	S3	*	*	*	10.1

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	0.71			
	S1	ns	0.92		
	S2	*	ns	1.13	
	S3	*	*	ns	1.54

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.106			
	S1	ns	0.089		
	S2	ns	ns	0.079	
	S3	ns	ns	ns	0.083

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.17			
	S1	ns	0.17		
	S2	*	*	0.25	
	S3	*	*	*	0.30

Total Biomass, g		S0	S1	S2	S3
	S0	3.53			
	S1	ns	3.16		
	S2	*	ns	2.00	
	S3	*	*	*	1.28

Relative Water, %		S0	S1	S2	S3
	S0	98.7			
	S1	ns	96.3		
	S2	*	ns	90.3	
	S3	*	*	ns	87.7

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-20.7			
	S1	*	-25.3		
	S2	*	*	-29.6	
	S3	*	ns	ns	-33.0

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	0.13			
	S1	ns	4.13		
	S1	ns	ns	5.72	
	S3	*	ns	ns	8.14

Shoot Sodium, %		S0	S2
	S0	0.05	
	S2	*	1.14

Root Sodium, %		S0	S2
	S0	0.18	
	S2	*	1.91

Shoot Potassium, %		S0	S2
	S0	4.59	
	S2	*	3.07

Root Potassium, %		S0	S2
	S0	4.76	
	S2	ns	2.86

Shoot K:Na		S0	S2
	S0	65.0	
	S2	*	-5.8

Root K:Na		S0	S2
	S0	59.2	
	S2	*	0.1

Shoot Chloride, %		S0	S2
	S0	1.09	
	S2	*	4.11

Root Chloride, %		S0	S2
	S0	0.51	
	S2	*	3.11

Shoot Na:Cl		S0	S2
	S0	0.066	
	S2	*	0.318

Root Na:Cl*		S0	S2
	S0	0.143	
	S2	*	0.586

Root:Shoot Na		S0	S2
	S0	1.136	
	S2	ns	2.270

Root:Shoot K		S0	S2
	S0	1.108	
	S2	ns	0.956

Root:Shoot Cl		S0	S2
	S0	0.511	
	S2	ns	0.797

Shoot Calcium, %		S0	S2
	S0	0.41	
	S2	ns	0.33

Root Calcium, %		S0	S2
	S0	0.21	
	S2	ns	0.32

Shoot Magnesium, %		S0	S2
	S0	0.18	
	S2	*	0.11

Root Magnesium, %		S0	S2
	S0	0.16	
	S2	ns	0.23

Shoot Phosphorus, %		S0	S2
	S0	0.84	
	S2	ns	0.81

Root Phosphorus, %		S0	S2
	S0	0.62	
	S2	*	1.10

Shoot Sulphur, %		S0	S2
	S0	0.52	
	S2	*	0.44

Root Sulphur, %		S0	S2
	S0	0.52	
	S2	ns	0.40

Agrostis punicea (SBL)

Shoot Height, cm		S0	S1	S2	S3
	S0	52.2			
	S1	*	34.8		
	S2	*	*	27.0	
	S3	*	*	ns	20.24

Root Length, cm		S0	S1	S2	S3
	S0	40.0			
	S1	ns	40.2		
	S2	ns	ns	33.1	
	S3	*	*	ns	26.1

Shoot Sodium, %		S0	S2
	S0	0.07	
	S2	*	2.55

Root Sodium, %		S0	S2
	S0	0.20	
	S2	*	1.84

Shoot Weight,g#		S0	S1	S2	S3
	S0	2.76			
	S1	*	1.44		
	S2	*	*	0.99	
	S3	*	*	ns	0.75

Root Weight, g#		S0	S1	S2	S3
	S0	0.50			
	S1	*	0.28		
	S2	*	ns	0.24	
	S3	*	ns	ns	0.15

