Plug pH pandect

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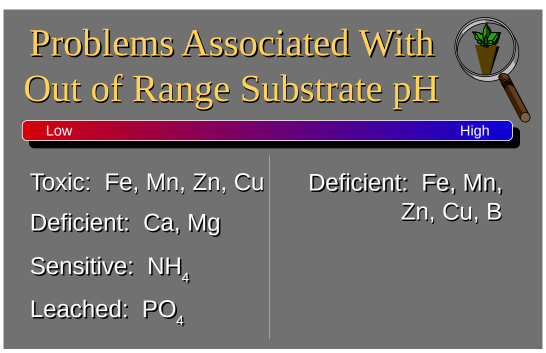
Successful plug production demands precise control of environmental factors—including substrate pH

Hank Kimble said it best on "Green Acres" when he would visit a farmer having problems: "Gee, I don't know; could be the pffffffffff of your soil." Plug production in a greenhouse is a long way from growing corn in the Great Plains, but Hank was on to something. Substrate pH is an important steering force in plug nutrition.

The impact substrate pH has on nutrient availability has been passed on to growers time and time again; one more time couldn't hurt (Figure 1). When the substrate solution pH is too high, micronutrient deficiencies can become a problem (Figure 2). If the substrate pH drops too low, micronutrients become more available, and excessive availability can lead to micronutrient toxicities in some bedding plant species we grow (Figure 3). Calcium and magnesium deficiencies can develop when the pH is too low. There is a greater chance of ammonium toxicity problems in low pH conditions; and phosphorus leaching increases at a low pH. Since pH can affect crop nutrition to such a large degree, guidelines have been suggested for substrate pH.



Avoid excessively high or low substrate pHs.

Unfortunately, the optimum pH for bedding plants differs by species. What may be best for vinca may be devastating for African marigolds. There are three major categories of bedding plant plugs with respect to optimum pH: those that require a high pH; those that require a low pH; and pH-tolerant species (Table 1). The target pH should be species dependent, based on the particular nutrient disorders each species is known to acquire.

The ideal production situation is one where substrate pH is identical to the requirements of the particular species being produced; and no changes occur. Preventing pH changes will eliminate many of the nutrient problems encountered in plug production. Unfortunately, there are many forces at work that affect substrate pH, and maintaining a constant pH is no easy task.

Forces Affecting Substrate pH in Plug Production

There are four major forces that affect the substrate solution pH during plug production: ❶ preplant materials such as dolomitic limestone put into the substrate and the substrate components themselves; ❷ the alkalinity of the irrigation water; ❸ the acidity / basicity of the fertilizers used during production; and ❹ the plant species being grown. With so many factors affecting pH, it's no wonder that pH stabilization is easier to write about than to implement!

Preplant materials. Most plug mixes are composed of ingredients such as peat moss that have a low pH. Limestone and other ingredients that raise the pH such as calcium hydroxide are commonly added to establish an initial substrate pH of about 5.4 to 6.0. Use Table 1 when deciding on your targeted initial pH. You may want to increase the liming charge and target 6.4 for high pH-requiring species and likewise lower it and target 5.4 for low pH-requiring species that are listed. For other species not listed as having special pH requirements, no adjustment may be needed if the substrate pH is in the 5.4 to 6.0 range.

Water alkalinity. The alkalinity of your irrigation water is a key player in the substrate solution pH. The greater the alkalinity, the greater the tendency for substrate pH to rise over time. Research at NCSU that varied the initial lime charge in plug trays and varied the alkalinity of irrigation water used in plug production shows that over time, the effect of the alkalinity in the irrigation water far exceeds that of the initial lime charge (Table 2). Acidification of high alkalinity water may be required to prevent an undesirable rise in substrate pH as demonstrated in Table 2.

Cooperative research between Allen Hammer and Brian Whipker at Purdue University and the NCSU plug research group led to the development of an Excel® spreadsheet that allows users to input their water pH and alkalinity then

Boron deficiency can be a problem on many plugs like these salvia, especially if the substrate pH is too high.

Table 1. Suggested substrate pH ranges for plugs grown in a soilless substrate.

Species	pH	Why?
Celosia	6.0 to 6.8	prevent Fe & Mn toxicity
Dianthus	6.0 to 6.8	prevent Ca deficiency & NH_4 toxicity
General Crops	5.4 to 6.8	pH tolerant
Geranium	6.0 to 6.8	prevent Fe & Mn toxicity
Marigold (African)	6.0 to 6.8	prevent Fe & Mn toxicity
Pansy	5.4 to 5.8	prevent B & Fe deficiency; avoid *Thielaviopsis*
Petunia	5.4 to 5.8	prevent B & Fe deficiency
Salvia	5.4 to 5.8	prevent B deficiency
Snapdragon	5.4 to 5.8	prevent B & Fe deficiency
Vinca	5.4 to 5.8	prevent B & Fe deficiency; avoid *Thielaviopsis*

select sulfuric, phosphoric, or nitric acid to use as an acidifying agent to reach a target pH or alkalinity. The spreadsheet modules calculate the nutrient additions from the acid injection and will report your acidification costs, if you input the price per gallon for the acid you wish to use. You can acquire a copy of this spreadsheet to aid in your water acidification needs via the world wide web (http://www2.ncsu.edu/ncsu/cals/hort_sci/floriculture/) or by contacting the authors.

