COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Ionic Balance and Growth of Carnation

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CFGA Bulletin 210 contained a review of recent literature on plant nutrition. The effects of organic anion (C-A) levels in the plant tissue on growth were introduced. To investigate these nutritional concepts on carnation growing in several environments, the following experiment was completed.

Experimental Methods

Plants were grown in 4 air conditioned chambers within a glasshouse previously described by Goldsberry (1). These chambers are connected in an east-west direction and are covered with polyvinyl film. The total solar radiation was recorded for a 46-day period by means of Sol-A-Meters in chamber 1 (east) and chamber 4 (west). Daily measurable radiation in chamber 4 exceeded that in chamber 1 by 1.15 cal/cm^2. The measurable daily radiation in chamber 4 exceeded that in chamber 1 by 27 minutes. Daily radiation during midday was nearly equal, hence most of the light differences between these two extremes occurred at the end of the day. In the design of the experiment, chambers 1 and 2 are designated as light level 1, and chambers 3 and 4 as light level 2.

Day temperature of all chambers was maintained at 68F±3. Night temperature was maintained at 58F±3.

Maintenance of CO_2 levels in the plant atmosphere was accomplished by using the injection and monitoring system described in detail by Goldsberry (1). Table 1 gives the confidence interval for these levels.

Table 1. Confidence intervals for the maintenance of CO_2 levels in the plant atmosphere

Chamber	95 percent CI	99 percent CI
1	495 ± 10 ppm CO_2	495 ± 13 ppm CO_2
2	864 ± 11	864 ± 15
3	854 ± 11	854 ± 15
4	455 ± 7	455 ± 9

The experiment was designed to study the effect of 3 variables on carnation growth: 1) nutrient solution treatment, 2) light level, and 3) CO_2 level. The effects of these three factors acting individually and interacting together were evaluated by use of 3-way analysis of variance. Design of the experiment follows:

2 light levels (chambers 1 and 2, and chambers 3 and 4) to detect the light effect.
2 CO_2 levels within each light level (chambers 1 and 4 = 475 ± 8 ppm CO_2, chambers 2 and 3 = 859 ppm ± 11 ppm CO_2).
14 nutrient treatments within each chamber.
2 pots/nutrient treatment/chamber.
2 plants/pot allowing for two harvest dates: 1 plant/pot harvested after 26 weeks of growth.

Plant Culture

Small cuttings were used to start each experiment to minimize starting "nutrient load." The Sim variety was used to minimize possible genetic effect on ion uptake. Rooted cuttings were planted and grown in perlite, considered inert and therefore ideal for a nutrient solution experiment.

Plants were watered daily until they became established in the perlite then they were watered every other day. At each watering pots were leached. Soluble salt readings and pH records revealed no salt accumulation or pH shift. This is to say that salt and pH reading of the leachate approximated those of the respective applied nutrient solutions.

Reagent grade chemicals, plastic nutrient solution

[1]This work was done by James L. Green in completing the M.Sc. degree at Colorado State University and was sponsored by Colorado Flower Growers Association, Inc.

containers, pot labels, etc., were used to minimize chemical contamination.

Nutrient Solution Composition

The nutrient solutions were formulated so that the variation among pH's was within the ± 0.2 pH units of tolerance established by Steiner (3). The variation in calculated atmospheres osmotic pressure was within the tolerance range ± 0.2 atmospheres reported as critical by Steiner, except in the concentration series. (See Table 2 for solution composition.)

In the replacement series, total ion content of the respective solutions was held constant. Within a solution, content of all ions other than the two replacing each other was held constant, and the sum of the two replacing ions was constant.

Table 2. Composition of the treatment solutions in parts per million. All solutions received 5 ppm Fe Sequestrene 330 and 1 ppm boron.

Treatment		K^+	Ca^{++}	Mg^{++}	Na^+	NH_4^+	NO_3^-	$SO_4^=$	$H_2PO_4^-$	Cl^-
K-Ca replacement series										
2		98	190	12	11	0	744	48	48	0
3		235	120	12	11	0	744	48	48	0
4		371	50	12	11	0	744	48	48	0
5		469	0	12	11	0	744	48	48	0
K-Na replacement series										
6		0	50	12	230	0	744	48	48	0
7		195	50	12	115	0	744	48	48	0
8		293	50	12	57	0	744	48	48	0
4		371	50	12	11	0	744	48	48	0
$K-NH_4$ replacement series										
10		313	50	12	0	27	713	48	48	0
11		195	50	12	0	54	620	48	48	0
NO_3-Cl replacement series										
11		195	50	12	0	54	620	48	48	0
13		195	50	12	0	54	496	48	48	71
14		195	50	12	0	54	372	48	48	142
Concentration series										
12	0X	tap water								
1	1X	242	33	8	8	0	486	32	32	0
4	1-1/2X	371	50	12	11	0	744	48	48	0
9	2X	485	67	16	15	0	1005	65	65	0

