Interaction Effects of Paclobutrazol and Salinity on Photosynthesis and Vegetative Growth of Strawberry Plants

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Abstract

Strawberry plants (*Fragaria* × *ananassa* Duch) are very susceptible to salinity. To investigate the interactive effects of paclobutrazol (PP_{333}) and salinity on gas exchange and growth factors of the plant, 3 levels of NaCl [0, 5, 10 mM] were incorporated into the nutrient solution, and 4 levels of PP_{333} [0, 10, 20, 30 mg/L] were applied by means of foliar sprays. Increased levels of salinity and PP_{333} resulted in reduced leaf area. The highest level of PP_{333} resulted in reduced shoot dry weight. Foliar application of 20 mg/L of PP_{333} mitigated detrimental effects of salinity on root dry weight and total plant dry weight. PP_{333} also mitigated negative effects of increased salinity on photosynthetic rate (A), water use efficiency, relative water content and chlorophyll content. Increased salinity and PP_{333} caused reductions in stomatal conductance (gs), transpiration rate (E), number of runners and petiole length. Specific leaf weight was increased by both salinity and PP_{333}.

INTRODUCTION

Strawberry plants are very sensitive to saline conditions, and reducing salt stress in hydroponic systems would be helpful. The most common practice is to increase leaching, however this method can be expensive and impractical. Few studies have focused on application of growth regulators to induce salt tolerance. However, there is a report that paclobutrazol (PP_{333}), a gibberelline biosynthesis inhibitor, promoted salt stress avoidance in peach (*Prunus persica* L.) (Abou El-Khashab et al., 1997). PP_{333} has also been shown to reduce the symptoms and mortality due to salt stress in *Rhamnus alternus* seedlings (Banon et al., 2003). PP_{333} also modulated salt induced alternations in pigment content, proline level, lipid peroxidation and antioxidant activity in leaves of zuzuba seedlings (Fletcher et al., 2000). These results imply that using growth regulators such as triazols may be an effective way of improving plant stress tolerance. The aim of this study was to determine the effect of PP_{333} on salt tolerance in strawberry plants under hydroponic conditions.

MATERIALS AND METHODS

Cold-stored rooted runner strawberry plants (*Fragaria* × *ananassa* Duch.) of 'Selva' cultivar were planted on 2nd August 2006 in 2 L containers filled with a mixture of perlite and peatmoss. Plants were fed continuously from the start of the experiment with a nutrient solution (Melspray). Sodium Chloride (NaCl) was incorporated into the nutrient solution. Three levels of Nacl [0, 5, 10 mM] and four levels of PP_{333} [0, 10, 20, 30 mg/L] were imposed at the beginning of the experiment. A hand sprayer was used to apply PP_{333} to the point of runoff. The design of the experiment was a complete randomized with five replications and twelve treatments.

Photosynthetic rate (A), transpiration rate (E) and stomatal conductance (gs) were measured on two dates (two and ten weeks after the start of the experiment) using LCi portable photosynthesis meter. (LICOR, INC). Water use efficiency (WUE) was calculated as A/E. The youngest fully expanded middle leaflet was selected for measurement on each occasion. To determine relative water content (RWC), for each replication four discs of leaf tissue (1 cm in diameter) were weighed, floated on distilled water for four hours to become fully turgid, weighed, dried at 70°C and then weighed again. The RWC was calculated as: % RWC = [(Fresh mass-Dry mass)/Turgid mass-Dry mass)] × 100. Leaf samples were randomly collected and mean leaf area was measured using a leaf area meter (Delta-T Devices, England). Shoot and root dry weight was recorded after gently washing and drying in an oven at 70°C for 72 hours. To determine specific leaf weight (SLW), ten leaf discs from each replication were prepared, then oven dried for 48 hours, after which dry weight of discs was calculated. Dry weight/area was determined as SLW. Chlorophyll content was measured using a chlorophyll meter (SPAD-502. Minolta Co.Ltd). Number of runners and petiole length were also counted and measured throughout the experiment. Data were analyzed using MSTATC software and means were compared by Duncan's test. The 5% probability level was accepted to indicate significance.

RESULTS AND DISCUSSION

Leaf area was reduced by both salinity and PP_{333}. The combined effects of high salinity and high rate of PP_{333} resulted in the lowest leaf area (Table 1). Reduced leaf area in strawberry cultivars 'Elsanta' and 'Korona' as a result of salinity stress has also been reported (Saied et al., 2005). Although high salinity reduced shoot dry weight of celery (De Pascale, 2003), in the present study shoot dry weight increased in response to increased salinity (to 5 mM) and PP_{333} (20 mg/L), respectively (Table 1). However a higher rate of PP_{333} (30 mg/L), resulted in reduced shoot dry wt. In general, increased salinity tended to reduce root dry weight, and a similar result was shown in two pepper cultivars (Chartzoulakis, 2000). However, application of PP_{333} tended to overcome the negative effect of salinity on root dry wt (Table 1). A similar trend was observed for total dry weight (data not shown). Also, decreased plant dry weight due to saline stress has been shown in strawberry (Kepenek and Koyuncu, 2002a).

Photosynthetic rate (A) was significantly reduced by salinity. A similar result was observed in the 'Korona' cultivar of strawberry (Saied et al., 2003). However PP_{333} increased it especially at the highest level of salinity (Table 1). Increasing of A by PP_{333} on apple has been reported by Huang et al. (1995). PP_{333} has been reported to increase A in peach cuttings treated with NaCl (Abou El-Khashab, 1996). Both PP_{333} and salinity have caused reduction in stomatal conductance (gs) (Table 1). Transpiration rate (E) was also not to be reduced significantly with increased concentration of PP_{333} in saline treated plant. Lowest E was associated with highest level of PP_{333} and NaCl (Table 1).

