

GROWTH REGULATION OF BEDDING PLANTS AND POINSETTIA USING LOW PHOSPHORUS FERTILIZATION AND EBB-AND FLOW IRRIGATION

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Abstract

Effects of low phosphorus (P) fertilization on morphological parameters of a number of bedding plants and *Poinsettia* were investigated in experiments using ebb and flow fertigation. P treatments applied in the nutrient solutions varied from 0.02 up to 1.2 mmol/l H_2PO_4 . It was established that to obtain any effects of P, stock fertilizer should not be incorporated in the potting soil.

General effects of P stress were lower fresh weights and plant heights. Other effects depended on the plant species involved. In *Pelargonium*, the number of side shoots and flowers were reduced by P stress. In *Petunia*, the number of buds was decreased at the most extreme P stress treatments. In *Salvia*, the number of lateral side shoots and flowers was reduced, whereas the number of internodes was not affected. In *Impatiens*, plant width and the number of internodes were reduced by P stress. However, number of flowers and number of shoots were not influenced. The results imply that for *Impatiens*, a positive plant appearance without the use of any chemical growth regulators is possible.

In *Poinsettia*, the number of branches and leaves were reduced by P stress. Furthermore, probably due to reallocation of P, the senescence of old leaves increased. It is concluded that P-fertilization can be reduced, under commercial growth conditions, without great negative side-effects.

key-words: phosphate, *Pelargonium*, *Petunia*, *Salvia*, *Impatiens*, *Euphorbia pulcherrima*

1. Introduction

In commercial bedding plant production, fertigation is normally conducted via top-irrigation with a nutrient solutions. Growth regulation in these systems is partly accomplished by limiting the amounts of nutrient solution in order to maintain the plants at virtually constant drought stress. However, this way of top-irrigation is labour intensive, induces heterogeneity in growth and cannot be automated easily.

Ebb-and flow irrigation systems have excellent possibilities for mechanisation, and are already widely used in potplant production in the Netherlands (Ploeger 1992). Less variation was found in growth of bedding plants with ebb- and flow irrigation compared with top-irrigation (de Graaf-van der Zande 1989), probably due to the fact

that water content of the potting soil is less variable. However, growth of e.g. *Petunia* was more vigorous on ebb-and flow, thereby increasing the requirement for growth regulators (Vogelezang et al. 1992). Therefore, in order to take advantage of an ebb-and flow system, measures must be taken in order to reduce stem elongation. Climatic regimes such as reversed day/night temperatures or temperature drops reduce stem elongation in a number of bedding plants (e.g. Hendriks et al. 1992). Drawbacks of these climatic regimes are 1) that lateral shoot formation is not as enhanced as with the use of growth regulators (Vogelezang et al. 1992), and 2) that their use is limited to a certain period of the growing season in e.g. the Netherlands. Therefore, there is a need for additional strategies for growth regulation.

Using ebb-and flow irrigation with *Pelargonium*, imposing salt stress in the soil by increasing the electrical conductivity of the nutrient solution did give good plant quality without the use of growth regulators (van Leeuwen 1993). However, uncontrolled salt accumulation in the soil solution tends to occur with ebb-and flow irrigation (Baas et al 1992, de Kreij 1988). Therefore, frequent soil sampling and adjustment of the nutrient solution becomes necessary.

A limitation of a specific nutrient may be another technique for growth control. A controlled application of nitrate in aeroponic systems retarded growth of a number of plant species without negative side effects, such as deficiency symptoms (Ingestad 1981). Comparable results were found when P was the limiting factor controlling growth rate (Ericsson and Ingestad 1988). However, it is likely that under commercial growing conditions, controlled application of nutrients is not feasible, inducing temporary shortages with concomitant deficiency symptoms. As P deficiency (usually darker leaves) has less negative ornamental value than nitrogen stress (yellowing of leaves), the former is preferred. The aims of this study were to study the effects of P stress on the growth and development of a number of bedding plants and *Poinsettia* using ebb-and flow fertigation.

2. Materials and methods

2.1 Experiment 1

In the Netherlands, the following amounts of fertilizers are normally applied to potting soil used for bedding plants (mmol/ litre soil): KNO_3 : 5.1; $\text{NH}_4\text{H}_2\text{PO}_4$: 1.65; $(\text{NH}_4)_2\text{SO}_4$: 1.52; MgSO_4 : 0.3.

