Mineral Nutrition of Strawberry Plants in Relation to Mite Injury[1]

L. P. Stoltz,[2] C. E. Chaplin,[2] A. M. Lasheen,[2] and J. G. Rodriguez[3]
University of Kentucky, Lexington

Abstract. Five clones of strawberries varying in degree of resistance to the two-spotted spider mite, *Tetranychus urticae* Koch, were grown at four nutrient levels. Foliage samples were analyzed for minerals, amino acids, total sugar and total starch. The plants were infested with this mite and were rated for injury. Nitrogen of clones and treatments showed significant correlation with mite injury at the 0.05 and 0.01 levels respectively. Phosphorus of clones was significantly correlated with mite injury. Mite injury and treatments, but not clones, were significantly correlated when the amino acids classified as non-essential to *Tetranychus urticae* were considered. Total starch and total sugar of treatments had significant negative correlations with mite damage.

The two-spotted spider mite, *Tetranychus urticae* Koch, has been one of the most serious pests of strawberry production in Kentucky and surrounding states. Chaplin *et al.* (2) have shown that there are many degrees of mite resistance in strawberries and that mite resistance can be improved by selective plant breeding. In an effort to determine the biochemical nature of this mite resistance, the following mineral nutrition study was conducted to determine the effects of nutrition on the biochemical constituents of strawberries, the relation of these to mite injury and the nutrition of the mites. Rodriguez (7), working with apple trees growing in nutrient solutions, found that *Tetranychus telarius* (= *urticae*) fecundity was positively correlated with N supply and absorption and negatively correlated with absorbed P. More recently his review of related work showed that other workers studying other plant hosts produced the same general results (8). Cannon and Terriere (1) reported no effect of the minor elements iron, manganese, zinc and cobalt on egg production of the two-spotted spider mite on beans.

The effect of nutrition on the amino acids in the leaf and their relation to the amino acids in mites was also studied since Rodriguez and Hampton (9) had previously indicated several amino acids as essential to the two-spotted spider mite. Sugar and starch were of interest since mite fecundity increased with increasing sucrose over the range of 1.0 to 2.0% when supplied in artificial diets (8), while fecundity was found to be negatively correlated with total carbohydrates of bean leaves (4).

Materials and Methods

Five strawberry clones, varying in resistance to the two-spotted spider mite from very susceptible to resistant were used in this experiment.[4]

The nutrient solution which Hoagland and Snyder (5) reported to give good growth of strawberries in quartz sand was chosen as the basal nutrient solution for this experiment and was designated Treatment No. 1; N, P, K, Ca, Na, and SO_4 were varied but all the other ions were held constant. Minor elements were supplied to all treatments and the solutions were adjusted to pH 6.0 using NaOH or H_2SO_4 (3). Treatment No. 2 had 1/5 of the N, P and K treatment No. 1; No. 3 had 1/10 of the N and 1/20 of the P and K, while No. 4 was the same as No. 2 except that 2/3 of the nitrogen was supplied in the ammonium form and only 1/3 was supplied in the nitrate form (see Table 1).

In January, 3 plants of a clone were planted in a 2-gallon crock. There were 4 replications of each treatment per clone, and the entire experiment was randomized on a greenhouse bench. The plants were watered with distilled water every day for 5 days, after which either nutrient solutions or water was supplied to the crocks on alternate days. Enough was supplied to each crock so that it drained completely through the sand.

Supplemental light was supplied by 40 W cool white fluorescent tubes placed 30 inches above the plants to furnish a 16-hour photoperiod when the natural photoperiod was less than 16 hours.

Foliage samples for chemical analysis were collected in April and the plants were infested with mites in May as described by Chaplain et al. (2). The mite colonies died out and could not be re-established during the summer. This phenomenon had been noted before (2). Therefore, the foliage samples were discarded since one of the objects of the study was to correlate mite damage with biochemical constituents of the plant.

The old mite damaged foliage was then removed and new foliage was allowed to develop during the summer and fall. Leaf samples consisting of the youngest mature leaves were taken on October 19. The sample consisted of 3 leaves from each treatment in each replication to form a composite sample. The plants were then infested with mites which multiplied and caused severe damage. The leaf samples were then lyophilized, ground in a Wiley mill to pass a 60-mesh screen and then stored at −10° F until used for analysis.

Nitrogen was analyzed by the macro-Kjeldahl method; K by flame photometry (Beckman Model B Spectrophotometer); and P, Ca, Mg, Mn, Fe, Cu, B and Zn by spectrographic analysis (ARL Direct Reading Emission Spectrograph).

Table 1. Nutrient variables supplied to strawberries grown in quartz sand.

Treatment	Milligrams per liter				
	N	PO_4	K	Ca	SO_4
T-1	210	95.00	235	200	192
T-2	42	19.00	47.0	200	576
T-3	21	4.75	11.5	185	576
T-4	42(14,28)[a]	19.00	47.0	160	576

[a]First number in parenthesis is N from NO_3 and second is from NH_4.

