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RESPONSE OF CHILE PEPPER (*Capsicum annuum* L.) TO SALT STRESS AND ORGANIC AND INORGANIC NITROGEN SOURCES: I.GROWTH AND YIELD

[RESPUESTA DE PLANTAS DE CHILE (*Capsicum annuum* L.) AL ESTRÉS SALINO Y FUENTES ORGANICAS E INORGANICAS DE NITROGENO: I. CRECIMIENTO Y RENDIMIENTO]

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SUMMARY

The effect of two sources of nitrogen on plant growth, and fruit yield of chile pepper (*Capsicum annuum* L.) cv. Sandia grown in greenhouse to increased salinity were evaluated. An organic source extracted from grass clippings in rates of 120 and 200 kg N ha^{-1}, and another inorganic (ammonium nitrate) in rate of 120 kg ha^{-1} were combined with low, moderate and high (1.5, 4.5, and 6.5 dS m^{-1}) salinity levels arranged in a randomized complete block design replicated four times. Salinity treatments reduced dry matter production, leaf area, relative growth rate and net assimilation rate but increased leaf area ratio. Mean fresh fruit yields decreased for each N rate and source combinations as soil salinity increased. The organic fertilizer produced higher fruit yields tan the inorganic fertilizer. The highest fruit yield was obtained with the increased rate of organic N. The fruit number was more affected by salinity than the individual fruit weight. This organic fertilizer may be an effective N source for chile pepper and other vegetable crops grown under non- and salt-stressed conditions.

Key words: Relative growth rate; net assimilation rate; leaf area ratio; yield.

RESUMEN

El efecto de dos fuentes de nitrógeno sobre el crecimiento de plantas y rendimiento de frutos de chile (*Capsicum annuum* L.) cv. Sandia cultivadas bajo condiciones de estrés salino fueron evaluados en invernadero. Una fuente orgánica extraída de residuos de zacates en dosis de 120 y 200 kg N ha^{-1} y otra inorgánica (nitrato de amonio) en dosis de 120 kg N ha^{-1} fueron combinados con niveles bajo, moderado y altos niveles de salinidad (1.5, 4.5 y 6.5 dS m^{-1}) arreglados en diseño de bloques completos al azar con cuatro repeticiones. Los tratamientos de salinidad redujeron la producción de materia seca, área foliar, la tasa de crecimiento relativo y la tasa neta de asimilación, pero incrementaron la relación de área foliar. Los rendimientos medios de frutos frescos disminuyeron para cada combinación de dosis y fuente de N conforme la salinidad del suelo se incrementó. El fertilizante orgánico produjo rendimientos de frutos más altos que el fertilizante inorgánico. El mayor rendimiento fue obtenido al incrementar la dosis orgánica de N. El número de frutos fue más afectado por salinidad que el peso individual de fruto. El fertilizante orgánico puede ser una fuente efectiva de N para la producción de chile y otros vegetales establecidos bajo condiciones de estrés o no estrés salinos.

Palabras claves: Tasa de crecimiento relativo; tasa neta de asimilación; relación de área foliar; rendimiento.

INTRODUCTION

In many areas of the world, soil salinization is an important concern for the sustainability of irrigated agriculture. High concentrations of salts in soil are responsible for large decreases in the yield of a variety of crops worldwide. The most evident effect of salinity is the reduction in plant growth and yield (Maas, 1996). Salinity inhibition of plant growth is the result of osmotic and ionic effects, and an ion imbalance due to decreased water and nutrient uptake (Greenway and Munns, 1980; Marschner, 1995).

A measure of the plant growth efficiency is obtained through its relative growth rate (RGR) (Shipley, 2000). RGR is described as the product of net assimilation rate (NAR) and leaf area ratio (LAR). Changes in RGR during growth are mediated by changes in either NAR or LAR (Poorter, 1989). NAR is an index of the photosynthetic-assimilatory capacity of the plant per unit leaf area, and LAR is an index of the leafiness of the plant (Hunt, 1990).

