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Composition of Irrigation Water Salinity Affects Growth Characteristics and Uptake of Selenium and Salt Ions by Soybean

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ABSTRACT

A greenhouse study was conducted to determine the effects of irrigation waters differing in salt composition on growth characteristics, salt ion and selenium (Se) accumulation, and distribution in plant components of the soybean (*Glycine max* L. Merr.) cultivar "Manokin." Plants were grown in sand cultures and irrigated with isoosmotic solutions containing (1) Cl^- as the dominant anion, or (2) a mixture of salts containing equal molar amounts of SO_4^{2-} and Cl^-. Six treatments of each salinity type were imposed. Electrical conductivities of the irrigation waters ranged from 2.1 to 13.0 dSm^{-1}. Selenium (1 $mg \cdot L^{-1}$, 12.7 μM) was added to all irrigation waters as Na_2SeO_4. Regardless of salinity type, soybean plants were generally taller under the low-salinity treatments in early vegetative stages of growth. Towards the end of vegetative stages and until final harvest, higher values of plant height, leaf area, and shoot dry weight were found at the intermediate salinity levels (5.0 and 9.2 dS m^{-1}), and higher salinity in general led to increased soybean leaf chlorophyll on a unit-area basis. Shoot-to-root ratios decreased with increasing chloride salinity, while the ratios remained nearly constant under the sulfate salinity treatment. Plant uptake and accumulation of salt ions (Ca^{2+}, Mg^{2+}, Na^+, Cl^-), K^+, total phosphorus (p), and total sulfur (s) were generally not related to the type of salinity, except total S, where higher concentrations were found in leaves, stems, and roots in the sulfate than under the chloride salinity treatment. Selenium concentration in leaves and seeds was about 4 mg kg^{-1} at final harvest when irrigated with the sulfate-based saline waters. Under the chloride salinity treatment, Se level was found to be about three times higher in leaves and five times higher in seeds. In conclusion, different solution concentrations of SO_4^{2-} and Cl^- had no significant effect on soybean biophysical growth parameters or ion distribution. Whereas shoot-to-root ratios

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decreased with increasing chloride salinity, high-sulfate salinity reduced Se uptake by "Manokin" soybean.

Keywords: soybean, selenium uptake, chloride salinity, sulfate salinity, ion inhibition, ion partitioning, shoot-to-root ratio, sand culture

INTRODUCTION

Agricultural drainage waters in the western United States and other arid regions of the world can become sufficiently saline to be detrimental to plant growth (Letey and Oster, 1993). Without a sustainable means of disposing of drainage water, increasing amounts of farmland will become salt impaired, suffer declines in productivity, and be lost to production. Reusing drainage water in production would reduce the final volume of drainage water and minimize the amount of land needed for its disposal (Grattan and Rhoades, 1990). Because most agricultural crops exhibit a finite range of tolerance to salinity before significant reduction in productivity occurs (Maas and Hoffman, 1977), the selection of plant species for drainage-water reuse should consider their salt-tolerance characteristics. In addition to the total salinity, the composition of ionic species, including the relative ratios of sodium, chloride, and sulfate, should also be considered when reusing saline drainage waters for irrigation (Pratt and Suarez, 1990; Bradford and Letey, 1993).

In addition to salinity, drainage waters often contain trace elements including selenium (Se) (Fujii and Swain, 1995). Although Se is toxic to shore birds and migratory waterfowl when it concentrates in the food chain of drainage evaporation ponds (Skorupa, 1998), in many parts of the United States and around the world there is generally a Se deficiency in animal feedstuffs (Mayland, 1994; Bañuelos and Mayland, 2000) and in human nutrition (Young et al., 1982; Solomons and Ruz, 1998; Adams et al., 2002). In livestock production, Se deficiency can be mediated by adding elemental Se in fertilizers and broadcasting to pastures (Whelan et al., 1994) or using Se-rich plant materials as supplemental animal feed (Bañuelos et al., 1997). In commercial soy-based infant formulas not supplemented with Se, Smith et al. (1982) found only 30% to 50% as much Se as in human milk. Formula manufacturers have thus begun Se supplementation in infant formulas. Johnson et al. (1993) found that infants fed a soy formula supplemented with Se had plasma and erythrocyte Se values lower than those infants fed with human milk, but plasma and erythrocyte glutathione peroxidase activities were normal, indicating that the physiological requirement for Se was being met. The frequent incidence of Keshan disease in parts of China was attributed partially to Se deficiency in human diets that consisted primarily of corn, potato, and soybeans (Fang et al., 2002).