In the experiment, the influence of P in the stock fertilizer was investigated. Therefore, in the treatments the amounts of $\text{NH}_4\text{H}_2\text{PO}_4$ in the stock fertilizer were 0, 0.4, and 1.65 mg/litre potting soil respectively (0, 25 and 100% treatments). NH_4^+ was compensated with $(\text{NH}_4)_2\text{SO}_4$.

Seedlings of *Pelargonium zonale* 'Pulsar red' were planted in week 4 1991 in 9 cm pots (volume 0.25 l), and 12 pots were placed in a tray. Seedlings of *Petunia* 'Blue Flash' were planted in week 6, 1991 in 8 cm pots (volume 0.2 l), with 15 pots per tray. The three P treatments of the potting soil were combined with 3 nutrient solutions with composition of the major elements as follows (mmol/l):

NH ₄ ⁺	K ⁺	Ca ²⁺	Mg ²⁺	NO ₃	SO ₄ ²⁻	H ₂ PO ₄ ⁻
1.1	5.5	3	0.75	10.6	1.14	1.22
1.1	5.5	3	0.75	10.6	1.59	0.32
1.1	5.5	3	0.75	10.6	1.72	0.06

Concentration of the minor elements in all nutrient solutions were ($\mu\text{mol/l}$): Fe 15, Mn 5, Zn 3, B 10, Cu 0.5, Mo 0.5. The treatments were combined with two subirrigation treatments. The trays in the so-called 'dry treatment' were sub-irrigated at visual wilting point. Trays in the 'wet treatment' were sub-irrigated approximately twice as often as trays in the 'dry treatment'.

The experiment had a three-factorial design with 3 levels of stock fertilization * 3 P levels in the nutrient solution * 2 irrigation strategies as independent variables. There were 3 trays per treatment. No growth regulators were used in the experiment.

At harvest after 11 weeks, 3 *Pelargonium* plants per tray were harvested, and leaf fresh weight, plant height (without flower stalks) and number of flower stalks were recorded.

Petunia plants were harvested after 7 weeks and leaf fresh weight, length of the longest leaf and number of flower buds were recorded. After drying (48 h, 70 degrees C.) leaves were analysed for P content, in a pooled sample per treatment.

2.2 Experiment 2

The second experiment was conducted in order to compare the effect of P stress with a control treatment in which growth regulators were used in combination with a standard P fertilization. No stock fertilizer of major elements was supplied to the potting soil.

Seedlings of *Pelargonium zonale* 'Pulsar red' were planted in week 8, 1992 in 9 cm pots (volume 0.28 l), and 12 pots were placed in a tray. *Salvia splendens* 'Flamex' and *Impatiens walleriana* 'Impulse' seedlings were planted in 8 cm pots (volume 0.19 l) in week 10.

The three bedding plant species received the same frequency of ebb- and flow irrigation. There were four independent benches with ebb- and flow per treatment.

The composition of the nutrient solution was as in experiment 1 except for the phosphate levels, which were on average 0.02, 0.09, 0.22 and 1.06 mmol/l H₂PO₄⁻, and the sulphate levels which compensated the phosphate. Growth regulators were applied as needed in the 1.06 mmol/l treatment, which was the reference treatment. Concentrations of growth regulators were 1 ml CCC/l for *Pelargonium* and *Impatiens*, and 4 g Alar-64/l for *Salvia*. However, the first time *Impatiens* was sprayed with 0.5 ml CCC/l, and *Salvia* with 2.5 g Alar-64/l

At harvest in week 19 (1.06 mmol/l treatment) through 22 (0.02 mmol/l), 24 *Pelargonium* plants per replicate were measured for shoot fresh weight, height (without flower stalks), number of side-shoots and number of flower stalks. For *Salvia* (week 16) and *Impatiens* (week 15) shoot fresh weight, height, number of side shoots and number of flowers were recorded of 30 plants per replicate. For *Salvia*, the number of internodes were also counted.

After drying, analysis of P was performed in leaves of each replicate of *Salvia* and *Pelargonium*.

