Impact of substrate salinity and root temperature on pepper growth and nutrition

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ABSTRACT
Pepper adaptation to soil salinity is a major problem in many countries under Mediterranean and intertropical climates. Four pepper varieties were exposed to three sodium chloride concentrations and two temperature levels. Marked behavioural differences were observed between varieties.

KEYWORDS
Capsicum, salt tolerance, growth, plant nutrition, mineral content.

Influence de la salinité et de la température du substrat sur la croissance et la nutrition du piment.

RÉSUMÉ
L'adaptation du piment à la salinité des sols est un problème majeur dans de nombreux pays à climat méditerranéen et intertropical. Quatre variétés de piment ont été soumises à trois concentrations en chlorure de sodium et à deux régimes de température. Des différences de comportement variétal importantes existent.

MOTS CLES
Capsicum, tolérance au sel, croissance, nutrition des plantes, teneur en éléments minéraux.

Influencia de la salinidad y de la temperatura del substrato sobre el crecimiento y la nutrición del pimiento.

RESUMEN
La adaptación del pimiento a la salinidad de los suelos es un problema mayor en numerosos países de clima mediterráneo e intertropical. Se sometieron cuatro variedades de pimiento a tres concentraciones en cloruro de sodio y a dos régimenes de temperatura. Existen diferencias importantes de comportamiento varietal.

PALABRAS CLAVES
Capsicum, tolerancia a la sal, crecimiento, nutrición de las plantas, contenido mineral.

introduction

Pepper has a marked economic impact and is an important food source in the tropics, where it is used as a fruit vegetable when sweet and as a spice when hot.

China is the main pepper-producing country, with a yearly crop output exceeding 2 Mt. Indonesia has the highest pepper-cropping area of 213 000 ha, according to 1990 FAO statistics. There are also many Mediterranean pepper-producing countries, eg, Turkey, Tunisia, Romania, Spain and, on a smaller scale, Italy (CARUSO, 1990).

In climatic zones suitable for pepper growing, this crop is often found in countries where saline soils are widespread. The species' ability to adapt to salinity is thus essential in many countries located in Mediterranean and intertropical climatic zones. With this adaptation, farmers can use a soilless cropping system for growing peppers using water containing a certain concentration of sodium chloride (NaCl). The salt may be derived from the water or be accumulated in a soilless cropping system as a result of closed-circuit recycling of nutrient solutions.

The present paper discusses the results of studies carried out to investigate interactions of substrate salinity, due to the presence of NaCl, with root temperature. Four pepper varieties were examined to analyse the reaction of this species to relatively low salinity levels, and assess the genetic diversity resulting from this adaptation.

materials and methods

test procedure

Four pepper varieties were studied: Yolo Wonder (American variety), HDA 103 and HDA 174 (doubled haploids, selected by INRA, Montfavet, France) and SC 81 (strain from the L Dimitrova Institute, Minag, Cuba).

Pepper roots were exposed to three different sodium chloride concentrations (0, 50 and 100 mM), added to the nutrient solution, and to two temperature levels (22 and 32 °C).

Seeds were sown on 28 March in quartzose, a chemically inert substrate. Germination occurred between 9 and 14 April, and the plantlets were transplanted on 2 May.

Plants were then grown hydroponically, with a nutrient solution containing (per litre): 6.5 mM NO_3^-, 0.5 mM $H_2PO_4^-$, 0.5 mM SO_4^-, 3.5 mM K^+, 1.5 mM Ca^{++}, 0.5 mM Mg^{++} and 0.5 mM NH_4^+. This solution was supplemented with the trace elements essential for plant growth: B, Cl, Cu, Fe, Mn, Mo and Zn. The tests were carried out from 5 to 25 May.

experimental design

Two plants/treatment were studied, each in a 1 litre plastic pot. Pots were tested according to a split-plot design. Two factors were tested in duplicate, variety and NaCl concentration, with root temperature as the subfactor.

analysis

At the end of the test, the dry matter of each organ was weighed after the roots, stem, petiole and lamina were separated and oven-dried at 80 °C for 48 h. The roots were prerinced twice with distilled water to remove all salt remaining on these organs.

Plant tissues were analysed for cation contents (K, Ca, Mg and Na) through dry mineralization (CORNILLON, 1984).

