Effect of Nitrogen, Phosphorus and Potassium on Growth and Xanthomonas Disease of Philodendron oxycardium

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Abstract. Philodendron oxycardium was grown in a medium of peat moss-sand 3:1 with applied nutrient solutions varying from 5 to 450 ppm of N, 0 to 50 ppm of P and 0 to 444 ppm of K. In the soil, these concentrations were somewhat increased by evaporation. Most of the leaf analyses were in the ranges 1.5 to 3.5% N, 0.08 to 0.40% P and 1.5 to 5.5% K. Within these ranges, growth decreased with an increase in N content and increased with an increase in P and K.

When inoculated with Xanthomonas sp., disease decreased with increasing N and was not much affected by K. Phosphorus had little effect on disease except in one of the 6 experiments, where a reduction was found when the leaf P exceeded 0.40%.

Old green leaves were more susceptible to inoculation than young. The disease did not reappear in plants after all leaves were removed and stems had produced new foliage. The pathogen did not carry over in stems, roots or potting medium.

Munnecke and Chandler (6) found small yellow and white, gram-negative rods occasionally associated with a leaf spotting of a Philodendron sp. but did not prove the bacteria to be pathogenic. McFadden (5) described a disease of P. oxycardium caused by a Xanthomonas sp.

At least 3 other diseases caused by Xanthomonas sp. have been found to be less severe with increasing N fertilization. Nayudu and Walker (7) considered this effect to be due to reduced host growth, high osmotic pressure of the nutrient solution, lower Ca and higher K or Na in the host tissues. Bird (1) found diminished growth of X. malvacearum in cultures and in cotton leaves by increasing or reducing the carbohydrate to N ratio from its optimum value for the bacterium. Blackmon (2) found that the presence of nitrogenous materials such as amino acids was involved in resistance to X. malvacearum in cotton. Thomas (8) decreased X. sesami disease of sesame by supplemental N when plants were given a 12 hr light period.

The disease described by McFadden (5) is difficult to control solely by application of bactericides so it would be desirable to develop cultural methods for reducing its severity. This possibility has been investigated by applying methods similar to those used by Harkness and Reynolds (3) in showing that the incidence of Phytophthora leaf spot on P. oxycardium was reduced by increasing the N content of the nutrient solution.

Inoculation and infection. In 2 preliminary experiments with 600 plants each, P. oxycardium leaves were inoculated with a 48-hr nutrient broth culture grown at 27°C, of the Xanthomonas sp. reported by McFadden (5). Various methods of inoculation were tried including spraying entire plants or swabbing old leaves, young leaves, leaf margins only, or small areas on the centers of upper or lower leaf surfaces.

Materials and Methods

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In the following nutritional experiments, all plants were sprayed with inoculum at least 2 times. In 1966 and 1967, plants were inoculated every 2 weeks so that all leaves were inoculated despite different growth rates. Infection usually became visible about 10 days after inoculation, and disease readings were generally begun 30 days later.

Fig. 1 illustrates typical disease symptoms. In moderate humidity, the only symptom may be pale brown leaf margins near the apex. In high humidity, narrow water-soaked streaks may extend from the leaf margins toward the center of the leaf. As these become brown, they often have wide yellowish halos which occasionally expand until the leaf is destroyed.

Culture and nutrition. Six experiments were made involving 4 groups of plants. The ranges of N, P and K in the applied solutions are listed in Table 1. In all plantings, the potting mix was a 5:1 mixture of peat moss-sand. The first experiment was on a concrete greenhouse bench with plots separated by boards. The second experiment was in 10 x 14 x 4 inch galvanized flats. In Experiments 3 to 6, the plastic flats were 7 1/2 x 6 x 3 inches. In Experiments 1 to 3 and 5, single-node stem cuttings bearing 1 leaf were rooted in vermiculite and transplanted to the potting mix. Experiments 4 and 6 were made on the regrowth obtained after the plants were cut back to soil level at the completion of Experiments 3 and 5. As in the infection experiment, no Xanthomonas disease was found on this new growth until it was inoculated.

Starting about a week after planting the rooted cuttings, the flats were filled to the brim with nutrient solutions twice a week, being careful to avoid making holes in the potting mix. The solutions provided the only water added to the flats.

