How shall we define the term quality? Anyone who has worked with flowers will stress keeping quality: the prolongation of their esthetic qualities to provide the maximum benefit to the user.

However, other considerations of quality beyond shelf life should be examined. Some of these, such as size, are subject to controversy. Is it always the largest flower that is of the best quality? What about the stem length and stem strength? Society of American Florists (SAF) grades and standards guidelines put heavy emphasis on both these factors – the longer and stronger the stem the higher the grade and hence the better the quality. Why can’t a short stem chrysanthemum be as high quality as a long stem bloom? Perhaps it has something to do with balance of size and symmetry.

Should a weak stemmed carnation be downgraded to a lesser quality? Perhaps so if the retail florist cannot use it without wireing the stem to provide the support needed.

Other SAF criteria call for foliage to be free of dirt and spray residue and from insect and disease injury. Foliage riddled with holes from insect feeding or covered with mildew and its attendant disfiguration is certainly not as attractive as undamaged foliage. If our plants were resistant to disease and insect attack then sprays would not be needed and hence no residue would result. Mineral nutrition affects on insect and disease injury will be considered later.

Another criterion, not part of SAF standards but certainly to be considered, is earliness of bloom. It is advantageous to be able to reduce the time needed to bring a flower crop to bloom and hence harvest, but is this a factor of quality?

Comments on nutrition

I will comment on nutrition in general with specifics of N and K effects, ionic balance, ammonium vs. nitrate forms of nitrogen, micro-nutrition, specific deficiencies and toxicities with a concluding statement on soluble salts.

Waters and his colleagues in Florida have performed intensive and extensive experiments with chrysanthemums and the effects of nutrition on growth, keeping quality, disease susceptibility and chemical composition. With field-grown 'Iceberg' fertilized with Osmocote 14-14-14, they found yield increased proportionally as rates of fertilizer applied were increased from 2400 to 4800 to 7200 lb./acre/season (19). Keeping quality, expressed as days, decreased from 13.7 to 16.2 to 15.2 for those rates and incidence of Botrytis increased from 34 to 43 to 53%. In a second study (20) Waters obtained optimum yields at 1500 to 1800 lb./acre. Keeping quality and Botrytis were in a medium range.

Reporting on a 3 year study of the influence of nutrition on the factors previously mentioned, Waters (21) stated optimal production was obtained at ca. 1760 lb. N/acre annually, which was similar to results obtained in the earlier studies.

Keeping quality decreased dramatically and significantly as N was increased through levels of 720, 1760 and 2800 lb. N/acre yr. Field infection of Botrytis also increased markedly as N was increased from 720 to 1760 lb. Potassium levels had little effect on growth response, disease severity or keeping quality.

In a subsequent study with 3 N levels and 2 lime levels, he found the same results for N, but lime had no affect on marketable yield, keeping quality or Botrytis.

Waters (22) reported on fertilizer applications at various growth stages of chrysanthemums. On a 16 week crop, maximum keeping quality and minimum deterioration by Botrytis was obtained by eliminating all fertilizer the last 4 weeks before harvest. He recommended an N-K ratio during the first two-thirds of the season from 0:1 to 1:2. These results substantiated earlier (1958) recommendations of Lunt and Kofranek.

Finally, Waters showed that optimum yields were obtained when most recently matured leaves contained 3.5 to 4.5% N and 3.5 to 6.0% K.

Hartman at Colorado studied the response of 'CSU White' carnations to irrigation frequency and nutrient solution concentration (7, 8). He concluded that increased watering frequency did not compensate for reduced nutrient solution concentration even though yield was increased more at the lower concentration by increasing the frequency of application. Also, increased nutrient solution concentration did not compensate for less frequent applications.

Ion balance studies

Sadasivaiah and Holley (16) have investigated ion balance in nutrition of greenhouse roses 'Forever Yours' in a replacement and concentration series. They observed decreased yield as Mg was increased from 2 to 6 me/liter and Ca was decreased from 6 to 2 me/liter. High Mg in nutrient solution interferes with uptake of Ca. In a K-Ca replacement series a high Ca/K ratio significantly affected stem length only. No significant differences for yield or fresh weight were seen.

Replacing 1 me/liter Ca with NH4 significantly increased yield, fresh weight, stem length and quality index. Further increase of NH4 had a depressing effect on yield. Zn, B, Fe and Mn increased with the first increments of NH4 increase but decreased as NH4 was raised to 2 me/liter.

In striking contrast the absence of NH4 in solutions resulted in chlorotic leaves. Plants receiving NH4 were not chlorotic. Literature reports state citric acid and sometimes other organic acids are high in chlorotic leaves. Several researchers have found NH4 nutrition decreases citric as well as other acid contents of leaves.

In the concentration series they found roses would produce normal yield even from relatively low total ion concentrations as long as balance is ideal.

Hartman (9) attempted to increase the organic ion concentration by modification of the nutrient solution for carnations. His efforts were unsuccessful. He stated that plants regulate their anion organic concentrations over a wide range of solution compositions.