Shoot Potassium, %		S0	S2
	S0	4.32	
	S2	*	2.29

Root Potassium, %		S0	S2
	S0	6.06	
	S2	*	3.73

Shoot K:Na		S0	S2
	S0	55.2	
	S2	*	-8.7

Root K:Na		S0	S2
	S0	73.5	
	S2	*	2.3

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.049			
	S1	ns	0.034		
	S2	*	ns	0.026	
	S3	*	ns	ns	0.021

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.021			
	S1	*	0.008		
	S2	*	ns	0.008	
	S3	*	ns	ns	0.007

Shoot Chloride, %		S0	S2
	S0	0.39	
	S2	*	3.51

Root Chloride, %		S0	S2
	S0	0.59	
	S2	*	2.39

Shoot Na:Cl		S0	S2
	S0	0.210	
	S2	*	0.728

Root Na:Cl*		S0	S2
	S0	0.155	
	S2	ns	0.225

Tiller Number#		S0	S1	S2	S3
	S0	36.9			
	S1	*	16.5		
	S2	*	ns	11.4	
	S3	*	*	*	5.4

Root:Shoot Length#		S0	S1	S2	S3
	S0	0.87			
	S1	ns	1.38		
	S2	*	ns	1.61	
	S3	*	*	*	2.65

Root:Shoot Na		S0	S2
	S0	1.283	
	S2	ns	0.744

Root:Shoot K		S0	S2
	S0	1.402	
	S2	ns	1.395

Root:Shoot Cl		S0	S2
	S0	1.454	
	S2	*	0.713

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.085			
	S1	ns	0.072		
	S2	ns	ns	0.055	
	S3	ns	ns	ns	0.053

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.22			
	S1	ns	0.25		
	S2	*	*	0.41	
	S3	*	*	*	0.47

Shoot Calcium, %		S0	S2
	S0	0.37	
	S2	ns	0.37

Root Calcium, %		S0	S2
	S0	0.22	
	S2	ns	0.27

Total Biomass, g		S0	S1	S2	S3
	S0	3.21			
	S1	*	1.70		
	S2	*	ns	1.22	
	S3	*	*	ns	0.90

Relative Water, %		S0	S1	S2	S3
	S0	100.9			
	S1	ns	97.7		
	S2	ns	ns	93.3	
	S3	*	*	ns	87.7

Shoot Magnesium, %		S0	S2
	S0	0.15	
	S2	*	0.10

Root Magnesium, %		S0	S2
	S0	0.18	
	S2	ns	0.20

Shoot Phosphorus, %		S0	S2
	S0	0.92	
	S2	ns	0.86

Root Phosphorus, %		S0	S2
	S0	1.95	
	S2	ns	2.09

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-18.0			
	S1	*	-25.2		
	S2	*	ns	-29.2	
	S3	*	*	ns	-32.6

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	0.14			
	S1	ns	5.80		
	S1	*	ns	8.68	
	S3	*	ns	ns	9.45

Shoot Sulphur, %		S0	S2
	S0	0.46	
	S2	ns	0.50

Root Sulphur, %		S0	S2
	S0	0.47	
	S2	ns	0.39

Agrostis punicea (LR)

Shoot Height, cm	S0	S1	S2	S3
S0	44.1			
S1	*	30.8		
S2	*	*	18.8	
S3	*	*	ns	13.7

Root Length, cm	S0	S1	S2	S3
S0	35.7			
S1	ns	39.5		
S2	*	*	19.6	
S3	*	*	ns	14.9

Shoot Weight,g#	S0	S1	S2	S3
S0	1.25			
S1	ns	0.82		
S2	*	ns	0.57	
S3	*	ns	ns	0.51

Root Weight, g#	S0	S1	S2	S3
S0	0.20			
S1	ns	0.15		
S2	ns	ns	0.08	
S3	*	ns	ns	0.03

Shoot Density (Wgt/Hgt), g/cm	S0	S1	S2	S3
S0	0.022			
S1	ns	0.015		
S2	ns	ns	0.014	
S3	ns	ns	ns	0.014