Soybeans are widely grown as a high-protein supplement for human consumption and for livestock feedstuffs. Total Se content in soybeans is generally very low, ranging from 0.07 to 0.20 mg/kg (MacLeod and Gupta, 1995). Whereas accumulation of Se was found in wheat (Grieve et al., 1999) and plant tissues of *Astragalus bisulcatus* (Duckart et al., 1992) and *Brassica oleracea* (Kopsell et al., 2000) by increasing sodium selenate concentrations in the substrate, grain Se concentration in soybeans was increased by increasing Se concentration in the planted seeds (Gupta and MacLeod, 1999). Selenium uptake by plants depends on many factors including substrate characteristics such as total salinity and the speciation of salt ions (Brown and Shrift, 1982; Läuchli, 1993; Wu, 1998). Because of similarities in chemical properties, significant reductions in Se uptake were found under sulfate-dominated salinity as compared with chloride salinity by many plant species including alfalfa (Mikkelsen et al., 1988), two saltgrass ecotypes (Enberg and Wu, 1995), and wheat (Grieve et al., 1999).

The objectives of this study were to determine (1) growth characteristics and (2) Se and salt ion accumulation in soybean plants subjected to irrigation with simulated drainage waters with variable degrees of either chloride- or sulfate-dominated salinity and containing the same sodium selenate concentration.

MATERIALS AND METHODS

A greenhouse study was conducted in sand tanks at the USDA-ARS George E. Brown, Jr. Salinity Laboratory in Riverside, CA. The sand tanks (1.2 m long × 0.6 m wide × 0.5 m deep) contained washed sand with an average bulk density of 1.54 $Mg \cdot m^{-3}$ and a volumetric water content of 0.09 $m^3 \cdot m^{-3}$ just before an irrigation and 0.17 $m^3 \cdot m^{-3}$ after drainage had nearly ceased.

On June 4, 1999, seeds of soybean cultivar "Manokin" were planted in 36 sand tanks randomly located in the greenhouse. The sand tanks were irrigated three times daily with a modified Hoagland's nutrient solution, a solution composition from Maas and Grieve (1990). Each irrigation cycle continued for ~15 min until the sand was completely saturated, after which the solution drained into 765 L reservoirs for reuse in the next irrigation. Each reservoir was connected to three sand tanks forming a closed system, and the three tanks that were connected to each reservoir were randomly situated in the greenhouse. A total of 12 reservoirs were used for the experiment.

Two weeks after planting, salts were added to the reservoirs in equal increments over a 5 d period. The gradual increase in solution salinity over this period was designed to prevent a sudden osmotic shock to the soybean seedlings. Six reservoirs were salinized to a chloride-based solution, with each reservoir possessing different target electrical conductivity (EC) values, namely 2.0, 5.0, 8.1, 10.0, 12.0, and 13.8 dS m^{-1}. The remaining six reservoirs were salinized with a sulfate-dominated mixed salt (SO_4^{2-} to Cl^- ratio 1:1 on a molar basis) following six levels of EC values: 2.0, 5.0, 8.1, 10.0, 11.9, and 13.7 dS m^{-1}. Selection

Table 1
Osmotic potential and concentrations of the salinizing salts of solutions used to irrigate soybean grown in greenhouse sand cultures

Salinity type	Osmotic potential (MPa)	Salt Ion Concentration ($mol \cdot m^{-3}$)				
		Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}	Cl^{-}
Chloride	0.06	2.6	1.5	6.0	1.5	11.0
	0.18	9.0	1.5	22.0	1.5	44.5
	0.29	16.9	1.5	35.0	1.5	73.4
	0.36	22.1	1.5	44.2	1.5	91.2
	0.44	25.9	1.5	54.0	1.5	110.0
	0.52	31.2	1.5	65.0	1.5	132.0
Sulfate	0.06	2.6	1.5	6.0	3.0	3.0
	0.18	5.2	3.9	34.4	17.4	16.6
	0.29	8.2	6.5	57.4	29.1	27.8
	0.36	10.1	8.2	72.5	36.8	35.1
	0.44	11.5	9.8	86.3	43.3	41.8
	0.52	12.2	12.0	106.0	51.5	51.2

of these salinity levels was based on previous experience with salt tolerance of the "Manokin" soybean (Kenworthy et al., 1996; Wang et al., 2001; Grieve et al., 2003). Solution osmotic potential and concentrations of the salinizing salts (Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}) are summarized in Table 1. On June 28, 1999, Na_2SeO_4 was added to each reservoir so that all tanks were irrigated with waters containing 1 mg $Se \cdot L^{-1}$ (12.7 μM). Water lost by evapotranspiration was replenished automatically each day to maintain constant osmotic potentials in the reservoirs. Solution EC and pH in the reservoirs were measured weekly with an EC/pH meter. The average EC values were 2.1, 4.9, 7.7, 9.2, 11.1, and 13.0 dS m^{-1} in the chloride salinity reservoirs; and 2.2, 5.0, 7.7, 9.2, 10.6, and 12.6 dS m^{-1} in the sulfate salinity reservoirs, respectively. The solution pH remained nearly constant at 7.6. Irrigation waters were also analyzed by inductively-coupled plasma optical-emission spectrometry (ICPOES) during the experiment to confirm that target ion concentrations were maintained. Chloride in the solutions was determined by coulometric-amperometric titration.