The form of N used (ammoniacal or nitrate) seems to have intrigued nutritionists throughout the years. D. I. Arnon (1) published a paper in Soil Science in 1937 with the title "Ammonium and nitrate nitrogen nutrition of barley at different seasons in relation to hydrogen ion concentration."

Crater (5) working with 'Giant #4 Indianapolis White' grown at different seasons of the year found NH4:NO3 was the best all year-round fertilizer. The use of urea resulted in the poorest crops produced in September and December.

Tsujita (18) compared NO3 vs. NH4 under low and high light conditions on 'Indianapolis Yellow'. Use of ammonium sulfate as the NH4 source resulted in statistically fewer days to bloom compared to NO3 sources. Larger flowers were obtained when plants were continuously fertilized with NH4N. NH4N during the first 7 weeks also resulted in larger stem diameter, greater stem stiffness and higher dry weight yields. He also found that plants under NO3N and reduced light intensity produced the smaller stem diameter.

Productivity of carnations

Green and Holley (6) contend the productivity of carnations was increased to levels attained with C-4 plants such as corn by adjusting the ratio of NH4-N to NO3-N supplied to seasonal solar radiation. During periods of low solar radiation the optimum formulation was 1/3 NH4N and 2/3 NO3-N. During high solar radiation formulation was all nitrate with no ammonium.

Their research supported the hypothesis that under high light intensity NO3 increases net photosynthesis (yield) by inhibiting photo respiration through competition for excess NADPH2 and by increasing the base photosynthesis rate through inhibiting O2 competition with CO2.
Under low light conditions where rate of NADPH₂ formation by the photosystem rather than CO₂ concentration would be limiting net photosynthesis, the competition of NO₃⁻ reduction would be detrimental to growth according to Kessler.

In my work (3), comparing ammonium nitrate, ammonium sulfate, calcium nitrate and sodium nitrate applied at two concentrations to 'Paul Mikkelsen' poinsettias grown in peat-lite mixes, there was an effect both from concentration and type of N used. Both sodium and ammonium sulfate applied at 800 ppm weekly were too strong and killed the plants. Calcium nitrate at 800 ppm was satisfactory. Ammonium nitrate at 800 ppm caused some foliar damage. Best results were obtained with Ca(NO₃)₂ at 400 ppm applied weekly. Low nitrification of peat-lite mixes was offered as the major reason for the results obtained.

Parker (2) at Colorado reported significant reductions in yield of carnations when either high (8 ppm) or low (0 ppm) B levels were used regardless of Ca level applied. Highest yields were at 0.8 and 4 ppm B at both Ca levels of 3.5 and 8.0 me/liter. Plants with no B flowered 2 to 3 weeks later than all other treatments.

Parker (13) also reported fresh weight yields of carnations are reduced if excessive levels of Fe, Mn, Zn and Cu are used (50, 50, 50 ppm, regardless of Ca level applied). Highest yields were at 0.8 and 4 ppm B at both Ca levels of 3.5 and 8.0 me/liter. Plants with no B flowered 2 to 3 weeks later than all other treatments.

Penneisingfeld (14) in Germany conducted a series of experiments over 18 years, first in water culture then in peat culture, and established parameters of nutrient levels essential to high yields and quality.

**Deficiencies and toxicities**

Kofranek and Kohl (personal communication, 1974) reported a K deficiency symptom on carnations they described as “little leaf.” At the time of bloom, where K nutrition may be marginal in a plant, excessive translocation of K from the small leaves immediately subtending the bloom results in tip necrosis of those leaves.

Jungk (11) and others reported an injury to poinsettias as a result of Mo deficiency. Necrosis and leaf distortion of 'Paul Mikkelsen', 'Eckes-Point C-1' and 'Annette Hegge' was determined to result from Mo deficiency.

We showed that petal necrosis of 'Indianapolis White' chrysanthemums was due to a B deficiency that was not reflected in low leaf levels (2).

Toxic levels of nutrient elements can reduce quality of ornamental plants and flowers.

Poole and Conover (15) of Florida have reported several specific instances of fluoride injury on foliage plants not only in the propagation bed but also in growing containers.

They identified necrotic spotting and tip burning in *Cordyline terminalis* and *Dracaena deremensis* as fluoride toxicity. The sources of F were superphosphate (50 to 100 ppm from 5 to 10 lb./cu. yd³ additions), German peat moss (4 ppm F), perlite (17 ppm F), and irrigation waters (0.1 to nearly 2 ppm F). As little as 0.25 ppm F may cause injury on sensitive species. Where municipalities add 1.0 ppm F to water supplies for tooth decay control, this could have serious consequences for foliage plant growers.

Schekel (17) on carnations and Waters et al. (23) on excess soluble salts in general, point out the problems that arise when nutrient elements are applied in excess quantities. Plant death, stunted growth, excessive wilting, marginal leaf burn, yellowing of new growth and small flowers may all be symptoms of excess soluble salts concentrations.

**Literature Cited**