Root Density (Wgt/Lgt), g/cm	S0	S1	S2	S3
S0	0.010			
S1	*	0.004		
S2	*	ns	0.002	
S3	*	ns	ns	0.002

Tiller Number#	S0	S1	S2	S3
S0	19.8			
S1	*	10.2		
S2	*	*	3.3	
S3	*	*	ns	2.6

Root:Shoot Length#	S0	S1	S2	S3
S0	0.95			
S1	ns	1.65		
S2	*	ns	2.36	
S3	*	*	*	3.36

Wgt/Tiller, g	S0	S1	S2	S3
S0	0.043			
S1	ns	0.046		
S2	ns	ns	0.042	
S3	ns	ns	ns	0.030

Root:Shoot Weight	S0	S1	S2	S3
S0	0.25			
S1	*	0.36		
S2	*	*	0.50	
S3	*	*	ns	0.51

Total Biomass, g	S0	S1	S2	S3
S0	1.45			
S1	ns	0.96		
S2	*	ns	0.65	
S3	*	ns	ns	0.52

Relative Water, %	S0	S1	S2	S3
S0	99.1			
S1	ns	98.9		
S2	ns	ns	91.8	
S3	*	*	*	68.2

Osmotic Potential, bars	S0	S1	S2	S3
S0	-21.4			
S1	ns	-25.9		
S2	*	ns	-27.3	
S3	*	*	ns	-31.4

Osmotic Adjustment, bars	S0	S1	S2	S3
S0	0.14			
S1	ns	4.19		
S1	ns	ns	3.36	
S3	ns	ns	ns	-1.07

Shoot Sodium, %	S0	S2
S0	0.05	
S2	*	3.18

Root Sodium, %	S0	S2
S0	0.21	
S2	*	3.32

Shoot Potassium, %	S0	S2
S0	3.87	
S2	*	1.92

Root Potassium, %	S0	S2
S0	6.56	
S2	*	4.03

Shoot K:Na	S0	S2
S0	47.8	
S2	*	-5.9

Root K:Na	S0	S2
S0	62.8	
S2	*	-1.2

Shoot Chloride, %	S0	S2
S0	0.35	
S2		na

Root Chloride, %	S0	S2
S0	na	
S2		na

Shoot Na:Cl	S0	S2
S0	0.193	
S2		na

Root Na:Cl*	S0	S2
S0	na	
S2		na

Root:Shoot Na	S0	S2
S0	1.465	
S2	ns	1.183

Root:Shoot K	S0	S2
S0	1.621	
S2	ns	1.575

Root:Shoot Cl	S0	S2
S0	na	
S2		na

Shoot Calcium, %	S0	S2
S0	0.38	
S2	*	0.55

Root Calcium, %	S0	S2
S0	0.26	
S2	ns	0.36

Shoot Magnesium, %	S0	S2
S0	0.16	
S2	ns	0.13

Root Magnesium, %	S0	S2
S0	0.19	
S2	ns	0.23

Shoot Phosphorus, %	S0	S2
S0	0.94	
S2	ns	0.81

Root Phosphorus, %	S0	S2
S0	1.73	
S2	*	3.66

Shoot Sulphur, %	S0	S2
S0	0.47	
S2	ns	0.53

Root Sulphur, %	S0	S2
S0	0.51	
S2	ns	0.47

Puccinellia stricta var. *perlaxa* (LIN)

Shoot Height, cm		S0	S1	S2	S3
	S0	27.2			
	S1	ns	25.6		
	S2	*	*	17.0	
	S3	*	*	ns	16.4

Root Length, cm		S0	S1	S2	S3
	S0	36.5			
	S1	ns	41.7		
	S2	ns	ns	38.8	
	S3	ns	ns	ns	42.0

Shoot Sodium, %		S0	S2
	S0	0.18	
	S2	*	2.25

Root Sodium, %		S0	S2
	S0	-0.03	
	S2	*	5.67

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	1.50			
	S1	ns	0.91		
	S2	*	*	0.21	
	S3	*	*	ns	0.11