Ammonium nitrate was the source of N, monobasic sodium phosphate of P and a 1:1 ratio of potassium sulfate: potassium chloride of K. The nutrients were dissolved in tap water containing 70-80 ppm of Ca, 2-5 ppm of Mg and traces of other elements. Whenever Mg deficiency was indicated by typical V-shaped chlorotic areas on the leaves, it was corrected by a single application of MgCl2.
magnesium sulfate to all solutions at the rate of 320 ppm of Mg.

According to previous work (3) the analyses of nutrient solution pressed from the mix, and thus some mix solutions were found with average number of lesions per leaf. Percentage of infected leaves was used in the other experiments. These 3 methods were considered comparable.

As soon as the disease ratings were completed, the plants were cut at the soil surface and weighed. Leaf analyses were made of typical leaf blades selected after the plants were weighed. A random selection was made of mature leaves showing no necrosis from disease or aging. For analyses, the leaves were oven dried at 60°C, then digested with sulfuric acid and hydrogen peroxide.

Nitrogen was determined by the Nessler method, P as Vanado-phospho-molybdate and K with a flame photometer.

**Results**

_Inoculation and infection._ McFadden's statement (5) that the pathogen entered only marginal hydathodes was verified. Old green leaves were more susceptible than young. The disease did not reappear in plants after all leaves were removed and stems had produced new foliage. The pathogen apparently did not carry over in the mix. Evaluation of culture and nutrition data. Table 2 contains data from a typical experiment. Data from

**Table 1. Description of experiments.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Dates</th>
<th>Applied nutrient range</th>
<th>Leaf analyses range</th>
<th>Disease rating range</th>
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<td></td>
<td>N(ppm)</td>
<td>P(ppm)</td>
<td>K(ppm)</td>
<td>N(%)</td>
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<tr>
<td>1</td>
<td>1/62-5/63</td>
<td>20-300</td>
<td>0-30</td>
<td>20-300</td>
</tr>
<tr>
<td>2</td>
<td>5/64-10/64</td>
<td>10-300</td>
<td>0-50</td>
<td>15-200</td>
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<tr>
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<td>10/64-3/65</td>
<td>10-300</td>
<td>0-50</td>
<td>0-285</td>
</tr>
<tr>
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<td>3/66-7/65</td>
<td>5-540</td>
<td>0-441</td>
<td>0-444</td>
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<tr>
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<td>3/66-8/66</td>
<td>5-540</td>
<td>0-441</td>
<td>0-444</td>
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<tr>
<td>6</td>
<td>3/66-2/67</td>
<td>5-540</td>
<td>0-441</td>
<td>0-444</td>
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</table>

*Experiments 4 and 6 were made on the growth obtained after cutting back to soil level at the end of the preceding experiments.

**Table 2. Leaf analysis, disease ratings and growth for Experiment 3.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Applied N (ppm)</th>
<th>Leaf N (%)</th>
<th>Applied P (ppm)</th>
<th>Leaf P (%)</th>
<th>Applied K (ppm)</th>
<th>Leaf K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>1.78bc</td>
<td>0.017b</td>
<td>430e</td>
<td>340b</td>
<td>76.7bc</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>2.09d</td>
<td>0.011a</td>
<td>2.97d</td>
<td>56.9ede</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>2.09d</td>
<td>0.011a</td>
<td>2.97d</td>
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<td>4</td>
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<td>0.011a</td>
<td>2.97d</td>
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</tbody>
</table>

*Four plots per treatment.

**Fig. 1. Philodendron oxycardium leaf infected with Xanthomonas sp.**
other experiments are included in the figures of this paper so as to give a larger sample of the data. All of the experiments gave significant correlations between leaf analyses and growth, and between leaf analyses and disease incidence. Although conditions varied from one experiment to another, some of the correlations were verified in most experiments.

The first comparisons were made between applied nutrient solutions and leaf analyses. Then, since the concentrations of applied solutions varied considerably from those in the mix, growth and disease incidence were correlated with leaf analyses.

Leaf analyses. Fig. 2, 3 and 4 for Experiment 4 show typical N, P and K results that are very similar to those obtained in the other sets. These curves derived from experimental points are in agreement with the regression equations.