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[2]Associate Professors, Department of Horticulture, University of Kentucky.
[3]Professor, Department of Entomology, University of Kentucky.

[4]Numbered selections have been described in a previous publication (2).

Free amino acids, starch and total sugar were analyzed by the methods previously described by Lasheen, et al. (6).

All plants were rated for mite injury by 4 persons trained to recognize this damage. The ratings ranged from 0 to 10, with 10 being a dead plant; each succeeding number 0 to 10 represented approximately 10% of the leaf surface damaged.

Results and Discussion

Table 2 shows that both clones and treatments had significant effects on mite injury though there were no interactions. The injury ratings of the clones indicate that Ky. 17-61-15 was significantly better at the 1% level than Ky. 1-63-11. It was better at the 5% level than 'Citation' but not better than 'Surecrop' or Ky. 22-61-9. In previous studies Ky. 22-61-9 had mite injury ratings comparable to those of Ky. 17-61-15 (2). We have no explanation why it did not show a resistance rating more consistent with its past performance.

The mite injury rating for treatment 1 which supplied optimal amounts of N, P and K, was not significantly different from that of treatment 2 which supplied only 1/5 the amount of N and 1/10 the amounts of P and K. The injury rating of treatment 1, however, was significantly higher than that of treatments 3 and 4.

A significant positive correlation was found between the mite injury rating and the percent of clones (r = .83) while that of treatments (r = .99) was highly significant. As has been pointed out, this type of relationship has been found to occur with this mite feeding on a number of host plants (8). Phosphorus content of clones was positively correlated with mite injury (r = .97) but correlation with treatment was non-significant (Table 2).

Potassium, Mg and Ca showed poor correlations with mite injury both by clones and by treatment. The minor

Table 2. Mite injury ratings and mineral analysis of strawberry leaves by clone and treatment.

Variable	Avg mite injury rating	Percent dry wt.					PPM				
		N[c]	P[d]	K	Ca	Mg	Mn	Fe	Cu	B	Zn
Clone											
1–63–11	8.03[a]	2.29	0.422	1.65	1.36	0.36	50	111	8.6	68	15
Citation	5.89	2.19	0.435	1.67	1.21	0.41	50	117	8.8	65	13
Surecrop	4.92	2.12	0.375	1.49	1.38	0.47	48	133	6.7	65	14
22–61–9	5.81	2.07	0.432	1.72	1.10	0.40	48	124	6.8	98	12
17–61–15	3.86	2.09	0.355	1.54	1.40	0.45	47	108	6.9	75	14
Treatment											
T-1	6.85[b]	2.36	0.437	1.64	1.29	0.42	50	119	5.6	72	14
T-2	5.67	2.12	0.385	1.66	1.30	0.42	48	122	6.8	77	13
T-3	4.96	2.05	0.376	1.56	1.29	0.43	45	111	8.0	71	13
T-4	5.34	2.08	0.417	1.58	1.27	0.41	52	122	9.7	78	14

[a]Clone LSD .05 = 1.97; .01 = 2.64.
[b]Treatment LSD .05 = 1.49; .01 = 2.15.
[c]Correlation with injury rating: clones r = .83*; treatments r = .99**.
[d]Correlation with injury rating: clones r = .97.**

Table 3. μ moles of amino acids per gram of dry weight in strawberry leaves by clone and by treatment.

Amino Acids	Clone					Treatment[a]			
	1–63–11	Cit.	Sure.	22–61–9	17–61–15	T-1	T-2	T-3	T-4
Essential									
Arginine	0.006	0.012	0.011	0.010	0.044	0.052	0.008	0.007	0.007
Histidine	0.012	0.008	0.013	0.010	0.012	0.011	0.012	0.012	0.010
Isoleucine	0.027	0.030	0.038	0.028	0.029	0.034	0.027	0.032	0.029
Leucine	0.024	0.020	0.026	0.020	0.019	0.027	0.020	0.023	0.018
Lysine	0.017	0.017	0.018	0.016	0.019	0.020	0.017	0.020	0.016
Phenylalanine	0.033	0.041	0.034	0.027	0.029	0.044	0.025	0.031	0.031
Tyrosine	0.033	0.028	0.028	0.025	0.022	0.041	0.022	0.024	0.023
Valine	0.052	0.053	0.061	0.045	0.047	0.066	0.042	0.048	0.050
Subtotal	0.204	0.209	0.229	0.181	0.221	0.295	0.173	0.197	0.184
Non-essential									
Alanine	0.500	0.380	0.570	0.470	0.390	0.820	0.300	0.360	0.370
Aspartic acid	0.026	0.033	0.017	0.043	0.041	0.034	0.047	0.021	0.026
Ethanolamine[b]	0.460	0.440	0.400	0.390	0.420	0.490	0.430	0.400	0.450
Glutamic	0.490	0.580	0.750	0.780	0.990	0.900	0.810	0.620	0.520
Glycine	0.058	0.070	0.072	0.085	0.152	0.120	0.060	0.090	0.080
α-Amino butyric acid[b]	1.990	1.830	1.640	1.860	1.300	2.310	1.600	1.440	1.570
Ornithine[b]	0.081	0.051	0.080	0.068	0.065	0.067	0.060	0.071	0.051
Proline	0.081	0.069	0.077	0.082	0.055	0.099	0.070	0.064	0.058
Serine	0.420	0.300	0.390	0.380	0.490	0.061	0.036	0.031	0.031
Threonine	0.230	0.210	0.260	0.290	0.290	0.380	0.250	0.100	0.210
Subtotal	4.336	3.963	4.256	4.448	4.193	5.281	3.663	3.197	3.366
Total	4.540	4.172	4.485	4.629	4.414	5.576	4.836	4.394	3.550