In many studies, researchers have hypothesized that N fertilizer additions mitigate the detrimental effect of salinity on plants (Grattan and Grieve, 1999; Kaya and Higgs, 2002; Kaya and Higgs, 2003a). There are several studies showing the effects of inorganic fertilization on crop growth and yield of pepper plants under non saline (Hedge, 1987; Payero et al., 1990; Hartz et al., 1993; Olsen et al., 1993; Guertal, 2000; Xu et al., 2001; Kirnak et al., 2003), and saline conditions (Gomez et al., 1996; Chartzoulakis and Klapaki, 2000; Patel et al., 2000; Kaya and Higgs, 2003b; Villa-Castorena et al., 2003). Furthermore, the addition of N to vegetable crops have produced similar or greater yields when organic C-based materials are used compared to inorganic N sources (Cushman and Snyder, 2002; Delate et al., 2003; Heeb et al., 2005) but little is known about whether the application of a plant- or C-based (organic) liquid fertilizer causes the same effects as inorganic fertilizers.

Therefore, one objective of this research was to analyze the importance of the growth parameters NAR, and LAR in explaining the variation in RGR and correlate these findings with the performance of inorganic and organic plant-based fertilizer on chile pepper under saline conditions. A second objective was to determine the effects of application of two N sources on the yield of chile pepper plants grown at three salinity levels.

MATERIALS AND METHODS

This study was carried out in a greenhouse at New Mexico State University located in Las Cruces, New Mexico, USA. Seedlings of chile pepper (*Capsicum annuum* L.) cv. "Sandia" grown for three weeks in small pots filled with peat and irrigated with tap water, were transplanted to plastic pots filled with 15 kg of a non saline (ECe = 0.9 dS m^{-1}), air dried soil passed through a 2 mm sieve. Brazito sandy loam (Mixed thermic Typic Torripsamment) (USDA, 1980) soil was used in the experiment.

The greenhouse experiment was arranged in a randomized complete block design where each salinity level, and N-fertilizer source and rate combination was replicated four times. Three salinity levels (low: 1.5 dS m^{-1}, moderate: 4.5 dS m^{-1}, and high: 6.5 dS m^{-1}) were prepared by adding solutions of a mixture of NaCl and $CaCl_2$ salts on a 1:1 equivalent weight ratio, which were added to soils to obtain the desired soil salinity levels (electrical conductivity, ECe, dS m^{-1}). The amount of each salt (mg) to add to the solution was calculated according to Villa-Castorena *et al*. (2003) as follow:

$$\text{Solution} = \frac{10\,ECe}{2} \times EW \times SSV \qquad [1]$$

where EW is the equivalent weight of each salt in mg meq^{-1}, and SSV is the soil saturation volume of the pot in L. The constant 10 is an empirical factor to convert ECe in dS m^{-1} to total dissolved salt in the soil saturated paste extract in meq L^{-1}, and this value is divided by 2 to consider the contribution of each salt to ECe. Each pot was salinized one-time with the addition of saline solutions a day before seedling transplant. Two sources of nitrogen (inorganic or organic, plant-based fertilizer) were combined to each salinity level at rate of 120 kg ha^{-1} inorganic fertilizer (IF) and two rates (120 and 200 kg ha^{-1}) organic, plant-based fertilizer (OF). Ammonium nitrate was used as the inorganic source. The OF was obtained from grass clippings, whose nutrients were extracted with water through a bioleaching process under anaerobic conditions (Saha, 2002). The N concentration (total Kjeldahl nitrogen, TKN) of this liquid fertilizer was 0.70 %. Each fertilizer rate was split in four equal doses and applied at transplanting, twenty days after transplanting, at flowering and after the first harvest. At the end of the experiment, plant height was measured from the shoot apex down to the base at the soil surface level, and stem diameter was measured with a caliper just below the cotyledonary node. Plants were collected at 72 days after transplanting by cutting their base close to the ground and taken apart into roots, stems, leaves, and fruits and washed with distilled water and then dried in a forced-air oven at 70 ºC for 72 h. Each dry material was ground in a Wiley Mill and passed through a 40-mesh sieve and the dry mass (DM) was measured. Leaf area (LA) was determined using a LI-COR 3000 leaf area meter (LI-COR, Lincoln, NE).