For assessment of growth characteristics, shoots of two plants were harvested (cut at the sand surface) from each tank on June 28, July 2, July 22, July 29, August 12, and three whole plants (including roots) were sampled from each tank on July 8. For assessment of both growth characteristics and salt ion and Se accumulation, a final harvest was made on September 15, when five whole plants (including roots and pods) were extracted from each tank. Immediately after each harvest, plant height was measured, then readings were made from nine leaves in the upper canopy of each plant using a Minolta

SPAD-502 meter*. Leaf chlorophyll was determined from a calibration derived from a subset of the SPAD meter readings against leaf chlorophyll content measurements made from leaf extracts using a Beckman DU 7500 spectrophotometer. After the plant height and chlorophyll measurements were taken, leaves were separated and total leaf area of each plant was measured by passing individual leaflets through a LICOR LI-3100 leaf area meter. For each harvest, dry weights of total above-ground plant parts (shoot) and roots (for July 8 and September 15 harvests) were measured after drying in a forced-air oven at 70°C for 72 h. For the September 15 harvest, pod dry weights were measured after drying. Shoot-to-root ratio was also calculated for the July 8 and September 15 harvests.

For assessment of Se uptake and salt ion accumulation, plant parts (pods, leaves, stems, and roots) were separated, washed in deionized water, dried in a forced-air oven at 70°C for 72 h, and ground to a fine powder to pass a 60 mesh screen. Total S, total P, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} were determined on nitric-perchloric acid digests of the tissue powders by ICPOES. Chloride was determined on nitric-acetic acid extracts by coulometric-amperometric titration. For tissue Se analysis, the method described by Briggs and Crock (1986) was followed.

The experiment design was a completely randomized block with two salinity types (chloride and sulfate), six salinity levels, and three replications. Statistical analyses of the Se and salt ion data were performed by ANOVA with mean comparisons using Tukey's standardized range test (SAS Institute, 1996).

RESULTS AND DISCUSSION

Under chloride salinity, soybean plants were generally taller in the low salinity treatments (2.1 and 4.9 dS m^{-1}) than in the high-salt treatments in early vegetative stages of growth or before 48 days after planting (DAP) (Figure 1). No significant difference was found in leaf area or shoot dry weight among the salinity levels up to about 55 DAP. Plant height, leaf area, and shoot dry weight appeared to be higher in the 7.7 and 9.2 dS m^{-1} treatments than under other salinity levels after 48 to 55 DAP. Plants that received high EC treatments (11.1 and 13.0 dS m^{-1}) showed consistently lower values in height, leaf area, and shoot dry weight. Under sulfate salinity, a similar trend (as to chloride salinity) was observed in plant height and in the two high-EC treatments (e.g., 10.6 and 12.6 dS m^{-1}) (Figure 2). However, higher plant height, leaf area, and shoot dry weight values were found under the intermediate salinity levels (5.0 and 7.7 dS m^{-1}) than under other treatments.

*Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Minnesota or the U.S. Department of Agriculture.