The results were assessed with an analysis of variance and Newman-Keuls test, using the statistical analysis software package developed by ITCF (STAT-ITCF) (ITCF : Institut technique des céréales et des fourrages, France).

results

growth

Dry matter production was found to depend significantly (5% level) on salinity and variety (fig 1). Root temperature did not affect plant matter synthesis.

When no sodium chloride was added, maximum growth was obtained with cvs Yolo Wonder and HDA 103. HDA 174 had the lowest dry matter accumulation at relatively low overall radiation levels. Intermediate results were obtained with SC 81. With the addition of 100 mM NaCl, maximum growth was noted for HDA 103, with dry matter accumulation 40% that of control plants cultivated without sodium chloride. Yolo Wonder and SC 81 showed the lowest growth, with dry matter accumulation levels only 31 and 33%, respectively, that obtained with no NaCl. HDA 174 showed the most interesting performance, with growth 50% that of the control.

mineral composition

Table I shows the mineral contents of various organs in the four pepper varieties. Potassium, calcium and magnesium contents decreased in the organs as the sodium concentration in the cultivation medium increased, except for the magnesium contents of HDA 103 and HDA 174 conducting organs (stems and petioles), which increased.

The sodium content in the organs naturally increased with the sodium concentration in the nutrient solution. However, the four varieties reacted differently to this element: little sodium was found in the roots and lamina of Yolo Wonder and SC 81, whereas HDA 103 and HDA 174 had high concentrations in these two organs. The conducting organs behaved differently. With sodium added to the nutrient solution, the sodium contents were high in Yolo Wonder and SC 81 varieties, and relatively low in HDA 103 and HDA 174.

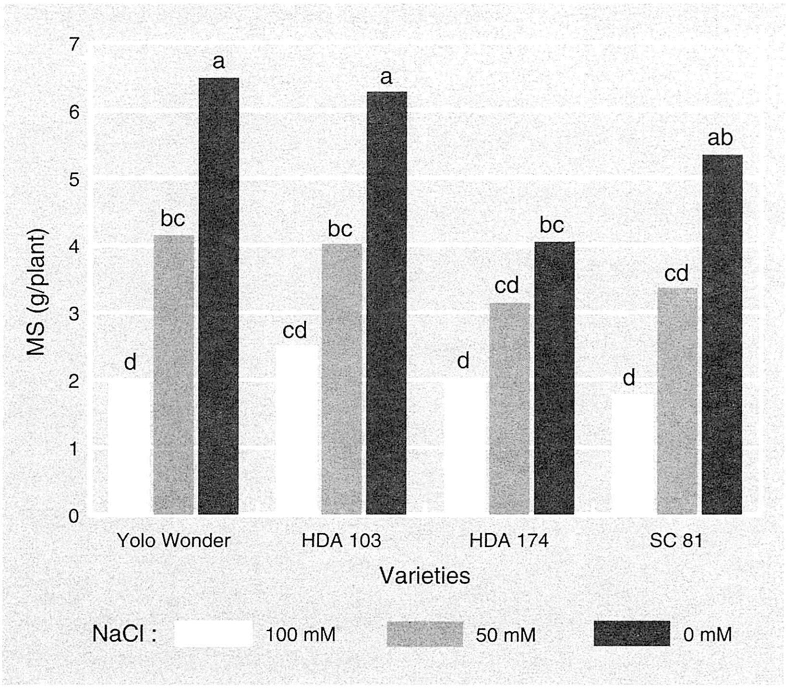

Figure 1
Effect of the NaCl concentration on pepper growth.

Relations between the sodium content in the lamina and other plant characteristics indicated evolutionary differences. There was no correlation between sodium content in the lamina and plant growth, as measured by the pooled total dry matter level at the end of the test (fig 2). Maximum growth was obtained with no sodium in the

Table I
Effect of the NaCl content on the mineral composition of pepper organs.