Values of dry weights of roots and shoots (leaf plus stem) together with leaf area, at transplanting and the end of the experiment were used to calculate RGR, NAR, and LAR. The mean RGR, i.e. the rate of increase in total dry weight per unit of plant dry weight and their components were calculated according to the following expressions (Hunt, 1982):

$$\mathrm{RGR} = \frac{\ln \mathrm{DW}_2 - \ln \mathrm{DW}_1}{t_2 - t_1} \ (\mathrm{mg\ g^{-1} d^{-1}}) \qquad [2]$$

$$\mathrm{NAR} = \left[\frac{\mathrm{DW}_2 - \mathrm{DW}_1}{t_2 - t_1}\right]\left[\frac{\ln \mathrm{LA}_2 - \ln \mathrm{LA}_1}{\mathrm{LA}_2 - \mathrm{LA}_1}\right] (\mathrm{mg\ cm^{-2} d^{-1}}) \ [3]$$

$$\mathrm{LAR} = \left[\frac{\mathrm{LA}_1}{\mathrm{DW}_1} + \frac{\mathrm{LA}_2}{\mathrm{DW}_2}\right] \times 0.5 \ (\mathrm{cm^2\ g^{-1}}) \qquad [4]$$

where DW is the total dry weight per plant (g), LA the total leaf area per plant (cm^2), and t the time from transplanting to final harvest (day). The subscripts 1 and 2 represent transplanting and final harvest respectively.

The plants were hand irrigated with inverse osmosis water (EC < 0.015 dS m^{-1}) and the plant water used during the plant growth period was determined by measuring the water volume added to the pots by weighing every day each pot to restore the soil moisture about field capacity. Chile pepper fruits were handpicked five times. At each harvest, the number of fruits and the weight of the fruits were determined. Fruit yields are the means of the fruits harvested from four plants of each treatment and reported in grams per plant.

The growth parameters and yield data were analyzed using the SAS package software for analysis of variance (ANOVA) to determine the effect of each treatment. Multiple mean comparisons were performed using Duncan's Multiple Range Test at the 0.05 level of probability. To investigate the relationships between RGR and its components NAR and LAR, correlation analyses were performed using SAS version 9.1. Relationships were considered significant at the 5% level.

RESULTS AND DISCUSSIONS

Growth of chile pepper plants

Salinity effects on chile pepper plant growth components as a function of N rate and source is reported in Table 1. Generally, a reduction in height is the plant's first response to salinity. In our study the mean plant height did not differ between fertilizer and salinity treatments. Only a linear trend in plant height was significant ($P<0.05$) in plants fertilized with 200 kg ha^{-1} OF. Reductions in plant height were observed by several authors Aliyu, 2000, Chartzoulakis and Klapaki, 2000, Kaya and Higgs, 2003b.

Stem diameter decreased in pepper plants fertilized with the low N rate of any N source. This response was linear and negatively significant ($P<0.01$) in pepper plants fertilized with 120 kg ha^{-1} OF, while this response was quadratic ($P<0.05$) in plants fertilized at the same N rate with IF, with a decrease in moderate salt-stressed plants followed by an increase in high salt-stressed plants. It has been shown that the growth of aerial organ is inhibited under salt stress by the decrease of root growth (Cramer *et al.*, 1989). Several authors suggested that, under saline stress, the osmotic effect is responsible for the aerial organ growth reduction (Muuns and Termaat, 1986; Yeo *et al.*, 1991; Rengel, 1992).

In general, chile pepper root dry weight decreased with increasing soil salinity. Significant decreases in root weight were noted for plants fertilized with 120 kg ha^{-1} IF and with 200 kg ha^{-1} OF as soil salinity levels increased. Only moderate salt-stressed plants showed differences between N rate and source treatments. Root dry weight decreased in a linear manner in plants fertilized with the high N-organic rate (200 kg ha^{-1}), and in a quadratic manner in plants fertilized with the low N-inorganic rate (120 kg ha^{-1}).

Mean shoot dry weight did not differ between salinity levels or fertility treatments. Reductions in root and shoot dry matter with increased salinity were also observed in salt-stressed pepper plants by Günes *et a*l. (1996), Kaya and Higgs (2003a), and Kaya and Higgs, (2003b).