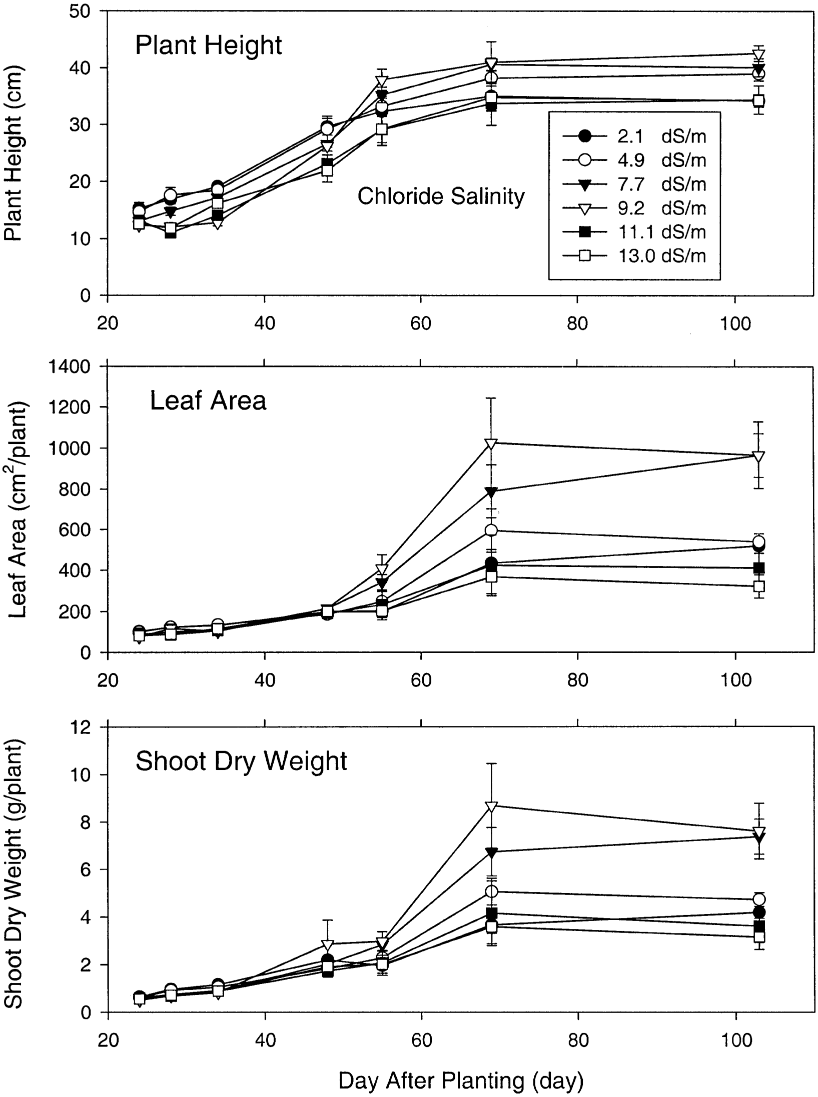

Figure 1. Plant height, leaf area, and shoot dry weight of soybean plants under six levels of chloride-based salinity.

Consistent with field and laboratory observations from a separate study (Wang et al., 2001), higher salinity in general led to increased soybean leaf chlorophyll on a unit-area basis for both salt types (Figure 3). The control treatments (2.1 or 2.2 dS m^{-1}) had the lowest leaf chlorophyll measurements throughout the experiment. Early in the season (34 DAP), root dry weight was

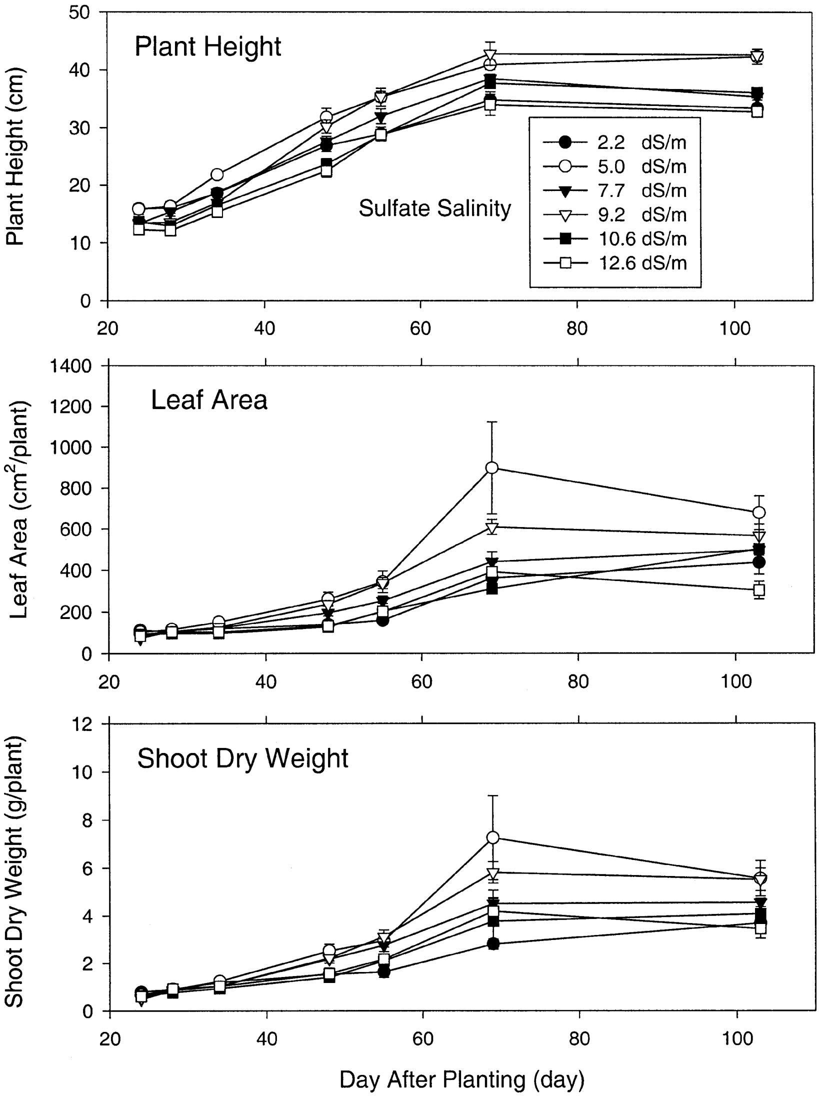

Figure 2. Plant height, leaf area, and shoot dry weight of soybean plants under six levels of sulfate-based salinity.