Varieties	*NaCl (mM)*	K^+			Ca^{++}			*Mg*			*Na*		
		Root	*Stem + petiole*	*Lamina*	*Root*	*Stem + petiole*	*Lamina*	*Root*	*Stem + petiole*	*Lamina*	*Root*	*Stem + petiole*	*Lamina*
Yolo Wonder	0	4.77	7.50	5.92	0.38	0.92	1.76	0.36	0.43	0.52	0.10	0.05	0.10
	50	3.44	5.77	5.38	0.20	0.62	1.22	0.26	0.32	0.45	0.90	2.13	0.90
	100	3.05	4.70	5.27	0.20	0.71	1.09	0.25	0.36	0.37	1.01	2.70	1.01
HDA 103	0	4.07	7.40	5.78	0.32	0.99	1.65	0.45	0.28	0.53	0.02	0.06	0.04
	50	2.68	5.65	4.04	0.25	0.64	1.02	0.26	0.33	0.46	2.29	1.54	2.19
	100	2.52	4.90	3.08	0.19	0.60	0.85	0.25	0.39	0.38	3.46	1.92	3.32
HDA 174	0	3.78	6.44	6.44	0.40	0.81	1.36	0.34	0.30	0.53	0.08	0.02	0.08
	50	2.58	6.40	4.15	0.24	0.90	1.14	0.27	0.37	0.48	1.80	1.32	1.80
	100	2.15	6.40	3.18	0.20	0.85	0.93	0.21	0.42	0.35	3.48	1.91	3.48
SC 81	0	5.47	6.95	6.69	0.38	0.59	1.88	0.32	0.28	0.61	0.06	0.02	0.06
	50	3.00	5.22	5.58	0.19	0.55	1.64	0.23	0.27	0.58	0.90	2.12	0.90
	100	2.30	3.34	5.10	0.17	0.52	1.47	0.19	0.24	0.52	1.08	3.12	1.08

organs in all varieties, but the lowest growth occurred when the sodium percentages ranged from 0.5% to more than 4% of the dry matter in the lamina, depending on the variety.

In the same way, variations in the potassium and sodium content in the lamina were dependent on the variety (fig 3). For Yolo Wonder and SC 81, sodium accumulation was limited, with little vari-

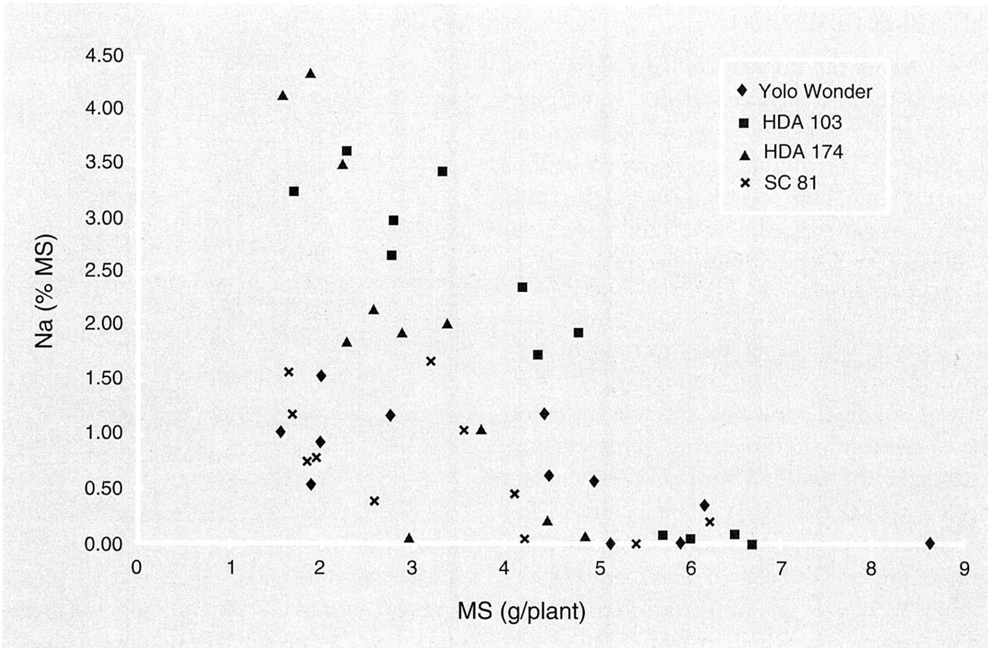

Figure 2
Correlation between pepper growth and Na content in the lamina.