As stated by Munns (2002), suppression of plant growth under saline conditions may either be due to the decreasing availability of water or to the increasing toxicity of sodium and chloride associated with increasing salinity. As no visual symptoms of salt toxicity such as "salt spots" or necroses were observed, the decreased root and shoot dry weights was apparently due to the accumulation of salts in the soil, which increase the osmotic pressure of the soil solution and greatly decreases the availability of water to the roots. Application of high N rates resulted in increased shoot and root dry weight. Shoot dry matter was greater than root dry matter. At higher levels of nitrogen supply, shoot growth is greatly stimulated and this in turn decreases the translocation of carbohydrates to the roots, thereby suppressing root growth (Murata, 1969). Leskovar *et al*. (1989) also found that root and shoot dry weights of pepper plants increased in response to N fertilization. In general, biomass production was higher in plants fertilized with the organic-N source than those fertilized with the inorganic source.

Table 1. Plant height, stem diameter, root and shoot dry weight, and leaf area of chile pepper in response to nitrogen source and rate grown under saline conditions.

Component	Soil Salinity dS m^{-1}	Fertilizer rate (kg ha^{-1}) and source			Significance
		120 OF	120 IF	200 OF	
	1.5	78.63 aA	77.00 aA	79.75 aA	NS
Plant height	4.5	67.00 aA	63.25 aA	67.25 aA	NS
(cm)	6.5	72.50 aA	67.00 aA	58.50 aA	NS
	Significance	NS	NS	NS	
	Linear	NS	NS	*	
	Quadratic	NS	NS	NS	
	1.5	1.13 aA	1.10 aA	1.16 aA	NS
Stem diameter	4.5	0.97 bA	0.98 abA	1.10 aA	NS
(cm)	6.5	0.90 bA	1.06 bA	0.97 aA	NS
	Significance	*	*	NS	
	Linear	**	NS	NS	
	Quadratic	NS	*	NS	
	1.5	35.96 aA	31.02 aA	40.65 aA	NS
Root dry weight	4.5	28.47 aA	22.20 bB	31.50 bA	*
(g plant^{-1})	6.5	25.47 aA	25.86 abA	26.32 bA	NS
	Significance	NS	*	*	
	Linear	NS	NS	*	
	Quadratic	NS	*	NS	
	1.5	167.99 aA	144.37 aA	180.16 aA	NS
Shoot dry weight	4.5	173.14 aA	142.64 aA	147.81 aA	NS
(g plant^{-1})	6.5	169.02 aA	140.62 aA	150.34 aA	NS
	Significance	NS	NS	NS	
	Linear	NS	NS	NS	
	Quadratic	NS	NS	NS	
	1.5	2519.5 aA	1671.4 aB	2818.1 aA	**
Leaf	4.5	2509.6 aA	1497.2 aB	2592.7 aB	*
area	6.5	3141.8 aA	1896.7 aB	1436.2 bAB	*
(cm^2 plant^{-1})	Significance	NS	NS	**	
	Linear	NS	NS	NS	
	Quadratic	NS	NS	**	

Means followed by the same letter are not significantly different within rows and column according to Duncan's test ($\alpha \leq 0.05$, n=3). Means indicated with lower case letters are compared for salinity effect at each N rate and source combination effect; means indicated with upper case letters are compared for N rate and source combination effect at each salinity level. NS indicates no significant at the > 0.05 probability level; * indicates significant at the 0.01< P ≤ 0.05 probability level; and * * indicates significant at the ≤ 0.01 probability level. IF = inorganic fertilizer; OF = organic plant-based fertilizer

Leaf area

In relation to leaf area, only plants fertilized with 200 kg ha^{-1} OF showed differences due to increasing soil salinity. In this treatment, leaf area best fit a quadratic model (orthogonal polynomial contrasts, quadratic *P*<0.01) with respect to the increasing soil salinity. On the other hand, for each soil salinity level, foliar area differed between N rate and source fertilizer treatments. Organic fertilization produced greater leaf area than inorganic fertilization. However, leaf area decreased with the application of the high organic N level compared to the low organic N level. Reductions in leaf area were also observed by Chartzoulakis and Loupasski (1997) in greenhouse eggplants affected by NaCl; by Li and Stanghellini (2001) in greenhouse tomato affected by root-zone salinity; by De Pascale *et al*. (2003) in salt-stressed pepper plants; A larger leaf area in relation to the mass of the leaves means a higher specific leaf area, and to support this relative increase in leaf area it requires a greater investment in the stem (De Groot *et al*., 2002). Increased dry mass of the stem of salt-stressed pepper plants related to increased dry mass of leaves was observed by Tadesse *et al*. (1999). In our study, although stem dry mass was greater than leaf dry mass, leaf area was more significant and positively correlated to leaf dry mass (R^2 = 0.79, P<0.0001) than to stem dry mass (R^2 = 0.17, P=0.0105). It was also observed that dry mass partitioning to stem decreased with increasing salinity while decreased leaf dry masses were more evident in high salt-stressed plants (data not shown).