very similar between the two types of salinity and across the whole range of EC levels (i.e., 2.1 to 13.0 dS m^{-1}) (Figure 4). At final harvest (103 DAP), plants subjected to chloride salinity exhibited higher root mass than those subjected to sulfate salinity at EC levels equal to or greater than 7.7 dS m^{-1}. It was also interesting to note that, rather than in the control, the highest root mass was

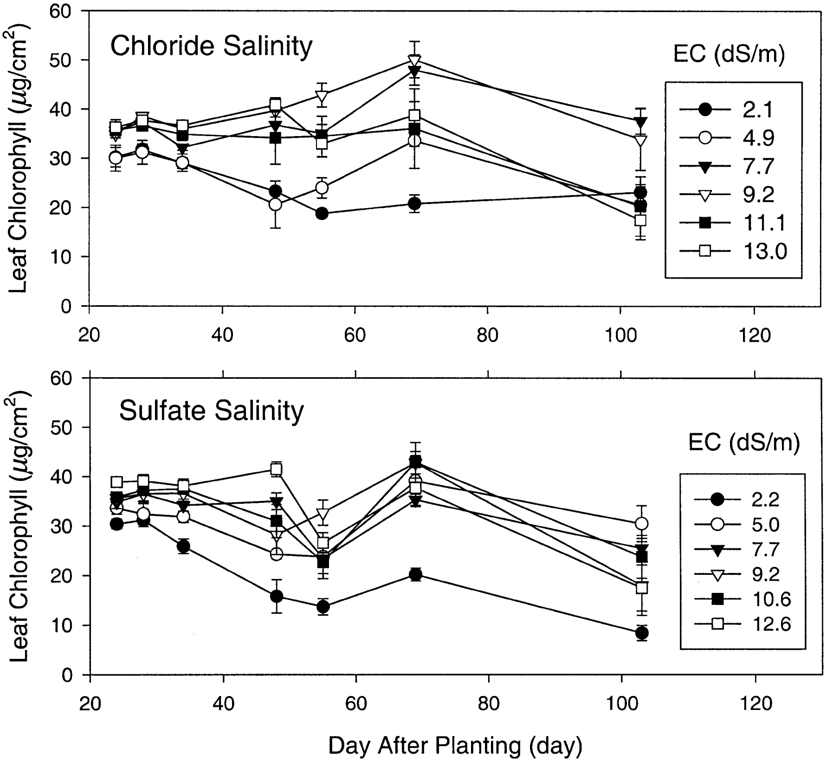

Figure 3. Soybean leaf chlorophyll under six levels of chloride- or sulfate-based salinity.

found in the 9.2 or 7.7 dS m^{-1} treatment under chloride salinity and 9.2 or 5.0 dS m^{-1} treatment under sulfate salinity, respectively. This was consistent with the plant height, leaf area, and shoot dry weight measurements where the highest values were generally found in the 5.0 to 9.2 dS m^{-1} treatments (Figures 1–2). Shoot-to-root dry weight ratio was lower in the chloride than in the sulfate salinity on both 34 and 103 DAP when EC levels were equal to or greater than 7.7 dS m^{-1} (Figure 5). This difference was caused by the fact that the shoot-to-root ratio decreased with increasing chloride salinity while the ratios remained nearly constant under sulfate salinity treatment. A reduction in shoot-to-root ratios with increasing chloride salinity was also found in another legume (alfalfa) (Esechie et al., 2002). The absolute values of shoot-to-root ratio increased from about 6 on 34 DAP to 14 on 103 DAP. On 103 DAP, soybean pod dry weight, exhibiting a trend similar to the root dry weight, was higher in the 9.2 or 7.7 dS m^{-1} treatment under chloride salinity and 9.2 or 5.0 dS m^{-1} treatment under sulfate salinity than in other EC levels (Figure 6).

Ion analyses indicated that, overall, leaves accumulated the highest amount of Ca^{2+} (505 to 764 mmoles kg^{-1}), whereas the seeds contained the least