2.3 Experiment 3

Pinched cuttings of *Poinsettia* 'Alstar'(red) and 'Regina'(white) were planted in week 32, 1993 in 0.75 litre pots filled with a 85% peat/15% perlite mixture. The experiment was set up as experiment 2, with four P treatments (0.05, 0.09, 0.24, and 0.94 mmol/l H_2PO_4^-). Growth regulators were applied as needed only in the 0.94 mmol/l treatment. There were 4 replicates per treatment. The plants were irrigated every day. At harvest, in week 48 1993, shoot fresh weight, number of leaves and branches, and number of dropped leaves were recorded for 6 plants per replicate. After drying, analysis of P was performed in leaves of each replicate of 'Regina'.

3. Results

3.1 Experiment 1

Results are given in tables 1 (*Pelargonium*) and 2 (*Petunia*). The P treatments had a profound effect on shoot fresh weight, height and flowering in both *Pelargonium* and *Petunia*. The significant P nutrient solution * P stock fertilizer interaction in the analysis of variance table indicates that for all parameters a maximum value is reached. Apparently, the P in the nutrient solution has no effect on growth when the standard (advised) amount of stock fertilizers is used in the potting soil. To obtain significant effects of P stress in both *Pelargonium* and *Petunia* in terms of plant height, no P should be incorporated in the stock fertilizer. Even in the treatments without stock fertilizer, effects on plant height were only significant with the 0.06 mmol H_2PO_4^- /l nutrient solution compared to the 0.32 mmol/l treatment. Only the shoot weight of *Pelargonium* was slightly decreased at the lowest P treatment.

Luxury consumption of P appears to take place. P concentrations in growth-reduced *Pelargonium* plants were below ca. 100 mmol/kg (table 1). For *Petunia*, P-limited plants had P concentrations below ca. 75 mmol/kg d.w. (table 2). Especially in *Petunia*, P concentrations in non-P limiting treatments were far above those at more limiting concentrations.

A lower irrigation frequency significantly decreased shoot fresh weight production and plant height in both *Pelargonium* and *Petunia*. However, this 'dry treatment' did not influence the number of flower stalks in *Pelargonium*, or the number of flower buds in *Petunia*. Apparently, drought stress had less effect on flowering parameters than phosphate stress.

No clear consistent P*irrigation interactions were found for all morphological parameters.

3.2 Experiment 2

In *Pelargonium* (table 3), the same effects on shoot weight, height and number of flower stalks were found as in experiment 1. Also, the number of side shoots was decreased by P stress. P concentration in the leaves indicates that the 0.22 mmol/l P treatment may have limited growth of *Pelargonium*.

Compared to the control treatment with growth regulators, a drastic reduction in

side-shoot formation and flowering was apparent.

In *Salvia*, P stress also reduced growth and height, number of side-shoots and number of flowers. Number of internodes however was not influenced. Compared to the control treatment with growth regulators, hardly any growth reduction was obtained however, and plant appearance was negatively affected by reduced leaf area (data not shown).

Due to P stress, *Impatiens* had reduced shoot weight, plant height and width and number of internodes, whereas number of shoots and number of flowers were not affected. Compared to the control treatment, no negative effects with respect to plant appearance were apparent.

3.3 Experiment 3

Since both *Poinsettia* cultivars 'Alstar' and 'Regina' reacted very similarly, and no P*cultivar interactions were found, in table 6 only the data of 'Regina' are given.

The effects of P stress on *Poinsettia* were very similar to e.g. *Pelargonium* or *Salvia*, since there was a decrease in shoot fresh weight, height and the number of side-shoots. Furthermore, the number of leaves decreased, and leaf area per leaf and bract were lower (data not shown). In the 0.05 and 0.09 mmol/l P treatments, the oldest leaves gradually turned yellow, and senesced. Although P concentrations in the leaves were about 1/3 of the control treatment, no visual effects of P deficiency were noticed in the 0.24 mmol/l treatment.