Relative growth rate (RGR)

Mean RGR differed significantly (P<0.0085) between soil salinity levels for all N rate and source combinations, ranging from 63.37 mg mg^{-1} day^{-1} for plants grown at low soil salinity to 61.14 and 61.73 mg mg^{-1} day^{-1} for plants grown at moderate and high soil salinity levels, respectively. Across soil salinity levels, there were no differences in the RGR of pepper plants fertilized with 120 kg ha^{-1} OF (Table 2). On the contrary, significant effects (P<0.05) on RGR were found in plants fertilized with the same N rate of IF, as well as those fertilized with 200 kg ha^{-1} OF. A quadratic trend (P<0.01) was observed in plants fertilized at the low rate with IF. At the high N rate of the organic source, RGR decreased linearly (P<0.05) with increasing soil salinity. A comparison of RGR across N source and rate combination treatments showed that RGR at increasing soil salinity showed significant differences in low and moderate soil salinity. In both salinity levels, a similar response was observed in RGR of plants fertilized with either N rate of organic-N fertilizer. Based on the decrease in dry matter between low and moderate soil salinity levels, crops with a salinity threshold ranging from 1.3 to 3.0 dS m^{-1} are classified as moderately sensitive to salinity (Maas and Hoffman, 1977); therefore, ‘Sandia’ pepper can be considered moderately sensitive to salinity. However, the RGR of plants fertilized with 120 kg ha^{-1} OF was higher than those fertilized with the same N rate of IF in the low and moderate salinity levels (Table 2). Decreased RGRs at increased salinity were also observed in pepper by Cornillon and Palloix (1997).

The decreased RGR was best explained by increased soil salinity in a comparison of RGR between treatments that were significant. In this situation, salinity was the main limiting factor. For this reason, it can be assumed that N was not a limiting factor.

Net assimilation ratio (NAR)

Averaging across soil salinity levels, and considering all N rate and source combinations, pepper plants differed significantly (P<0.0171) in mean NAR, ranging from 3.99 mg mg^{-1} day^{-1} for plants grown at low soil salinity to 3.67 and 3.27 mg mg^{-1} day^{-1} for plants grown at moderate and high soil salinity levels, respectively. Pepper plants fertilized with organic N fertilizer at both rates showed a significant response in NAR with soil salinity (Table 2). The NAR decreased linearly (P<0.01) as soil salinity levels increased for plants fertilized with the low N rate of organic fertilizer. There were differences (P<0.01) between N rate and source combination treatments in pepper plants grown at high salinity. The NAR of plants fertilized with the organic source at both N rates did not differ. However, at the same N rate of 120 kg ha^{-1}, NAR of plants fertilized with organic fertilizer differed from those fertilized with inorganic fertilizer only for the high salinity.

Reductions in RGR were accompanied by decreases in net assimilation rates (NAR) and increases in leaf area ratio (LAR). Reduction in NAR is most likely due to a decrease in photosynthesis (Poorter, 2002).

Leaf area ratio (LAR)

Contrary to NAR, for all N rate and source combinations, mean LAR increased significantly (P<0.0143) from 61.14 cm^2 g^{-1} for plants grown at low soil salinity to 61.53, and 62.48 cm^2 g^{-1} for plant grown at moderate, and high soil salinity levels. Similar to NAR, pepper plants fertilized with OF at both N rates showed a significant effect in LAR across soil salinity levels (Table 2). The LAR increased linearly (P<0.01) with increasing soil salinity levels in plants fertilized with the low N rate of OF, whereas a quadratic trend (P<0.05) was observed in plants fertilized with the high N rate of OF. Pepper plants grown at high soil salinity, and fertilized with organic N had a higher LAR than those fertilized with the inorganic source. The LAR relates the leaf area to the dry matter resulting from photosynthesis. A larger proportion of the assimilate products were used in the formation of the photosynthetic apparatus (leaf area) with increasing salinity. Leaves of slow growing plants may accumulate considerable amounts of secondary compounds, which can increase the dry weight of the leaves (Poorter, 1989). So, the increase in LAR in pepper plants is associated with the increase in leaf weight ratio.