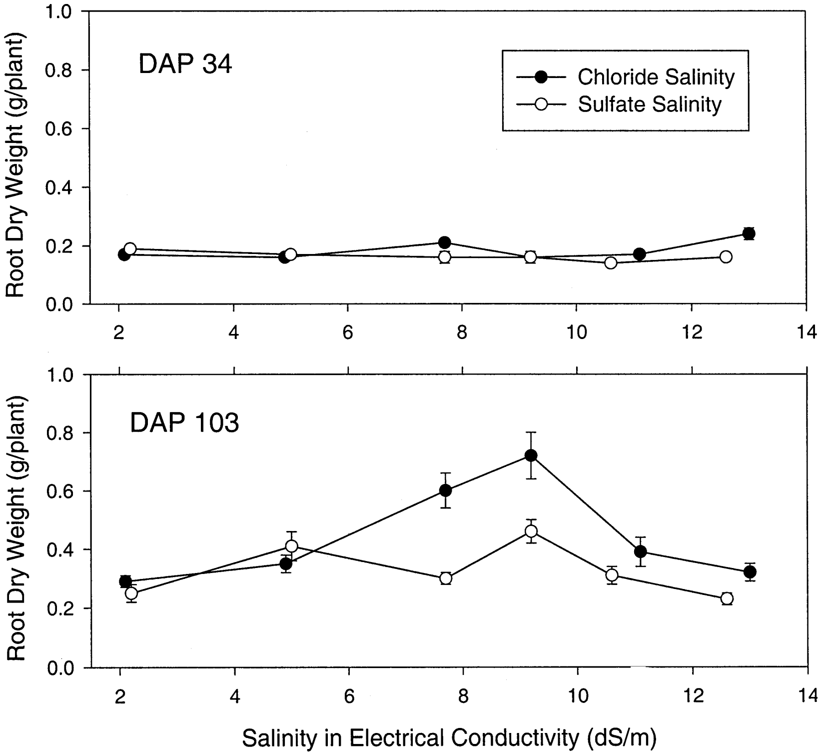

Figure 4. Soybean root dry weight 34 and 103 days after planting (DAP) under six levels of chloride- or sulfate-based salinity.

(54 to 74 mmoles Ca^{2+} kg^{-1}). Stems and roots accumulated intermediate amounts of Ca^{2+} (Table 2). The type of salinity (either chloride- or sulfate-based) did not affect Ca^{2+} uptake. For Mg^{2+}, the highest amount was also found in leaves. However, the lowest amount was found not only in all seeds but also in stems and roots that received the chloride-based salinity. Statistically significant in most places, plant uptake of Na^+ was related to the level of salinity; high EC led to more Na^+ accumulation. While seeds tended to exclude Na^+, stem and root tissues accumulated relatively high concentrations of Na^+. Again, the type of salinity did not affect Na^+ uptake. For K^+, the highest concentrations were found in seeds, followed by leaves, stems, and roots. These general trends of Ca^{2+}, Na^+, and K^+ distribution among soybean parts were consistent with results from a field study (Grieve et al., 2003). A similar trend (as to K^+) was observed in total P, where the seeds contained the highest concentrations, followed by the leaves, stems, and roots. Because of the treatment in salinity type (i.e., chloride- vs. sulfate-based), plant uptake of total S

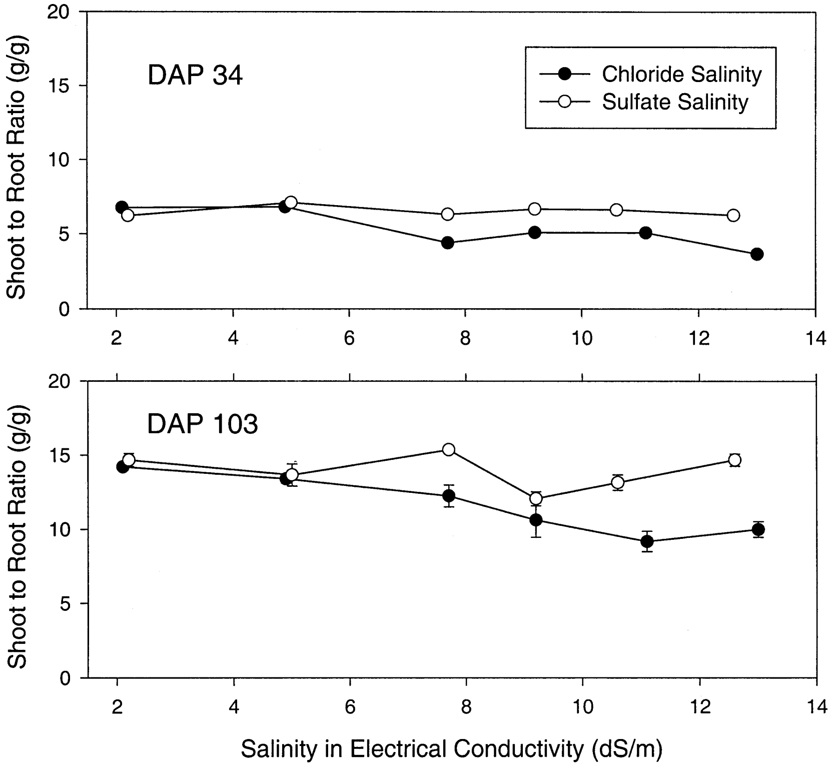

Figure 5. Soybean shoot-to-root dry weight ratio 34 and 103 days after planting (DAP) under six levels of chloride- or sulfate-based salinity.

was significantly higher under sulfate salinity than under chloride treatment in leaves, stems, and roots. In the seeds, however, total S was identical between the two salinity types, indicating an intrinsic mechanism for selective or active S accumulation by the "Manokin" soybean. Similar to the results for Na^+, plant uptake of Cl^- was related to the level of salinity; high EC led to more Cl^- accumulation. While seeds avoided Na^+, the highest Cl^- accumulation occurred in the stems and roots. Because the sulfate salinity treatment contained equal molar amount of chloride, more Cl^- uptake also occurred in higher EC values of the sulfate salinity treatment, but at relatively lower concentrations than in the chloride salinity treatment.