Tissue Analysis

All tissue analyses were determined by the Colorado State University Soil Testing Laboratory. Tissue analyses made at CSU were compared with tissue analyses determined by the emission spectrograph at Cornell University on 18 duplicate samples. In general, CSU tests were slightly lower for each ion but conversion of results from one method to another could be made with reasonable accuracy. Tissue samples were collected, dried, and prepared as described by Nelson and Boodley (2).

Nutrient solutions are expressed in parts per million (ppm), Table 2. All tissue analyses are stated in milligram equivalents per kilogram dry matter (me/kg dm).

Stomatal Measurements

A method of measuring carnation stomates was described in CFGA Bulletin 194. Using this method a preliminary study indicated the leaf section and the leaf to be sampled for most accurate measurement of environmental effects on the stomatal aperture. While some effects of environment are reported in the results of this experiment, the detailed methods, results and measurements will be reported in a later article.

Relation of (C-A) Content to Yield

After uptake and the partial conversion of the inorganic ions of the nutrient solution salts, there resulted an accumulation in the plant tissue of the inorganic cations: K+, Na+, Mg++, and Ca++ and of the inorganic anions: NO_3^-, Cl^-, $H_2PO_4^-$, and $SO_4^=$. The sum of these cations and anions in milligram equivalents per kilogram dry material is given by C and A respectively. C equals the total salt cations in the plant tissue; A equals the inorganic salt content, and (C-A) equals the organic salt content of the plant material. In determining the (C-A), it was not necessary to account for the very low quantities of the other inorganic ions in the plant tissue.

At suboptimal growth, the (C-A) of the carnation plant varied depending on nutrition and other factors

(Fig. 1). But optimal growth was invariably associated with the normal organic salt content. There was a highly significant correlation between increase in (C-A) content of the tissue and increase in plant yield.

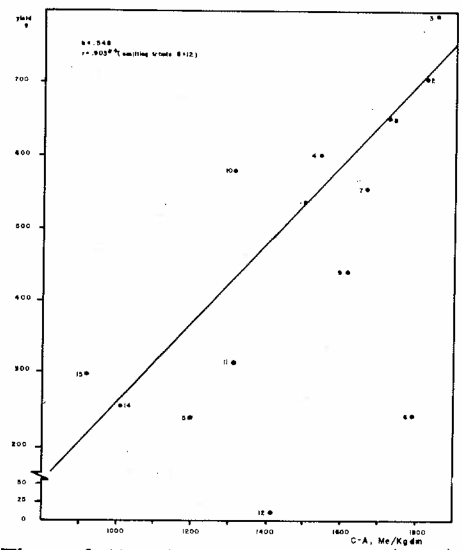

Fig. 1. The relation between yield and (C-A) content of the carnation tissue.

Variation in (C-A) content was mainly related to change in the cation concentration (C) of the plant tissue (Fig. 2a). Cation concentration was positively

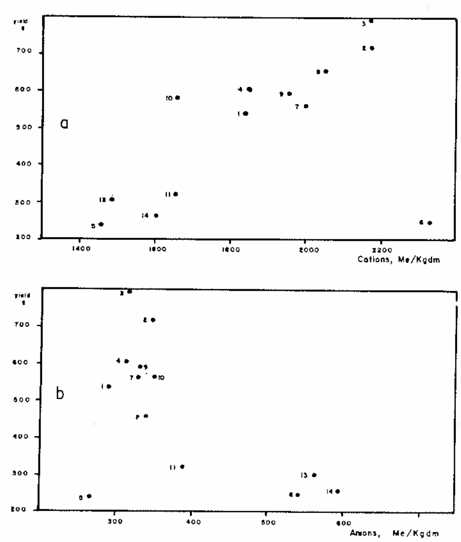

Fig. 2. (a). The relation between yield and cation concentration of the carnation plant. (b). The relation between yield and the anion concentration of the carnation plant.

correlated with yield except in the case of extreme sodium imbalance (Fig. 2a, point 6). Inorganic anion concentration in the plant tissue (A) remained fairly constant, (Fig. 2b). There was a significant negative slope relating yield and anion concentration. Higher anion concentration in the plant was associated with lower yields (Fig. 2b).