Salinity reduced WUE and RWC. However PP_{333} could overcome these reductions (Table 1). It has also been reported that increasing salinity adversely affected WUE in tomato (Al-Karaki, 2000). Salinity did not affect RWC in peach, although PP_{333} application increased RWC in high salinity (Abou El-Khashab et al., 1997). But in *Rhamnus alternus* seedlings, salinity reduced RWC (Banon et al., 2003).

Specific leaf weight was increased by both salinity and PP_{333} and the interaction was significant (Table 1). Though salinity reduced chlorophyll content of the leaves, however PP_{333} reduced this reduction rate (Table 1). Reduced chlorophyll content due to salinity has been reported for strawberry cultivars, 'Oso Grande' and 'Camarosa' (Kaya et al., 2002). Both PP_{333} and salinity reduced the number of runners and petiole length (Table 1). Similar results regarding runner numbers has been reported by Kepenek and Koyuncu (2002b). In general, it can be concluded that PP_{333} reduced the stress effect of salinity probably through production of some special organic compounds in the cells. To some extent plants are naturally capable of withstanding stresses and PP_{333} increases the potentials. Moreover PP_{333} reduces membrane permeability and increases antioxidant enzyme activity, which is a defense mechanism (Banon et al., 2003). Reduction in undesirable ions in the cell due to use of PP_{333} will result in better growth and development of the plant (Abou-El Khashab, 1997). It might be possible that PP_{333} caused changes in the photosynthetic activity of chloroplasts. The reduction in leaf area was corrected by the thicker leaves and the increase of their photosynthetic capacity.

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Tables

Table 1. Effects of NaCl and PP33 treatments on vegetative and physiological traits of strawberry plants.

Salinity (mM)	PP$_{333}$ (mg·L^{-1})					PP$_{333}$ (mg·L^{-1})				
	0	10	30	30	Mean	0	10	20	30	Mean
	Leaf area (cm^2)					Shoot dry wt (g)				
0	59.3a[1]	44.5c	43.7c	42.0cd	47.4a	38.1a	25.3c	19.0d	16.1de	24.6a
5	53.0b	42.2cd	40.4cd	38.7de	43.6b	17.8de	24.4c	30.0b	17.0de	22.3b
10	50.3b	43.3c	36.3e	32.0f	40.4c	14.8e	26.5c	23.4c	17.1de	20.4c
Mean	54.2a	43.3b	40.1c	37.5d		23.6a	25.4a	24.1a	16.7b	
	Root dry weight (g)					Photosynthetic rate(A) (μmol m^{-2}s^{-1})				
0	21.4b	20.4b	10.7f	20.6bc	18.3a	7.6ef	9.1cde	11.3ab	12.1a	10.0a
5	11f	18.4cd	24.2a	16.4de	17.5a	6.6f	8.3def	8.9cde	9.5cd	8.3b
10	9.8f	16.0de	14.5e	14.0e	13.6b	4.5g	10.1bc	8.9cde	7.7def	7.8b
Mean	14.1c	18.3a	16.5b	17.0ab		6.2b	9.25a	9.7a	9.8a	
	Stomatal conductance					Transpiration rate (E)				
0	202.5a	160.0b	137.5cde	130.0def	157.5a	7.9a	6.11cde	5.39de	5.28de	6.17a
5	170.0b	150bcd	145bcde	132.5cdef	149.4a	7.26ab	6.75bc	6.0cde	5.39de	6.35a
10	140cde	122.5def	120ef	107.5f	122.5b	6.54bc	6.4bcd	6.82bc	4.98e	6.19a
Mean	170.8a	144.2b	134.2bc	123.3c		7.24a	6.42b	6.07b	5.21c	
	Water use efficiency (A/E)					Relative water content (RWC)				
0	0.95cd	1.48cd	2.12a	2.03a	1.71a	71abc	70abcd	68bcd	74.24a	70.6a
5	0.90ef	1.23de	1.52cd	1.83bc	1.37b	65cde	75.19a	64.3de	72.3ab	69.3a
10	0.67ef	1.59cd	1.31de	1.54cd	1.28a	72.6ab	70.4abc	59.71e	61.96e	66.2b
Mean	0.84c	1.43b	1.65b	1.89a		69.69a	71.71a	63.96b	69.5a	
	Specific leaf weight (SLW)					Chloropyll content				
0	64.3fg	71.65c	63g	76.43a	68.8a	1.25d	1.44bc	1.5abc	1.58a	1.44a
5	66.7de	65.98ef	66.53def	74.30ab	68.4a	1.10e	1.45bc	1.43bc	1.59a	1.3b
10	66.63g	71.68c	72.85bc	68.8d	69.24a	1.08e	1.41c	1.51abc	1.53ab	1.38b
Mean	64.89d	69.77b	67.47c	73.18a		1.14c	1.43b	1.48b	1.57a	
	Runner number					Petiole length (cm)				
0	7.8a	4.4cd	2.6e	1.6f	4.10a	7.82ab	6.67cd	6.44de	4.37g	5.75b
5	6.4b	4.4cd	2.2ef	1.6f	3.65b	8.73a	5.47ef	5.64ef	4.24g	6.32a
10	3.8d	4.8c	2.0ef	1.4f	3.0c	8.31ab	7.44bc	4.99fg	5.64ef	6.09ab
Mean	6.00a	4.53b	2.26c	1.53d		8.29a	6.64b	5.69c	4.75c	

[1] Mean followed by the same letter (small letters for means and capital letters for means of rows and columns) are not significantly different at 5 % level of probability using DMRT.