Selenium uptake by the "Manokin" soybean was strongly related to the composition of ion species in the saline irrigation waters. The lowest concentrations of Se, about 4 mg kg^{-1}, were found in leaves and seeds when irrigated with the sulfate-based saline waters (Table 3). Under the chloride salinity treatment, about three times as much Se was found in the leaves and five times as much was found in the seeds. Clearly, Se uptake by the soybean was inhibited by the

Table 2
Ion concentrations in leaves, stems, and roots of "Manokin" soybean grown in greenhouse sand cultures and irrigated with chloride- or sulfate-based saline waters

Plant Part	Salinity type	Actual EC ($dS \cdot m^{-1}$)	Salt ion concentration* ($mmol \cdot kg^{-1}$ dry weight)						
			Ca^{2+}	Mg^{2+}	Na^+	K^+	P	S	Cl^-
Leaf	Cl^-	2.1	635c	370d	9a	440c	218c	70a	19a
Leaf	Cl^-	4.9	678c	308d	9a	255b	95c	54a	39a
Leaf	Cl^-	7.7	760c	238c	5a	225b	62b	52a	63b
Leaf	Cl^-	9.2	716c	199c	10a	250b	46b	50a	68b
Leaf	Cl^-	11.1	764c	211c	114b	171a	43b	47a	339c
Leaf	Cl^-	13.0	753c	230c	94b	160a	57b	43a	379c
Leaf	SO_4^{2-}	2.2	511c	373d	13a	596d	332d	81a	21a
Leaf	SO_4^{2-}	5.0	613c	389d	5a	316c	115c	74a	25a
Leaf	SO_4^{2-}	7.7	528c	464d	8a	246b	112c	108b	22a
Leaf	SO_4^{2-}	9.2	609c	446d	60b	227b	137c	145b	44a
Leaf	SO_4^{2-}	10.6	658c	500d	206b	312c	207c	351c	108b
Leaf	SO_4^{2-}	12.6	505c	472d	142b	280b	156c	274c	97b
Seed	Cl^-	2.1	73a	93a	5a	452c	126c	98b	12a
Seed	Cl^-	4.9	69a	83a	5a	421c	114c	92b	17a
Seed	Cl^-	7.7	70a	85a	9a	457c	115c	100b	23a
Seed	Cl^-	9.2	70a	81a	12a	451c	100c	100b	26a
Seed	Cl^-	11.1	81a	75a	26a	460c	102c	96b	55b
Seed	Cl^-	13.0	77a	73a	42a	460c	94c	91b	67b
Seed	SO_4^{2-}	2.2	74a	84a	4a	436c	141c	85b	15a
Seed	SO_4^{2-}	5.0	68a	95a	6a	446c	134c	103b	11a
Seed	SO_4^{2-}	7.7	56a	81a	9a	397c	123c	96b	13a
Seed	SO_4^{2-}	9.2	54a	78a	15a	423c	117c	111b	15a
Seed	SO_4^{2-}	10.6	64a	81a	33a	411c	137c	113b	17a
Seed	SO_4^{2-}	12.6	55a	78a	21a	383c	128c	101b	13a
Stem	Cl^-	2.1	227b	85a	21a	249b	32b	50a	39a
Stem	Cl^-	4.9	277b	96a	77b	142a	13a	61a	189b
Stem	Cl^-	7.7	349b	120b	65b	166a	15a	42a	337c
Stem	Cl^-	9.2	344b	96a	136b	214b	15a	35a	410c
Stem	Cl^-	11.1	340b	102a	397c	117a	12a	39a	1427d
Stem	Cl^-	13.0	328b	85a	508c	89a	12a	43a	1301d
Stem	SO_4^{2-}	2.2	205b	91a	19a	264b	42b	76a	53a
Stem	SO_4^{2-}	5.0	208b	131b	57b	283b	40b	97b	134b
Stem	SO_4^{2-}	7.7	184b	124b	152b	149a	18a	158b	106b
Stem	SO_4^{2-}	9.2	226b	163b	278c	114a	22a	199c	206b
Stem	SO_4^{2-}	10.6	228b	133b	565c	117a	32b	288c	422c
Stem	SO_4^{2-}	12.6	161b	127b	548c	113a	18a	266c	470c
Root	Cl^-	2.1	248b	73a	202b	90a	15a	78a	427c
Root	Cl^-	4.9	301b	100a	197b	89a	16a	74a	465c

(Continued on next page)

Table 2

Ion concentrations in leaves, stems, and roots of "Manokin" soybean grown in greenhouse sand cultures and irrigated with chloride- or sulfate-based saline waters (Continued)