RGR relationships with other growth parameters

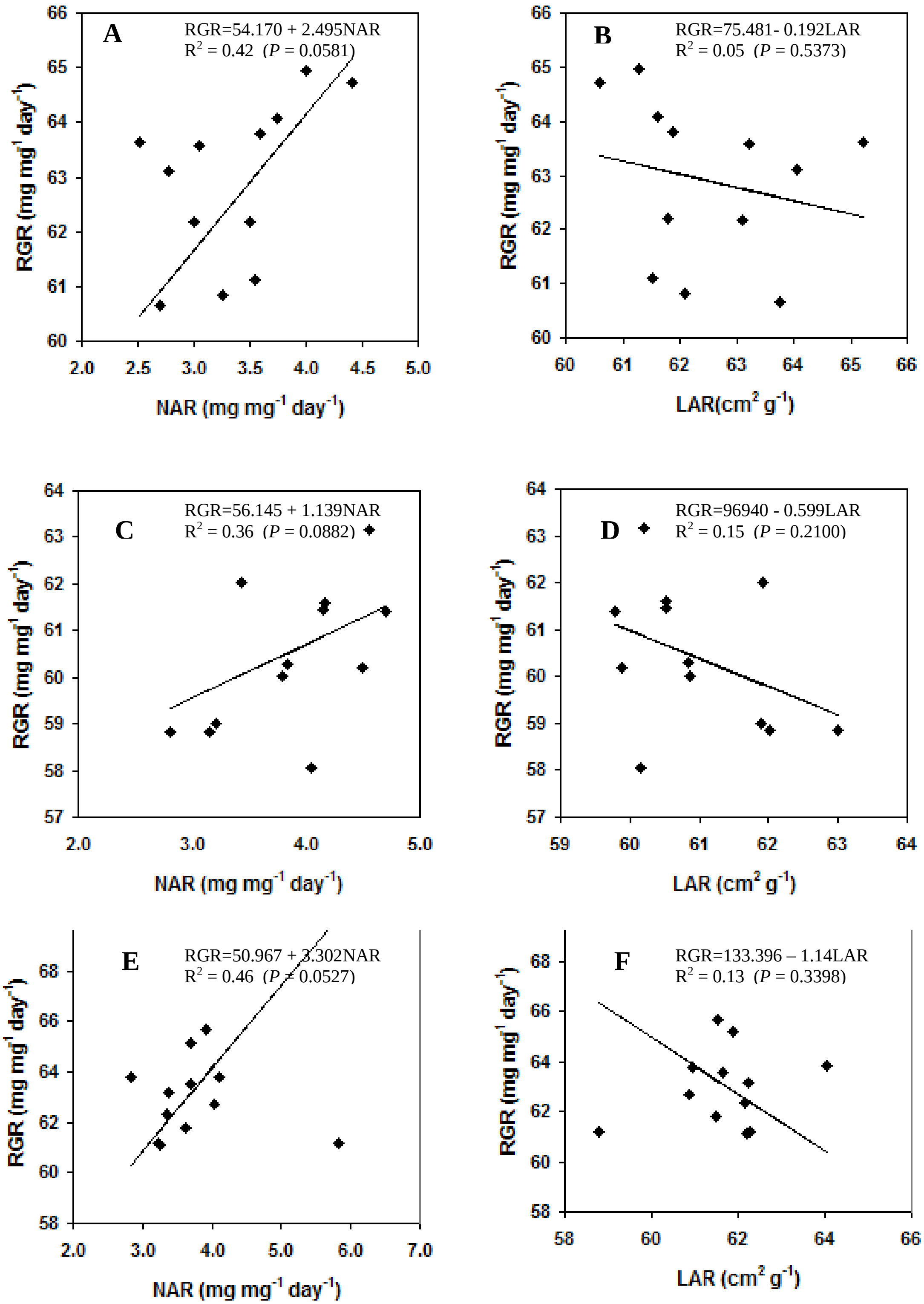
Figure 1 illustrates the relationships between the RGR and the other growth parameters (NAR, and LAR) across soil salinity levels.