Root Weight, g[#]		S0	S1	S2	S3
	S0	0.39			
	S1	ns	0.24		
	S2	*	ns	0.16	
	S3	*	ns	ns	0.15

Shoot Potassium, %		S0	S2
	S0	4.83	
	S2	ns	4.58

Root Potassium, %		S0	S2
	S0	3.12	
	S2	*	6.72

Shoot K:Na		S0	S2
	S0	53.7	
	S2	*	10.9

Root K:Na		S0	S2
	S0	53.0	
	S2	*	2.4

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.056			
	S1	ns	0.042		
	S2	*	ns	0.028	
	S3	*	ns	ns	0.024

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.009			
	S1	*	0.005		
	S2	*	ns	0.004	
	S3	*	ns	ns	0.003

Shoot Chloride, %		S0	S2
	S0	0.61	
	S2	*	4.14

Root Chloride, %		S0	S2
	S0	0.36	
	S2		na

Shoot Na:Cl		S0	S2
	S0	0.282	
	S2	*	0.543

Root Na:Cl*		S0	S2
	S0	0.225	
	S2		na

Tiller Number#		S0	S1	S2	S3
	S0	49.5			
	S1	ns	30.3		
	S2	*	ns	24.5	
	S3	*	ns	ns	20.5

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	1.09			
	S1	ns	1.35		
	S2	*	*	1.74	
	S3	*	*	ns	1.85

Root:Shoot Na		S0	S2
	S0	0.563	
	S2	*	2.450

Root:Shoot K		S0	S2
	S0	1.319	
	S2	ns	1.650

Root:Shoot Cl		S0	S2
	S0	0.638	
	S2		na

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.020			
	S1	ns	0.031		
	S2	ns	ns	0.014	
	S3	ns	ns	ns	0.015

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.19			
	S1	ns	0.17		
	S2	*	*	0.25	
	S3	*	*	ns	0.27

Shoot Calcium, %		S0	S2
	S0	0.53	
	S2	*	0.30

Root Calcium, %		S0	S2
	S0	0.21	
	S2	*	0.44

Total Biomass, g		S0	S1	S2	S3
	S0	1.92			
	S1	ns	1.18		
	S2	*	ns	0.38	
	S3	*	*	ns	0.27

Relative Water, %		S0	S1	S2	S3
	S0	93.7			
	S1	ns	90.0		
	S2	*	*	75.1	
	S3	*	ns	ns	82.8

Shoot Magnesium, %		S0	S2
	S0	0.25	
	S2	*	0.15

Root Magnesium, %		S0	S2
	S0	0.07	
	S2	*	0.15

Shoot Phosphorus, %		S0	S2
	S0	0.69	
	S2	ns	0.68

Root Phosphorus, %		S0	S2
	S0	0.46	
	S2	ns	1.28

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-20.9			
	S1	ns	-25.8		
	S2	*	ns	-26.2	
	S3	*	ns	ns	-29.9

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	-0.13			
	S1	ns	3.37		
	S1	ns	ns	-0.24	
	S3	ns	ns	ns	4.79

Shoot Sulphur, %		S0	S2
	S0	0.68	
	S2	ns	0.62

Root Sulphur, %		S0	S2
	S0	0.65	
	S2	*	1.49

Agrostis avenacea (SHR)

Shoot Height, cm		S0	S1	S2	S3
	S0	48.4			
	S1	*	27.3		
	S2	*	*	4.2	
	S3	*	*	ns	1.9

Root Length, cm		S0	S1	S2	S3
	S0	39.7			
	S1	ns	36.2		
	S2	*	*	18.7	
	S3	*	*	ns	12.2

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	2.17			
	S1	*	0.21		
	S2	*	ns	-0.23	
	S3	*	*	ns	-0.30