Increasing the solution concentration of N, P or K increased the leaf concentration of the element added, but the rate of increase became less at higher solution concentrations. Leaf P did not increase for solution concentrations exceeding 15 ppm. Most responses showed no interaction between P and the other nutrients, but there was interaction between N and K. Increasing N caused an appreciable decrease in leaf K, but solution K had only a slight effect on leaf N. Calcium was decreased by N even more than was K. For example, in Experiment 4, Ca ranged from 2.25 to 2.83% when the N level was 10 ppm and from 1.38 to 1.82% when N was 120 or 300 ppm. Potassium had little effect on Ca.

Plant growth. Fig. 5, 6 and 7 show growth responses to leaf N, P and K in spite of considerable scattering of the points due to each curve ignoring variations in two of the nutrients. Phosphorus appears to have little effect except that growth is considerably reduced for values of P less than 0.15%. That was confirmed in other experiments. Growth increased with leaf K in the 1.3 to 5.0% K range which was also confirmed in other experiments. Fig. 6 illustrates a highly significant decrease in growth with leaf N in the 1.6 to 3.0% N range even when P and K were reasonably high. That also was indicated in other experiments but in no other case was it possible to separate the effect of N from that of leaf K. For example, in Experiment 5 as shown in Table 2, the maximum growth was obtained for considerably less than the maximum N and K, and the highest value of N as found in Treatment 15 gave one of the lowest yields. Nevertheless, the low yield in Treatment 15 may have been partly caused by the low K while the other three very low growth treatments were obviously affected by low P.

Light intensity had considerable effect on growth but did not appreciably affect nutrient concentration or disease incidence. Experiments 5 and 6 gave growth data of low significance because they were conducted in a greenhouse where the illumination varied according to the location.

Disease incidence. Table 1 lists the ranges of leaf analyses and disease ratings obtained in each experiment. Regression equations (not presented) for each experiment were calculated to apply throughout those ranges. In order to compare the different experiments, each equation was multiplied by the appropriate factor to make the disease incidence equal 100 for average analyses of 2.00%, 0.27% and 3.70% for N, P and K respectively. In Fig. 8, these adjusted equations are plotted for selected values of the leaf analyses. In all cases P was assigned the value of 0.27%. Fig. 8A shows the effect of leaf N on disease when K is low and Fig. 8C when K is high. Fig. 8B shows the effect of leaf K

Fig. 2. Effect of solution N on leaf K in Experiment 4. Fig. 3. Effect of solution K on leaf N in Experiment 4.

on disease when N is low and Fig. 8D when N is high. In selecting the fixed values of N and K for these curves, it was necessary to stay within the range of experimental values or at least close enough to those values so the equations were applicable. In Fig. 8A, it was necessary to select a different low value for K in Experiment 6 than in the other experiments because the lowest experimental value for K was much higher than in Experiments 1 to 4. The fixed value of K was immaterial in Experiment 5 because the equation showed no effect of N.

According to the regressions equations, P had a negligible effect on disease except in Experiment 5. The equations for that experiment showed a significant decrease with an increase in P. When the actual data were plotted as in Fig. 10, the effect was found to be almost entirely due to the inclusion of treatments with leaf P greater than 0.41%. The other experiments had no values in this range.

The curve for Experiment 3 in Fig. 8C is the only curve showing an increase in disease as N increases, and the data in Table 2 indicate that the high K curve may be outside the range of the equation. Five per cent K was chosen as the high K value since it was less than the maximum in the experiment, but the 8 treatments which gave more than 3.5% K were all in the narrow range of 1.78 to 2.30% N. Probably the reliable range for the equation covers a much narrower range of N values when K is high than when it is low. Consequently, the regression equation for Experiment 3 is not a true indication of an increase in disease as N increases.

Fig. 8. Effect of leaf N and K on disease according to regression equations.

In Fig. 9 the experimental data for Experiments 3 and 6 are plotted without regard to values of P and K. The general tendency was for the disease to decrease in Experiment 3 as N increased despite considerable scattering of the experimental points. Experiment 6 had unusually consistent data and taking this experiment by itself, one might say that when N is less than 1.6%, the disease incidence is high for all values of K and P but when N is greater than 2.1%, the disease incidence is low, at least for values of K greater than 3.6%. In none of the other experiments (except No. 5 when P was greater than 0.40%) were disease incidence values of less than 15% obtained so this wide range of disease values from 1.4 to 75.3% infection in Experiment 6 may make it more significant.