Plant Part	Salinity type	Actual EC ($dS \cdot m^{-1}$)	Salt ion concentration* ($mmol \cdot kg^{-1}$ dry weight)						
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	P	S	Cl^{-}
Root	Cl^{-}	7.7	359b	105a	270b	94a	12a	57a	749d
Root	Cl^{-}	9.2	388b	84a	409c	112a	7a	61a	1192d
Root	Cl^{-}	11.1	342b	76a	404c	117a	12a	53a	1266d
Root	Cl^{-}	13.0	537c	83a	706d	104a	10a	69a	2460d
Root	SO_4^{2-}	2.2	200b	88a	131b	103a	16a	95b	185b
Root	SO_4^{2-}	5.0	199b	104a	302c	100a	17a	134b	305c
Root	SO_4^{2-}	7.7	212b	230c	765d	138a	13a	346c	746d
Root	SO_4^{2-}	9.2	218b	144b	539c	75a	11a	245c	499c
Root	SO_4^{2-}	10.6	203b	201c	788d	117a	13a	355c	747d
Root	SO_4^{2-}	12.6	272b	225c	672d	128a	14a	404c	689d

*Different letters indicate significant difference ($P = 0.05$) for the same ion among all plant parts and salinity levels.

presence of sulfur. This result is consistent with findings on Se uptake by other plant species such as alfalfa (Mikkelsen et al., 1988), saltgrasses (Enberg and Wu, 1995), and wheat (Grieve et al., 1999). Low EC levels in the sulfate salinity treatment (2.2 or 5.0 dS m^{-1}) resulted in higher Se uptake in the leaves and seeds than did higher EC treatments. This is likely attributable to the insufficient SO_4^{2-} concentrations in the solution (to compete for Se uptake), compared with those in the higher salinity treatments (Table 1). There was virtually no difference in

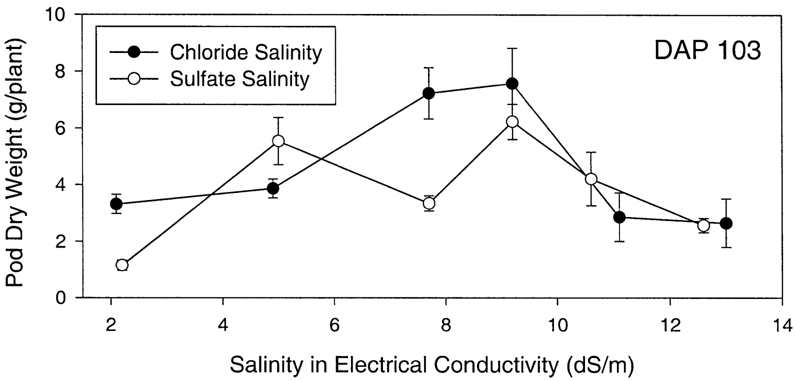

Figure 6. Soybean pod dry weight 103 days after planting (DAP) under six levels of chloride- or sulfate-based salinity.

Table 3
Selenium (Se) concentrations in leaves and seeds of "Manokin" soybean grown in greenhouse sand cultures and irrigated with chloride- or sulfate-based saline waters

Plant part	Salinity type	Actual EC ($dS \cdot m^{-1}$)	Se* ($mg\ kg^{-1}$)
Leaf	Cl^-	2.1	12.5c
Leaf	Cl^-	4.9	10.0c
Leaf	Cl^-	7.7	9.9c
Leaf	Cl^-	9.2	11.2c
Leaf	Cl^-	11.1	13.7c
Leaf	Cl^-	13.0	11.7c
Leaf	SO_4^{2-}	2.2	10.7c
Leaf	SO_4^{2-}	5.0	4.8a
Leaf	SO_4^{2-}	7.7	4.3a
Leaf	SO_4^{2-}	9.2	5.0a
Leaf	SO_4^{2-}	10.6	7.0b
Leaf	SO_4^{2-}	12.6	5.2a
Seed	Cl^-	2.1	20.0d
Seed	Cl^-	4.9	18.5d
Seed	Cl^-	7.7	20.0d
Seed	Cl^-	9.2	18.1d
Seed	Cl^-	11.1	24.6d
Seed	Cl^-	13.0	21.6d
Seed	SO_4^{2-}	2.2	14.5c
Seed	SO_4^{2-}	5.0	7.3b
Seed	SO_4^{2-}	7.7	5.1a
Seed	SO_4^{2-}	9.2	4.2a
Seed	SO_4^{2-}	10.6	4.2a
Seed	SO_4^{2-}	12.6	3.3a

*Different letters indicate significant difference ($P = 0.05$) among all plant parts and salinity levels.

rate of Se uptake among different EC levels under chloride salinity (Table 3). However, significantly higher amounts of Se accumulated in the seeds than in the leaves when irrigated with the chloride-based saline water.

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