Root Weight, g[#]		S0	S1	S2	S3
	S0	0.44			
	S1	*	0.15		
	S2	*	ns	0.05	
	S3	*	ns	ns	0.03

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.046			
	S1	*	0.017		
	S2	*	ns	0.021	
	S3	*	ns	ns	0.017

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.010			
	S1	*	0.004		
	S2	*	ns	0.002	
	S3	*	ns	ns	0.002

Tiller Number#		S0	S1	S2	S3
	S0	27.4			
	S1	*	10.0		
	S2	*	*	2.7	
	S3	*	*	ns	1.7

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	0.74			
	S1	*	1.11		
	S2	*	*	1.73	
	S3	*	*	ns	1.75

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.073			
	S1	ns	0.053		
	S2	ns	ns	0.050	
	S3	*	ns	ns	0.028

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.16			
	S1	ns	0.20		
	S2	*	ns	0.24	
	S3	*	ns	ns	0.23

Total Biomass, g		S0	S1	S2	S3
	S0	2.62			
	S1	*	0.37		
	S2	*	ns	-0.17	
	S3	*	*	ns	-0.26

Relative Water, %		S0	S1	S2	S3
	S0	98.0			
	S1	ns	96.5		
	S2	ns	ns	91.1	
	S3	*	*	ns	85.7

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-19.5			
	S1	ns	-19.7		
	S2	*	*	-25.3	
	S3	*	*	ns	-28.3

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	-0.14			
	S1	ns	-0.17		
	S1	ns	ns	3.44	
	S3	ns	ns	ns	4.85

Shoot Sodium, %		S0	S2
	S0	0.13	
	S2	*	3.85

Root Sodium, %		S0	S2
	S0	-0.03	
	S2	*	2.03

Shoot Potassium, %		S0	S2
	S0	5.28	
	S2	*	2.96

Root Potassium, %		S0	S2
	S0	3.93	
	S2	*	3.09

Shoot K:Na		S0	S2
	S0	78.3	
	S2	*	7.30

Root K:Na		S0	S2
	S0	50.7	
	S2	*	1.5

Shoot Chloride, %		S0	S2
	S0	0.57	
	S2	*	6.53

Root Chloride, %		S0	S2
	S0	0.39	
	S2		na

Shoot Na:Cl		S0	S2
	S0	0.187	
	S2	*	0.605

Root Na:Cl*		S0	S2
	S0	0.240	
	S2		na

Root:Shoot Na		S0	S2
	S0	0.873	
	S2	ns	0.469

Root:Shoot K		S0	S2
	S0	0.649	
	S2	ns	1.022

Root:Shoot Cl		S0	S2
	S0	0.561	
	S2		na

Shoot Calcium, %		S0	S2
	S0	0.44	
	S2	*	0.59

Root Calcium, %		S0	S2
	S0	0.19	
	S2	ns	0.14

Shoot Magnesium, %		S0	S2
	S0	0.21	
	S2	*	0.15

Root Magnesium, %		S0	S2
	S0	0.16	
	S2	ns	0.15

Shoot Phosphorus, %		S0	S2
	S0	1.09	
	S2	ns	1.23

Root Phosphorus, %		S0	S2
	S0	1.80	
	S2	ns	2.24

Shoot Sulphur, %		S0	S2
	S0	0.47	
	S2	ns	0.50

Root Sulphur, %		S0	S2
	S0	0.36	
	S2	ns	0.52

Agrostis avenacea (WM)

Shoot Height, cm		S0	S1	S2	S3
	S0	53.8			
	S1	*	37.8		
	S2	*	*	27.0	
	S3	*	*	ns	20.8

Root Length, cm		S0	S1	S2	S3
	S0	50.4			
	S1	*	29.9		
	S2	ns	*	50.9	
	S3	ns	ns	ns	40.4

Shoot Weight,g[#]		S0	S1	S2	S3
	S0	6.10			
	S1	*	2.29		
	S2	*	*	1.29	
	S3	*	*	*	0.46