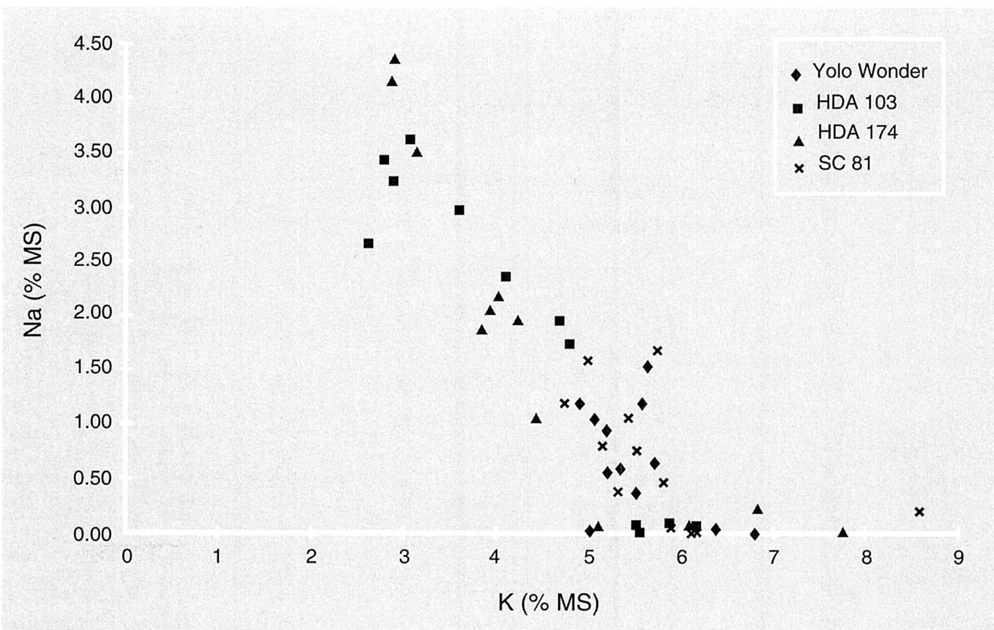

Figure 3
Correlation between potassium and Na contents in the lamina of pepper plants.

ation in the potassium content; however, for HDA 103 and HDA 174, there was high sodium accumulation and an especially marked reduction in the potassium content in the lamina. This sodium accumulation in leaves did not induce any serious toxicity phenomena in the two latter varieties since their growth was less affected than that of varieties with low sodium accumulation. Moreover, there were no visual toxicity symptoms linked with sodium accumulation visible in the lamina in either HDA 103 or HDA 174.

The sum of the potassium and sodium contents in the lamina varied according to the variety, increasing very little in Yolo Wonder leaves, remaining relatively constant for SC 81, while increasing significantly for HDA 103 and HDA 174. Varieties with the highest increase in osmotic pressure showed the most interesting behaviour: maximum dry matter accumulation rate in the plant with the highest NaCl concentration in the nutrient solution.

For the same root sodium content, the relation between this content and that of the lamina varied according to two models (fig 4), a linear model for Yolo Wonder and SC 81 varieties, and a quadratic model for HDA 103 and HDA 174. For the same Na^+ concentration range in the roots, the shoot sodium contents ranged from 0.5 to 1% and from 3 to 4.5%.

discussion and conclusion

This study confirmed the susceptibility of pepper to salinity. Significant differences had already been pointed out by other authors (LESSANI and MARSCHNER, 1978). However, YANEZ *et al* (1992) showed that pepper is much more susceptible to changes in the soil water potential than to soil salinity variations.

There were marked varietal differences: the HDA 103 variety achieved maximum growth with all of the NaCl concentrations used, whereas Yolo Wonder had the best growth with no NaCl and minimum growth with 100 mM sodium chloride. The two other varieties showed intermediate behaviours.