[a]Correlation of total non-essential amino acids with mite injury ratings r = 0.98**.
[b]Not classified as essential or non-essential by Rodriguez and Hampton (9).

elements were not varied and the content in the tissues appear to be rather uniform within a group; only one (the B content of Ky. 22-61-9) seems out of line. No symptoms of nutrient deficiency occurred on the plants during the time they were in the experiment; however, the plants receiving treatment 1 were consistently noted to be more vigorous than those of the other treatments.

Table 3 shows the amounts of amino acids both by clone and by treatment; they have been divided on the basis of essential and non-essential amino acids for mites according to Rodriguez and Hampton (9). A highly significant correlation was found between mite injury and total non-essential amino acids by treatment but not by clone; essential amino acids were not significantly correlated with either treatment or clone. These results indicate that amino acids should be discounted as a primary agent of mite resistance, but the content of amino acids in the plant is influenced by its nutritional status and reflects to some degree the overall vigor of the plants. Other amino acids were found, but they either occurred in very low concentrations or the particular amino acid did not occur in all samples and was therefore not computed. One interesting fact was that α-amino butyric acid which occurred in the highest concentration in the foliage could not be detected in the mite carcasses, (Rodriguez et al., unpublished)[5]. No significant correlations between the amino acids in the strawberry leaves on which the mites fed and the mite carcasses could be determined. This is indicative of the fact that the amino acids in the foliage are not critical for the mites' nutrition though they may show some preference for foliage high in amino acid content.

Table 4 shows the total sugar and total starch of strawberry leaves by clone and treatment. Correlations between total sugar and starch of clones with injury ratings were not significant. Significant negative correlations were found to exist, however, when they were tested with treatment mite injury, and this agrees generally with Henneberry (4) who reported fecundity of this species to be negatively correlated with total carbohydrates.

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Table 4. Total sugar and total starch in strawberry by clone and by treatment.

Clone or treatment	Percent dry wt.	
	Total sugar	Total starch
1–63–11	11.50	1.25
Citation	10.71	1.27
Surecrop	10.25	1.27
22–61–9	10.99	1.25
17–61–15	11.79	0.90
T-1	10.20[a]	0.82[b]
T-2	10.53	1.42
T-3	11.75	1.59
T-4	11.22	1.55

[a]Correlation of total sugar with mite injury ratings; r = –0.90.*
[b]Correlation of total starch with mite injury ratings; r = –0.98.**

Literature Cited

1. Cannon, W. H., Jr., and L. C. Terriere. 1966. Egg production of the two-spotted spider mite on bean plants supplied nutrient solutions containing various concentrations of iron, manganese, zinc and cobalt. *J. Econ. Ent.* 59:89–93.
2. Chaplin, C. E., L. P. Stoltz and J. G. Rodriguez. 1968. The inheritance of resistance to the two-spotted mite, *Tetranychus urticae* Koch in strawberries. *Proc. Amer. Soc. Hort. Sci.* 92: 376–380.
3. Clark, J. H. 1933. Reaction of the nutrient medium as affecting growth of strawberry plants. *Proc. Amer. Soc. Hort. Sci.* 30:283–287.
4. Henneberry, T. J. 1963. Effect of host plant condition and fertilization on two-spotted spider mite fecundity. *J. Econ. Ent.* 56:503–505.
5. Hoagland, D. R., and W. C. Snyder. 1933. Nutrition of strawberry plant under controlled conditions: (a) Effects of deficiencies of boron and certain other elements: (b) Susceptibility to injury from sodium salts. *Proc. Amer. Soc. Hort. Sci.* 30:288–294.
6. Lasheen, A. M., C. E. Chaplin, and R. N. Harmon. 1970. Biochemical comparison of fruit buds in five peach cultivars in varying degrees of cold hardiness. *J. Amer. Soc. Hort. Sci.* 95:177–181.
7. Rodriguez, J. G. 1958. The comparative NPK nutrition of *Panonychus ulmi* (Koch) and *Tetranychus telarius* (L.) on apple trees. *J. Econ. Ent.* 51:369–373.
8. ————. 1964. Nutritional studies in the Acarina. *Acarologia* 6:324–337.
9. ————, and R. E. Hampton. 1966. Essential amino acids determined in the two-spotted spider mite, *Tetranychus urticae* Koch (Acarina, tetranychidae) with glucose - U-C 14. *J. Ins. Physiol.* 12:1209–1216.