Fertilizer acidity / basicity. Most of the fertilizer salts we use have some effect on the substrate pH (Table 3). Some such as 21-7-7 are very acid (high acidity) while others such as 15-0-15 are fairly basic (high basicity). Fertilizer acidity / basicity relates to how the pH of the substrate solution changes after the fertilizer is applied and plants absorb nutrients from the substrate. The ratings given in Table 3 are used by fertilizer manufacturers, but are based on the fate of fertilizer salts in a mineral based soil out in the field as measured by researchers in the 1930s! Further research is needed to better define acidity and basicity of common fertilizers in greenhouse substrates.

We can lower, raise, or hold constant the pH of plugs by fertilizer selection. Unfortunately, most acidic fertilizers also have a correspondingly high proportion of ammoniacal nitrogen and cannot be relied on as the only means of reducing the substrate pH. If too much ammoniacal nitrogen is applied in plug production, the plants will stretch excessively and would develop undesirably succulent growth. Therefore, most of the fertilizers used in plug production should be low in ammoniacal + urea nitrogen and high in nitrate nitrogen; and will tend to be basic residue materials.

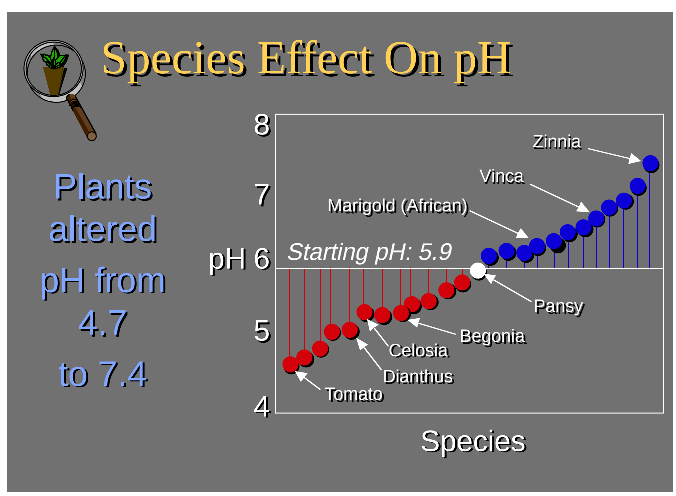
Manganese and iron toxicity on geraniums can be stimulated by low substrate pH.

Species effect on substrate pH. Research at NCSU has shown that bedding plants will modify the substrate pH during germination and seedling growth (Figure 4). However, many species change the pH to a level that is not best for their growth! For example, celosia and dianthus (both grow best at a higher pH) tend to lower the substrate pH. Vinca raised the substrate pH, though vinca grows best at a lower pH. Growers must be aware of species effects on substrate pH, especially when monitoring the pH of a plug crop during production. Imagine the nightmare of a plug producer basing their entire pH control program on samples of a single species; or on a combined sample of different species. Do you monitor the substrate pH of your species separately and adjust pH according to sample results? Our research results indicate you should.

Plug pH Stabilization Strategies

One goal of the NCSU plug research group is to create a pH regulation strategy for use in plug production. We need to establish pH base lines for major plug species, similar to those suggested in Table 1. Next, upper and lower "decision points" must be determined for each species. Decision points are limits that determine when action must be taken to correct or prevent an out-of-range pH. We have already described the tools available to us in regulating pH -- preplant materials, regulation of water alkalinity, and fertilizer selection tailored for each species. The final stage of a pH stabilization strategy is to decide how to control pH in your particular production system, then to monitor frequently to assure that you are within the acceptable pH range for each of your crops.

The example pH plot in Figure 5 is assuming a pH base line of 5.8; an upper decision limit of 6.2; and a lower decision limit of 5.4. For this hypothetical species, a grower would target pH 5.8 when adding the liming components into the substrate prior to seeding. They would want to take corrective measures to lower pH if sampling showed a substrate pH of 6.2 or above. Corrective



Seedlings have the ability to alter the substrate pH, and the resulting change is not always in their favor.