RGR of plants fertilized at low N rate of OF was nearly significant and positively correlated to NAR (R^2 = 0.42, Fig. 1A) but was not correlated to LAR (R^2 = 0.05, Fig. 1B). In plants fertilized with the low N rate of IF, although there were no significant correlations, RGR showed a positive correlation with NAR (R^2 = 0.36, Fig. 1C), and a weak negative correlation with LAR (R^2 = 0.15, Fig. 1D). The RGR of chile pepper plants fertilized with 200 kg ha^{-1} OF showed a nearly significant strong positive correlation with NAR (R^2 = 0.46, Fig. 1E), and a no significant weak negative correlation with LAR (R^2 = 0.13, Fig. 1F).

Table 2. Relative growth rate (RGR, mg g^{-1} d^{-1}), net assimilation rate (NAR, mg cm^{-2} d^{-1}) and leaf area ratio (LAR, cm^2 g^{-1}) of chile pepper in response to nitrogen source and rate grown under saline conditions.

Component	Soil Salinity	Fertilizer rate (kg ha^{-1}) and source			Signifi-
	dS m^{-1}	120 OF	120 IF	200 OF	cance
	1.5	63.98 aA	61.69 aB	64.44 aA	*
RGR	4.5	62.20 aA	58.93 bB	62.30 bA	**
	6.5	62.50 aA	60.58 abA	62.10 bA	NS
	Significance	NS	*	*	
	Linear	NS	NS	*	
	Quadratic	NS	**	NS	
	1.5	3.91 aA	4.29 aA	3.77 abA	NS
NAR	4.5	3.29 aA	3.44 aA	4.29 aA	NS
	6.5	2.81 bB	3.83 aA	3.15 bB	**
	Significance	**	NS	*	
	Linear	**	NS	NS	
	Quadratic	NS	NS	NS	
	1.5	61.32 bA	60.44 aA	61.65 abA	NS
LAR	4.5	62.38 abA	61.50 aA	60.69 bA	NS
	6.5	63.83 aA	60.94 aB	62.66 aA	**
	Significance	*	NS	*	
	Linear	**	NS	NS	
	Quadratic	NS	NS	*	
	1.5	167.45 aA	168.40 aA	166.78 aA	NS
SLA	4.5	167.69 aA	166.29 aA	166.21 aA	NS
	6.5	168.11 aA	167.46 aA	167.10 aA	NS
	Significance	NS	NS	NS	
	Linear	NS	NS	NS	
	Quadratic	NS	NS	NS	
	1.5	0.34 bAB	0.31 Bb	0.35 abA	*
LWR	4.5	0.37 bA	0.35 aA	0.33 bA	NS
	6.5	0.40 aA	0.33 abB	0.38 aA	**
	Significance	*	*	*	
	Linear	**	NS	NS	
	Quadratic	NS	*	NS	

Means followed by the same letter are not significantly different within rows and column according to Duncan's test ($\alpha \leq 0.05$, n=3). Means indicated with lower case letters are compared for salinity effect at each N rate and source combination effect; means indicated with upper case letters are compared for N rate and source combination effect at each salinity level. NS indicates no significant at the > 0.05 probability level; * indicates significant at the $0.01 < P \leq 0.05$ probability level; and * * indicates significant at the ≤ 0.01 probability level. IF = inorganic fertilizer; OF = organic plant-based fertilizer.



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The results presented in this study show that RGR was more related to NAR (the increase in mass per unit leaf and time) than LAR (the ratio of leaf area and total plant weight). These results agree with those obtained by Cramer et al. (1990) where RGR of salt-stressed barley was better correlated with the photosynthetic growth component NAR but not with LAR. On the other hand, Poorter and Nagel (2000) established that plants respond to limiting resource supply by allocating biomass to the various organs. Under salt stress, reduced growth correlates with a reduction in NAR due in part to damage of the photosynthetic apparatus (Poorter, 2002).