Root Weight, g[#]		S0	S1	S2	S3
	S0	1.06			
	S1	*	0.23		
	S2	*	*	0.41	
	S3	*	ns	ns	0.28

Shoot Density (Wgt/Hgt), g/cm		S0	S1	S2	S3
	S0	0.110			
	S1	*	0.064		
	S2	*	ns	0.051	
	S3	*	ns	ns	0.032

Root Density (Wgt/Lgt), g/cm		S0	S1	S2	S3
	S0	0.021			
	S1	*	0.008		
	S2	*	ns	0.008	
	S3	*	ns	ns	0.007

Tiller Number#		S0	S1	S2	S3
	S0	48.6			
	S1	*	24.2		
	S2	*	ns	22.5	
	S3	*	*	*	12.0

Root:Shoot Length[#]		S0	S1	S2	S3
	S0	0.87			
	S1	ns	0.68		
	S2	*	*	1.58	
	S3	*	*	ns	1.54

Wgt/Tiller, g		S0	S1	S2	S3
	S0	0.125			
	S1	ns	0.091		
	S2	*	ns	0.063	
	S3	*	ns	ns	0.065

Root:Shoot Weight		S0	S1	S2	S3
	S0	0.16			
	S1	ns	0.13		
	S2	*	*	0.26	
	S3	*	*	*	0.32

Total Biomass, g		S0	S1	S2	S3
	S0	7.16			
	S1	*	2.54		
	S2	*	ns	1.72	
	S3	*	*	*	0.76

Relative Water, %		S0	S1	S2	S3
	S0	97.6			
	S1	ns	93.9		
	S2	ns	ns	91.6	
	S3	ns	ns	ns	91.3

Osmotic Potential, bars		S0	S1	S2	S3
	S0	-17.8			
	S1	*	-24.7		
	S2	*	ns	-25.0	
	S3	*	ns	ns	-26.2

Osmotic Adjustment, bars		S0	S1	S2	S3
	S0	-0.14			
	S1	ns	5.28		
	S1	ns	ns	5.29	
	S3	*	ns	ns	6.22

Shoot Sodium, %		S0	S2
	S0	0.10	
	S2	*	1.70

Root Sodium, %		S0	S2
	S0	-0.07	
	S2	*	1.97

Shoot Potassium, %		S0	S2
	S0	1.94	
	S2	*	4.48

Root Potassium, %		S0	S2
	S0	3.84	
	S2	ns	3.32

Shoot K:Na		S0	S2
	S0	31.7	
	S2	*	12.1

Root K:Na		S0	S2
	S0	113.5	
	S2	*	2.9

Shoot Chloride, %		S0	S2
	S0	1.04	
	S2	*	3.29

Root Chloride, %		S0	S2
	S0	0.40	
	S2	*	3.29

Shoot Na:Cl		S0	S2
	S0	0.069	
	S2	*	0.513

Root Na:Cl*		S0	S2
	S0	0.094	
	S2	*	0.664

Root:Shoot Na		S0	S2
	S0	0.662	
	S2	ns	1.289

Root:Shoot K		S0	S2
	S0	4.325	
	S2	*	0.697

Root:Shoot Cl		S0	S2
	S0	0.364	
	S2	*	1.083

Shoot Calcium, %		S0	S2
	S0	0.36	
	S2	ns	0.31

Root Calcium, %		S0	S2
	S0	0.16	
	S2	ns	0.12

Shoot Magnesium, %		S0	S2
	S0	0.23	
	S2	*	0.14

Root Magnesium, %		S0	S2
	S0	0.15	
	S2	ns	0.18

Shoot Phosphorus, %		S0	S2
	S0	0.96	
	S2	*	0.77

Root Phosphorus, %		S0	S2
	S0	0.53	
	S2	ns	0.77

Shoot Sulphur, %		S0	S2
	S0	0.45	
	S2	ns	0.42

Root Sulphur, %		S0	S2
	S0	0.56	
	S2	ns	0.63