4. Discussion

The experiments were performed to investigate whether growth reduction of bedding plants and *Poinsettia* could be realized with ebb-and flow irrigation using low P fertilization as an alternative for chemical growth regulators. To obtain any effects of P limitation, experiment 1 showed that the stock fertilizer should not be incorporated in the potting soil. Using the leaf nutrient analysis and dry weight data (not shown in tables 1 and 2), it could be calculated that around 50% of the total uptake of P, by supra-optimal P-fed plants, was available from the stock fertilizer. For N and K, these values were 17 and 27%, respectively. When no stock fertilizer was added, effects of P stress became apparent when the concentration was less than 0.3 mmol H₂PO₄/l (tables 3,4,5), which is only 20 % of the advised P concentration for most of the bedding plants in the Netherlands (anonymous 1993). For *Poinsettia*, even 0.24 mmol/l did not inhibit growth and development (table 6). It is therefore obvious that under practical growth conditions the rate of P fertilization is far above the need for optimal growth, and lower rates can be applied without any risk for P-deficiency. This conclusion is in accordance with findings of large accumulations of P in the top soil in ebb-and flow cultivation (de Krij 1988).

In general, as a result of P stress growth, height and leaf area of *Pelargonium*, *Petunia*, *Salvia*, *Impatiens* and *Poinsettia* were reduced. Visual P deficiency symptoms, as necrotic spots in the tissue of the older leaves in *Pelargonium*, occurred in only the most extreme treatments. The characteristic purple ring in the leaves of *Pelargonium* showed a darker colour due to P stress, increasing its ornamental value. In *Poinsettia*, the oldest leaves gradually died and senesced in the low P treatments,

which may be the result of P remobilization from old to young leaves (Marschner 1986).

Favourable results of P stress were obtained in *Impatiens* without negative side-effects. However, height reduction was insufficient for *Salvia* (table 4). Moreover, side-shoot formation and flowering, important features determining ornamental value of bedding plants, were reduced in *Pelargonium* and *Salvia* compared to a control treatment with growth regulators. A delay in flower initiation is in accordance with results obtained in subterranean clover (Rossiter 1978).

Bedding plant growers normally grow a large number of species at the same time. It follows from the species-dependent response that P stress alone can not be used as a sole alternative to the use of growth regulators. The use of P as a growth regulator may be further restricted by the limited concentration range of 0.1-0.3 mmol/l in which it proved effective. If crops like *Salvia* and *Pelargonium* are grown in soil supplied with stock fertilizer -thereby avoiding or alleviating P stress-, no negative effects of using very low P concentrations in the nutrient solution are expected.

However, a combination of different alternative measures is probably the most sensible strategy to decrease the application of growth regulators. Indeed, combined DIF, P stress and salt stress treatments have already proved to produce good plant quality without growth regulators in *Pelargonium* with ebb-and flow irrigation (van Leeuwen 1993).

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5. References

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Table 1. Morphological parameters and leaf P concentration of *Pelargonium* in the different treatments of experiment 1. Significance of F-values in ANOVA table: ***, P<0.001; **, P<0.01; *, P<0.05; ns, not significant. L.S.D. = least significant difference at P=0.05

P stock fertil. (%)	P nutr.sol. (mmol/l)	shoot fresh wt. (g)		height (cm)		no. of flower stalks		P (mmol/kg d.w.)
		irrig. 'wet'	irrig. 'dry'	irrig. 'wet'	irrig. 'dry'	irrig. 'wet'	irrig. 'dry'	
0	0.06	18.2	16.9	15.2	15.1	0.5	0.4	41
0	0.32	41.5	33.5	21.9	20.2	1.3	1.4	97
0	1.22	45.2	37.1	23.5	21.5	1.8	1.3	188
25	0.06	30.2	24.8	19.3	18.0	1.8	1.6	56
25	0.32	44.9	34.2	24.3	22.2	1.9	1.4	104
25	1.22	43.7	36.0	24.0	23.3	1.6	1.5	195
100	0.06	40.1	34.6	21.9	21.1	1.7	1.7	97
100	0.32	42.0	39.1	22.8	21.8	1.9	1.8	154
100	1.22	45.1	38.8	24.8	22.2	1.8	1.8	200
	L.S.D.		2.5		2.8		0.5	

ANOVA table

P nutr.solution	***	***	**
P stock fertilizer	***	***	***
irrigation	***	**	ns
P nutr.sol.*P stock fert.	***	**	***
P nutr.sol.*irrigation	**	ns	ns
P stock fert.*irrigation	*	ns	ns
P nutr.sol.*P stock fert.*irrig.	**	ns	ns

Table 2. Morphological parameters and leaf P concentration of *Petunia* in the different treatment of experiment 1. Significance symbols as in table 1.