Fruit yield response to salinity and nitrogen source

Fruit yield of chile pepper was affected as result of salinity and N source and rate treatments, though their interaction was no significant in both years (Table 3). Yield of chile pepper decreased at increased soil salinity. Similar results were observed by Chartzoulakis and Klapaki (2000) in two greenhouse pepper hybrids grown at salinities higher than 4.1 dS m^{-1}, and by Villa-Castorena *et al*. (2003), who found that salinities greater than or equal to 3.5 dS m^{-1} reduced chile pepper yield. In our experiments, although salinity and fertilizer had a significant effect on fruit yield between treatments, comparisons within each saline treatment showed no significance in fruit yield irrespective of whether plants were fertilized with the organic source or with the inorganic source. However, the salinity effect was more highly significant (P < 0.001) than the fertilizer effect (P = 0.0336). As it was established by Grattan and Grieve (1994), when the salinity factor severely limits growth, the fertilizer factor has little influence on yield. Although it was not significant, regardless of N source, increasing N rate from 120 to 200 kg ha^{-1} the fruit yields were increased and the greatest yields were produced with organic, plant-based fertilizer. Increases in yield of salt-stressed pepper were also observed by Kaya and Higgs (2003a) when pepper plants were supplemented with urea or supplemented with potassium nitrate (Kaya and Higgs, 2003b). The reduced fruit yields of salt-stressed chile pepper plants were due to a decrease in the number of fruits rather than fruit weight. Chartzoulakis and Klapaki (2000) reported that fruit number and fruit weight of salt-stressed pepper plants were reduced at salinities greater than 4.1 dS m^{-1} and Gomez et al. (1996) observed that the number of fruits and mean weight of fresh fruit of sweet pepper were reduced by increased salinity but increased N fertilizer from 2 to 15 meq L^{-1} reduced the detrimental effect of salinity on the number and weight of fruit.

Table 3. Number and weight of fruits, and fresh fruit yield of chile pepper in response to N source and rate combination grown under saline conditions.

Component	Soil Salinity dS m^{-1}	Fertilizer rate (kg ha^{-1}) and source			Significance
		120 OF	120 IF	200 OF	
	1.5	25.00 aA	26.50 aA	30.25 aA	NS
Fruit,	4.5	19.50 aA	21.75 bA	27.25 aA	NS
No. $plant^{-1}$	6.5	15.25 aB	14.75 cB	23.50 aA	*
	Significance	NS	**	NS	
	Linear	NS	**	NS	
	Quadratic	NS	NS	NS	
Individual Fruit	1.5	22.34 aA	19.92 aA	19.10 aA	NS
weight,	4.5	19.09 abA	17.88 aA	17.52 aA	NS
g	6.5	14.76 bA	17.49 aA	14.80 aA	NS
	Significance	*	NS	NS	
	Linear	*	NS	NS	
	Quadratic	NS	NS	NS	
Fruit	1.5	577.8 aA	533.8 aA	639.4 aA	NS
Yield,	4.5	363.9 abA	404.1 bA	479.5 bA	NS
g $plant^{-1}$	6.5	236.5 bA	248.2 cA	364.9 bA	NS
	Significance	*	**	**	
	Linear	*	**	**	
	Quadratic	NS	NS	NS	

Means followed by the same letter are not significantly different within rows and column according to Duncan's Multiple Range Test ($\alpha \leq 0.05$, n=4). Means indicated with lower case letters are compared for salinity effect at each N rate and source combination effect; means indicated with upper case letters are compared for N rate and source combination effect at each salinity level. NS indicates no significance at the > 0.05 probability level; * indicates significance at the $0.01 < P \leq 0.05$ probability level; and * * indicates significance at the ≤ 0.01 probability level. IF = inorganic fertilizer; OF = organic plant-based fertilizer.

CONCLUSIONS

Chile pepper plants responded to increased salinity by reducing their relative growth rate (RGR) and net assimilation rate (NAR), and increasing leaf area ratio (LAR). The response of RGR to different N rate and source was most likely due to the physiological growth component, NAR, rather than the amount of leaf area per unit plant mass (LAR).

Our results showed a reduction on fruit yield. This decrease was due to a decrease in the number of fruits rather than fruit weight. Even though it was not statically significant, fruit yields of chile pepper fertilized with the organic, plant-based fertilizer were greater than fruit yields of plants fertilized with the inorganic fertilizer. Furthermore, high rates of OF increased fruit yield within the same salinity level supporting the hypothesis that N supplementation ameliorates the adverse effects of salinity on yield of crops.

Finally, these experiments gave evidence that chile pepper plants fertilized with organic, plant-based liquid fertilizer from grass clippings may be an effective source of nutrition for chile pepper and other vegetable crops grown under non- and salt-stressed conditions.

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