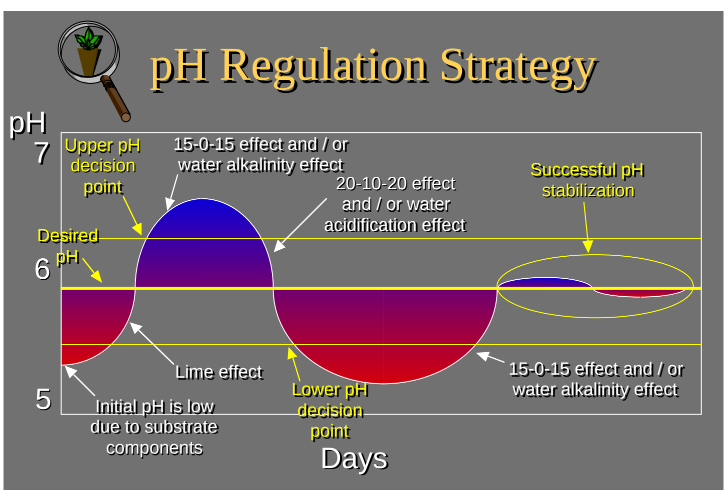
Table 2. Change in Vinca 'Pretty in Rose' substrate pH due to initial substrate liming charge (dolomitic limestone) and irrigation water alkalinity.

Lime addition	Water alkalinity	Substrate pH on day: 1*	28	49
6.4 lb/yd^3	0 meq/L	5.1	4.9	6.0
6.4 lb/yd^3	4 meq/L	5.2	6.0	7.1
6.4 lb/yd^3	5.4 meq/L	5.2	6.5	7.4
10.5 lb/yd^3	0 meq/L	5.3	5.1	6.3
10.5 lb/yd^3	4 meq/L	5.3	6.2	7.1
10.5 lb/yd^3	5.4 meq/L	5.3	6.8	7.4
16.9 lb/yd^3	0 meq/L	5.4	5.3	6.6
16.9 lb/yd^3	4 meq/L	5.4	6.2	7.1
16.9 lb/yd^3	5.4 meq/L	5.5	6.8	7.6

*Irrigation with different alkalinity waters began on day1, which was at the beginning of plug Stage II.

measures to lower pH include: ❶ acidifying your water down to pH 5.8 (neutralizing ~80% of the alkalinity in your irrigation water); ❷ discontinuing the use of basic residue fertilizers, such as calcium nitrate and using acid-residue fertilizers to lower the pH, if plants are capable of tolerating the ammoniacal nitrogen addition; and ❸ in severe cases, drenching with aluminum sulfate or iron sulfate to rapidly lower pH. The substrate pH would need to be raised if it fell below 5.4. Corrective measures to raise pH include: ❶ discontinuing irrigation water acidification, if any is employed; ❷ using basic-residue fertilizers to raise the substrate pH; and ❸ in severe cases, injecting potassium bicarbonate to increase the alkalinity of your irrigation water to increase the substrate solution pH.

There is still much to learn about pH regulation and how to incorporate it into a plug nutrition program. We have only begun to outline standards, but we hope to eventually create control graphs similar to Figure 5 for most plug species produced. Through careful monitoring and precise production management, plug pH problems can be avoided. However, if you do encounter nutrient imbalances in your plug production, take Hank's advice and check out your substrate's pfffffffffff.



A sample pH regulation strategy.

Appreciation is expressed to The Fred C. Gloeckner Foundation and BPFI for their financial support of the research that helped form the basis for this article. For more information about this article, contact Doug Bailey at (919) 515-1195 or e-mail him at doug_bailey@ncsu.edu.

Table 3. Potential acidity or basicity and percent of total nitrogen in the ammonium plus urea form for several commercial fertilizers.

Fertilizer*	Potential acidity or basicity**	NH_4 (%)***
21-7-7	1,700 A	90
21-7-7	1,560 A	100
20-2-20	800 A	69
20-18-18	710 A	73
24-7-15	612 A	58
20-18-20	610 A	69
20-20-20	583 A	69
20-9-20	510 A	42
20-20-20	474 A	69
16-17-17	440 A	44
20-10-20	422 A	40
21-5-20	418 A	40
20-10-20	393 A	38
21-7-7	369 A	100
15-15-15	261 A	52
17-17-17	218 A	51
15-16-17	215 A	47
15-16-17	165 A	30
20-5-30	153 A	56
17-5-24	125 A	31
20-5-30	118 A	54
20-5-30	100 A	54
15-11-29	91 A	43
15-5-25	76 A	28
15-10-30	76 A	39
20-0-20	40 A	25
21-0-20	15 A	48
20-0-20	0	69
16-4-12	73 B	38
17-0-17	75 B	20
15-5-15	135 B	28
13-2-13	200 B	11
14-0-14	220 B	8
15-0-15	319 B	13
15.5-0-0	400 B	6
15-0-15	420 B	13
13-0-44	460 B	0

*Notice that identical analyses can have different acidities, basicities, and percent NH_4, depending on the manufacturer.
**A = pounds of calcium carbonate limestone required to neutralize the acidity caused by using one ton of the specified fertilizer. B = equivalent pounds of calcium carbonate limestone added by using one ton of the fertilizer.
***Refers to the percentage of total nitrogen that is in the ammonium plus urea forms; the remaining nitrogen is nitrate-N.