Two contrasting types of behaviour characterized the mineral contents. Yolo Wonder and SC 81 varieties reacted as nonhalophytic plants, but HDA 103 and HDA 174 behaved as halophytic plants (GREENWAY and MUNNS, 1980): Yolo Wonder and SC 81 did not accumulate sodium in the roots and lamina, whereas HDA 103 and HDA 174 accumulated Na in the roots, especially in the lamina. This sodium accumulation, the

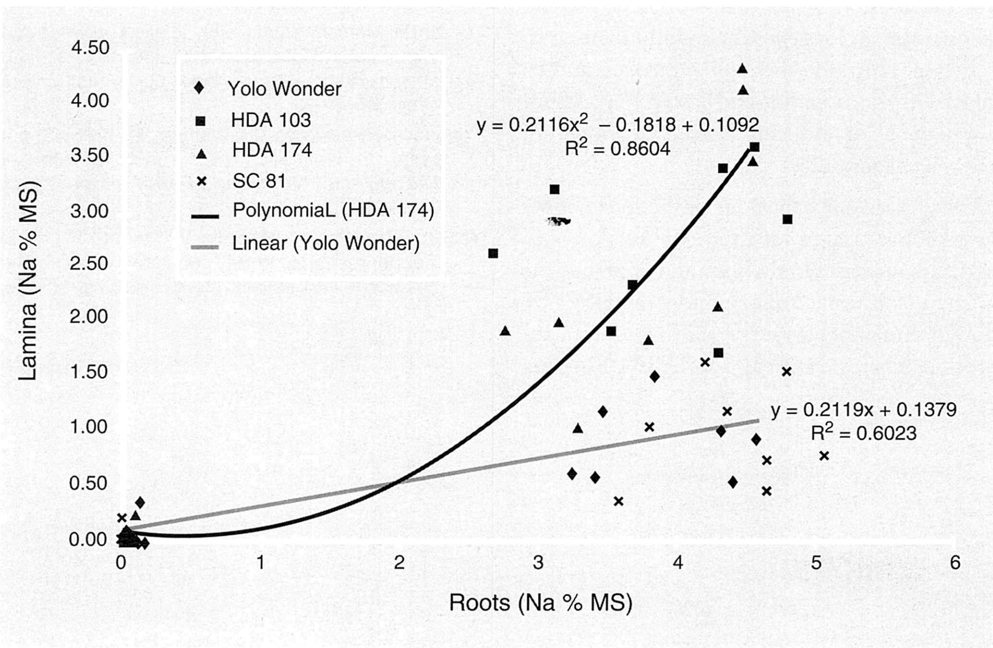

Figure 4
Correlation between the Na content in the roots and lamina of pepper plants.

marked modification in the K^+/Na^+ ratio and the increase in osmotic pressure enabled these varieties to grow better when the nutrient medium contained 100 mM NaCl.

TERMAAT *et al* (1995) showed that 0.48 MPa pressure applied to the roots of wheat and barley plantlets did not affect plantlet growth, indicating that turgescence pressure had no impact on cell growth.

Sodium was partly substituted for potassium in HDA 103 and HDA 174, whereas this phenomenon was negligible in the two other varieties. K and Na competed for their uptake by the plant, and this phenomenon differed between varieties. Yolo Wonder and SC 81 seemed to have a high selective capacity with respect to the uptake of potassium rather than sodium, but this capacity was lower in HDA 103 and HDA 174.

The sodium content in the conducting organs was higher in Yolo Wonder and SC 81, suggesting that the roots have no barrier role with respect to the migration of Na towards aerial parts. Sodium seems to be continuously transferred from the aerial parts to the roots so as to maintain very low Na levels in the lamina of varieties that do not accumulate sodium in this organ.

According to DURAND and LACAN (1994), high sodium retention occurs in soybean stems, since the Na concentration decreases in the xylem flow near the apex. It seems that old leaves play an essential role in lowering the sodium content in crude sap. However, these phenomena could be linked with the ascending and descending sodium flow in the plant, inducing sodium accumulation near the collar.

In conclusion, the behaviour of the four pepper varieties investigated varied in conjunction with moderate increases in the sodium content of the nutrient solution. Yolo Wonder and SC 81 showed similar behaviours regarding sodium absorption, whereas HDA 103 and HDA 174 took up less potassium while accumulating relatively large amounts of sodium. This difference was expressed by better relative growth of varieties showing sodium accumulation in the lamina when the nutrient solution contained high NaCl concentrations. A high sodium content in the conducting organs of varieties with low Na content in the lamina (Yolo Wonder and SC 81) suggested sodium transfer from the roots to the lamina, and also reverse transfer from the lamina to the roots.

The reduced growth observed at 100 mM NaCl, especially for Yolo Wonder, could have resulted from a higher metabolic activity necessary for the plant to transfer sodium from the aerial parts to the roots.

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