P stock fertil. (%)	P nutr.sol (mmol/l)	shoot fresh wt. (g)		height (cm)		no. of buds		P (mmol/kg d.w.)
		irrig. 'wet'	irrig. 'dry'	irrig. 'wet'	irrig. 'dry'	irrig. 'wet'	irrig. 'dry'	
0	0.06	8.7	6.1	9.9	7.5	0.4	0.2	13
0	0.32	25.8	20.0	24.5	20.9	1.6	1.9	76
0	1.22	26.9	20.2	25.1	20.2	1.1	1.3	269
25	0.06	21.0	16.5	22.0	17.8	2.0	1.2	27
25	0.32	25.0	22.8	25.8	23.4	1.3	1.8	86
25	1.22	27.9	20.6	26.0	21.1	1.7	1.5	216
100	0.06	28.5	20.8	25.4	22.0	2.9	1.9	138
100	0.32	26.8	20.9	25.6	21.2	1.8	1.3	190
100	1.22	27.6	22.9	25.8	22.7	1.2	1.7	240
	L.S.D.		2.9		2.5		0.7	

ANOVA table

P nutrient solution	***	***	ns
P stock fertilizer	***	***	***
irrigation	***	***	ns
P nutr.sol.*P stock fert.	***	***	***
P nutr.sol.*irrigation	ns	ns	**
P stock fert.*irrigation	ns	ns	**
P nutr.sol.*Pstock fert.*irrig.	*	ns	ns

Table 3. Morphological parameters and leaf P concentrations of *Pelargonium* in experiment 2.

P nutr. solution (mmol/l)	shoot fresh wt. (g)	height (cm)	no. of side-shoots	no. of flower stalks	P shoot (mmol/kg d.w.)
0.02	19.7	12.8	0.4	0.6	19
0.09	33.4	19.6	1.1	0.9	40
0.22	55.2	30.1	1.2	1.6	55
1.06 + gr. reg.	50.8	16.9	4.3	3.6	236
L.S.D.	3.7	1.6	0.5	0.2	24

Table 4. Morphological parameters and leaf P concentrations of *Salvia* in experiment 2.

P nutr. solution (mmol/l)	shoot fresh wt. (g)	height (cm)	no. of side-shoots	no. of internodes	no. of flowers	P (mmol/kg d.w.)
0.02	7.1	18.7	2.3	5.9	8.5	25
0.09	9.3	21.2	3.6	6.0	9.2	34
0.22	12.1	24.6	5.7	5.5	10.8	51
1.06 + gr. reg.	10.4	11.5	8.1	5.9	11.2	198
L.S.D.	3.4	3.6	2.9	n.s.	1.7	28

Table 5. Morphological parameters of *Impatiens* in experiment 2.

P nutr. solution (mmol/l)	shoot fresh wt. (g)	height (cm)	no. of side-shoots	no. of flowers	no. of internodes	width (cm)
0.02	10.3	5.4	4.1	3.1	5.9	13.9
0.09	12.7	6.2	4.1	2.9	6.7	15.3
0.22	17.9	8.8	4.0	3.1	6.9	20.2
1.06 + gr. reg.	21.6	11.3	4.2	3.4	7.4	22.8
L.S.D.	2.1	1.4	n.s.	n.s.	0.6	2.5

Table 6. Morphological parameters and leaf P concentrations of *Poinsettia* in experiment 3.

P nutr. solution (mmol/l)	shoot fresh wt. (g)	height (cm)	no. of branches	no. of leaves	no. of dropped leaves	P (mmol/kg d.w.)
0.05	41.5	12.6	5.4	21.8	5.5	43
0.09	53.5	14.7	5.8	31.4	2.8	50
0.24	80.5	22.3	5.9	40.0	0	84
0.94 + gr. reg.	83.8	15.5	6.3	41.3	0	244
L.S.D.	9.2	3.0	0.7	8.7	1.1	9