Fig. 8A, 8C and 9 show that the disease generally decreased as N increased. The failure of Fig. 8A and C to show the decrease in Experiment 5 is believed to be due to the difficulty of calculating regression equations from a limited number of experimental points. In this experiment, the P effect was much larger than the N effect and there was some correlation between P and N values so N was left out of the equation. The correlation between P and N may have been fortuitous and direct comparison on the basis of N concentrations alone gives results similar to the curve for Experiment 6 in Fig. 9. In Experiment 5, 10 treatments ranged from 1.51 to 2.06% N with an average of 1.89%, while the other 13 treatments ranged from 2.10 to 2.48% N with an average of 2.29%. The 10 treatments with low N averaged 35.0% infection while the high N treatments averaged 16.1% infection. This decrease in disease with increasing N is similar to that found in the other experiments so it may be concluded that all 6 experiments showed a decrease in disease with increasing N.

Fig. 8B and D show decreasing disease with increasing K in 4 of the experiments and a slight increase in the other 2 experiments. These are significant discrepancies but in no case is there a large effect so it may be concluded that disease is only slightly affected by K.

No significant correlation was found between disease incidence and top weights.

**DISCUSSION**

Growth was affected by leaf contents of N, P and K so it is difficult to separate the effect of individual elements, but Fig. 6 shows a 5 fold decrease in growth
from 1.5 to 2.6% N. This is consistent with the other data to the extent that none of the 6 experiments showed a maximum growth rate for levels of leaf N greater than 1.5% which was approximately the lowest value obtained. Other observers (3, 9) also failed to find a maximum growth rate for levels of leaf N greater than 1.2% N.

The increase in growth from increasing K to 5.0% as shown in Fig. 7 is consistent with the results of Hogan (4) who showed increased growth as the K content of the leaves increased from 2.15 to 3.15%, and practically no change in the narrow range from 3.15 to 3.64%. He did not investigate the 3.64 to 5.0% range.

Fig. 4 and 5 indicated that applying 15 ppm of P or obtaining 0.2 and 0.3% P in the leaves was adequate for growth. Hogan (4) investigated an entirely different range of P values, namely 0, 90 and 279 ppm in solutions which gave 0.247, 0.654 and 0.905% P in the leaves. Increased growth was obtained in that range which indicates that it would be desirable to investigate the effects on disease of P rates greater than 50 ppm. In fact, results of the one experiment illustrated in Fig. 10 suggest that high P might reduce disease incidence.

Since K stimulated growth and apparently did not increase disease, it may be desirable to use large amounts of K fertilizer when high N is applied to reduce disease. These would tend to counteract growth reduction by excessive N. In some cases, it seemed that a big reduction of disease could be obtained without an excessive reduction of growth but that would depend on the extent of the infection and many other factors. In Experiment 6 disease ratings of less than 10% of the maximum value were found for growths of 40 to 60% of the maximum value. (Disease ratings are plotted in Fig. 9).

Nayudu and Walker (7) believe protection from bacterial spot of tomatoes is caused by growth reduction due to high osmotic pressure around the roots. That observation does not apply to our results with Xanthomonas disease on Philodendron even though increasing N, P and K increased osmotic pressure, and the most effective disease treatment was to increase N. Despite the fact that this also decreased growth, the Philodendron bacterial disease decrease seems to be related more to increased N than to reduced growth because increasing P and K stimulated growth but did not appreciably increase disease.

The behavior of this disease is somewhat similar to that of Phytophthora leaf spot (3) in that it was reduced by increasing N. Phytophthora leaf spot, however, seemed to be more easily reduced by decreasing K while this bacterial disease is only slightly affected by K. Because it is safe to stimulate growth with high levels of P and K, it would be more practical to control this bacterial disease by adjusting the fertilizer program than it would be with the Phytophthora fungus.

In contrast to the fungus disease of Philodendron, Xanthomonas disease is difficult to control with bactericides but appears not to be carried over in soil. Therefore, the best means of controlling Xanthomonas disease may include use of high rates of N and strict sanitation to avoid contamination by diseased plants.

LITERATURE CITED