The correlation between total cation and total anion content per plant and yield is graphed in figure 3. The difference between the cation salt content and the total inorganic anion content at any given yield is

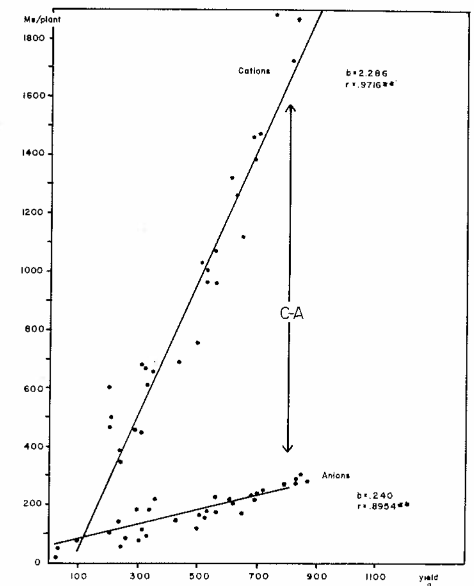

Fig. 3. Correlation between total cation and total anion content per plant and yield.

equal to the (C-A). As total cation content per plant increased, yield increased. Total inorganic anion content per plant was also positively correlated with yield. When inorganic anion concentration in the tissue was increased, yield decreased. What, at first glance, appears to be conflicting results may be explained by pointing out the difference between concentration of anions in the tissue and total uptake or content of anions per plant. The latter is the concentration of anions multiplied by the yield of the plant. Those plants which had the highest (C-A) content, usually due to low anion concentration (A), had the highest yield and consequently high total anion content.

Conclusions

One of the prerequisites of optimal growth was a 'normal' (C-A) organic salt content. But, depending on nutrition, a 'normal' (C-A) was not always associated with optimal growth (Fig. 1, point 6). Factors in the external environment and in the applied nutrient solution composition need to be studied to determine their effect on the ionic balance of the plant and plant yield.

Light, CO_2 and Nutrient Solution Effects

The photosynthetic response of carnation to varying light has not been determined. It is not known whether the light supplied in this experiment was saturating, or if the plants were still responding to increases in light.

In this experiment there were two CO_2 levels: Chambers 1 and 4 at 475 ppm and chambers 2 and 3 at 859 ppm.

Effects on Yield

High light (level 2) and high CO_2 (level 2) both acted to increase the yield of the carnation plant (table 3). However, they were not acting together. This is illustrated in figure 4 where the deviations affected by light and CO_2 from the average yield are plotted. A large positive deviation from the average yield due to high CO_2 (C2) was usually accompanied by a slight positive deviation due to high light (L2) or even by a negative deviation. The same was true of the large positive deviations from the average yield attributable to high light. They were accompanied by a slight positive deviation due to high CO_2 or by a negative deviation. The high yield in the K-Ca replacement series, treatment 3, and the high yield in the K-Na replacement series, treatment 8 (treatments having optimum nutrient balance for their series) was induced by high light.

Nutrient treatments 2, 4, 7 and the concentration series (Fig. 4) were imbalanced solutions. In these treatments the greater positive deviation from the average yield was due to the higher CO_2 level.

Table 3. The effects of nutrient treatment, environmental CO_2, and daily total light on ion content, yield, and stomatal aperture of the carnation plant as determined by three-way analysis of variance

	Nutrient treatment	CO_2	Light level	Nutrient treatment X CO_2
1. Cations, me/kg dm	**	**	ns	**
Cations per plant	**	*	ns	ns
2. Potassium, me/kg dm	**	ns	ns	**
Potassium per plant	**	*	ns	ns
3. Calcium, me/kg dm	**	ns	ns	**
Calcium per plant	**	*	*	ns
4. Magnesium, me/kg dm	**	**	ns	ns
Magnesium per plant	**	*	ns	ns
5. Sodium, me/kg dm	**	ns	ns	ns
Sodium per plant	**	ns	ns	ns
6. Anions, me/kg dm	**	ns	ns	ns
Anions per plant	**	ns	ns	**
7. Nitrate, me/kg dm	**	*	ns	**
Nitrate per plant	**	ns	ns	**
8. Sulfate, me/kg dm	**	ns	ns	ns
Sulfate per plant	**	ns	ns	*
9. Phosphate, me/kg dm	**	ns	ns	ns
Phosphate per plant	**	ns	ns	**
10. Chloride, me/kg dm	**	*	*	ns
Chloride per plant	**	**	*	**
11. Organic Nitrogen				
Org. N, me/kg dm	**	ns	ns	ns
Org. N per plant	**	ns	ns	*
12. (C-A), me/kg dm	**	**	ns	**
(C-A) per plant	**	**	ns	**

* significant
** highly significant
ns not significant

In the concentration series, at the lowest ion concentration low CO_2 and high light acted equally in causing a positive deviation from the average yield. At the higher ion concentrations, there was a reverse effect with high CO_2 and low light causing a positive deviation from the average yield.

High CO_2 compared to low CO_2 greatly reduced the stomatal aperture. Neither light nor nutrient treatment had an effect on stomatal aperture.

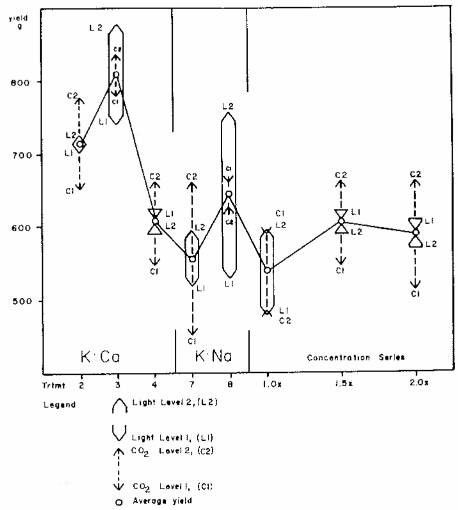

Fig. 4. Deviations from average yield affected by light and CO_2. Light and CO_2 levels are listed under Methods.

Effects of Light, CO_2, and Nutrient Solution on Ion Content

Chloride concentration in the plant tissue was the only ion concentration influenced by the light level. Chloride concentration increased with increasing light. Because higher light in general caused higher yields, there was a significant increase in the total chloride content per plant. This was also true of calcium content per plant (Table 3).

High CO_2 decreased the chloride concentration in the plant tissue. As in the concentration series, there was a positive deviation from the average yield due to high light accompanied by a negative deviation due to high CO_2. Or, high CO_2 and high light had opposite effects on the chloride uptake.

Magnesium was the only cation whose concentration in the plant tissue was significantly affected by the CO_2 level. Magnesium concentration in the tissue was higher at the higher CO_2 level. The total magnesium content per plant was also higher at the higher CO_2 level.

There was an increase in the (C-A) content of the plant at the higher CO_2 level. An increase in the cation concentration at the higher CO_2 level was not accompanied by a change in anion concentration. The change in the (C-A) content was due mainly to this change in the cation content of the tissue.

Conclusions

Optimum (C-A) is one of the prerequisites for optimum growth. The (C-A) was unchanged by the light level, but was significantly changed by the differential effect of CO_2 on ion uptake. The cation concentration (C) was significantly increased by an increase in magnesium concentration at the higher CO_2 level, and the inorganic anion concentration (A) was decreased by the decrease in chloride uptake at the higher CO_2 level.

The main effect of CO_2 was control of stomatal aperture and possible related effect on rate of ion uptake, transpiration, and translocation. High CO_2 probably reduces ion uptake and stress on the transpiration rate: 1) at greater ion concentration of the nutrient solution, there was a positive deviation from the average yield at the higher CO_2 level; 2) with suboptimal nutrient solutions, there was a positive deviation from the average yield at the higher CO_2 level; and 3) by reducing the transpiration, higher CO_2 may have functioned to reduce the uptake of the chloride ion.

The main effect of the higher light level was probably the increase in photosynthesis. There was no indication that the light difference was of a magnitude to effect the stomatal aperture and transpiration rate. But there was an unexplained increase in chloride uptake at the higher light level.

Literature Cited

1. Goldsberry, K. L. 1963. Effects of carbon dioxide on carnation. Proc. Amer. Soc. Hort. Sci. 83: 753-760.
2. Nelson, P. V. and J. W. Boodley. 1965. Development of a set of standard leaf composition values for carnation. Proc. Amer. Soc. Hort. Sci. 86: 641-649.
3. Steiner, A. A. 1961. A universal method for preparing nutrient solutions of a certain desired composition. Plant and Soil Sci. 15:134-154.