J. Amer. Soc. Hort. Sci. 103(3):306–308. 1978.

Determination of Irrigation and Fertilizer Practices for Jade Plant [*Crassula argentea* (L.) Thunb.][1]

J. Spooner, L. Daley, G. Ware, and M. Vines
Department of Horticulture, University of Georgia, Athens, GA 30602

Additional index words. plant nutrition, succulent plants

Abstract. **Daily watering gave increased growth of jade plants over weekly watering if fertilizer was applied. The optimum fertilizer rate with either weekly or daily watering was calculated as 100 ml of 250 ppm N of a 20N:8.6 P:16.6K fertilizer per 10 cm pot.**

Although succulent plants adapt well to drought and limited water, many growers contend the lack of care is the secret of successful succulent culture believing frequent watering and fertilization are harmful. Accepted practice is to allow the soil in which these plants grow to dry out between waterings, particularly since succulents do not show visible signs of wilting as do non-succulents.

The frequency of watering is dependent on the physical characteristics of the growth media. Neither a review of the literature nor discussions with growers uncovered a "recommended" standard soil mix for succulents, although "well-drained soil" seemed to be the common denominator (2-4, 9-12). Since many succulents and cacti are indigenous to the sandy soils of the desert, well-drained soil has a logical basis.

It is generally accepted that plants under water stress grow less than plants supplied with adequate water. If this is correct, commercial growers should be able to produce larger succulents and in a shorter time by eliminating water stress. This study was undertaken to investigate the effect of 2 different watering regimes on plant growth of jade, a popular ornamental succulent. Since possible nutrient loss could occur through leaching as a result of the watering schedule, 5 nutrient levels were included in the study.

Materials and Methods

Plant material and growth conditions. Terminal cuttings with 2 to 4 leaves were taken from stock jade plants and rooted in moist sand and potted in 10 cm plastic pots filled with a standard potting media (Metro Mix 200, W.R. Grace Co.). At the time of potting the upper pair of mature leaves was notched in order to identify all subsequent growth. Plants were placed in a fiberglass greenhouse on August 23 with temp ranging from $24^{o} - 30^{o}$C (day) and $10^{o} - 21^{o}$ (night).

Experimental design. The 2 × 5 factorial experiment consisted of 10 treatment combination of 2 watering regimes and 5 fertilizer rates with 10 plants per treatment. Treatments were replicated 4 times and randomized within the greenhouse. Water was applied at the rate of 100 to 150 ml per pot at either daily or weekly intervals. The time (0700 hr) and amount of water applied daily was controlled by a 120 v solenoid value. Weekly water was applied by hand at the same rate. Five fertilizer treatments made from distilled water or Peters' nutrient 20:20:20 (20 N:8.6 P:16.6K) containing 0, 50, 100, 200 or 400 ppm N were applied weekly in 100 ml aliquots to designated pots.

After 6 months when some plants had reached a size that their top wt caused the pots to overturn, the plants were harvested. All yield data and samples for assay were taken on growth occurring above the previously notched leaves.

Protein and chlorophyll. Random samples of leaves were taken on Feb. 19 and ground in a mortar in 0.1 M Tris-phosphate buffer pH 7.5 (4:1, vol buffer:fresh wt). Protein was assayed by the Bradford technique (5) and chlorophyll by the Arnon method (1).

Titratable acid. Leaf samples were taken at 0600 hr and at 1730 hr when acidity differences were at their greatest (8). Tissue (10 to 20g fresh wt) was weighed and immersed in boiling water to kill enzyme activity and to disrupt cell integrity. The tissue was ground in a mortar, transferred along with all wash-water to a container and steeped in boiling water for 20 min. Titration to pH 8.5 was with 0.095 N NaOH, and the results expressed in net titratable acid (difference in titratable acid in meq/100g fresh wt between samples taken at 0600 hr and samples taken at 1730 hr).

Results and Discussion

The jade plants watered daily grew well and no plants were lost, contrary to what might be expected based on current growing recommendations. Jade plants growing in the same greenhouse under the standard "water and dry-out" practice did not die but grew very little (data not included).

The relationship among fertilizer rates and water regimes on fresh wt production of tops is shown in Fig. 1. Daily watering produced significantly larger plants ($p < 5\%$) at the higher fertilizer rates (100, 200, and 400 ppm) than weekly watering. When no fertilizer was applied, the daily watering probably leached nutrients out of the soil as significantly smaller plants were produced. Best plant growth in these experiments was produced with daily watering at a fertilizer rate calculated to be 232 ppm N.

The number of leaves per plant was not affected by fertilizer rate in the weekly treatment but daily water at the 200 ppm fertilizer rate produced significantly more leaves (Fig. 2) with the optimum fertilizer rate calculated to be 248 ppm N.

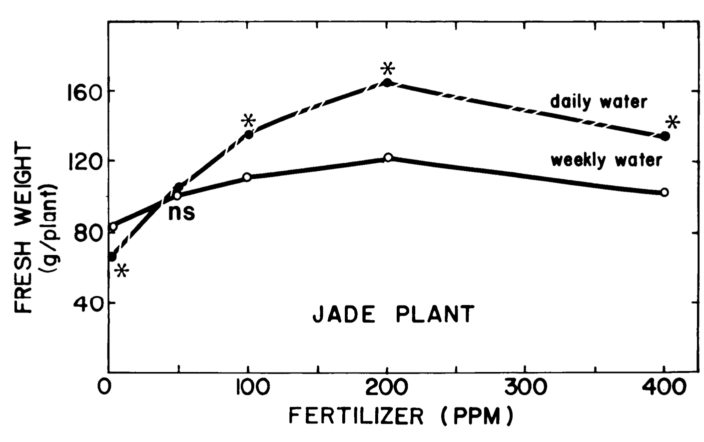

Fig. 1. Fresh wt (g/plant) of jade plants grown 6 months at specified fertilizer and water regimes. Significance (*) or non-significance (ns) at 5% level of probability between water regimes at a given rate of fertilizer application.

[1]Received for publication May 11, 1977.

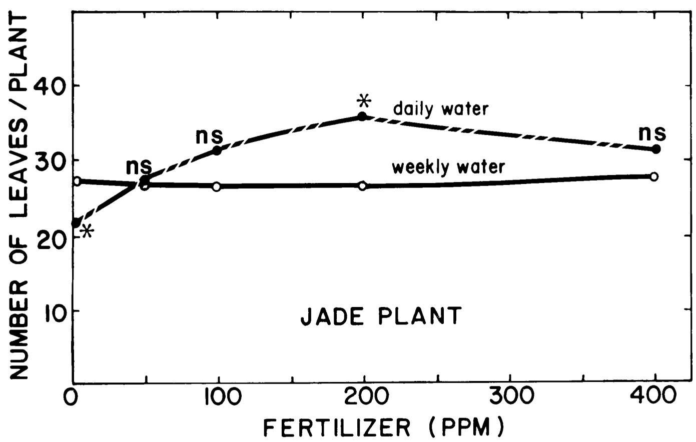

Fig. 2. Number of leaves per jade plant grown 6 months at specified fertilizer and water regimes. Significance (*) or non-significance (ns) at 5% level of probability between water regimes at a given rate of fertilizer application.

The growth response measured as the average wt per leaf versus fertilizer treatment for weekly and daily watering schedules is given in Fig. 3. A test of homogenity reveals that linear and quadratic effects of fertilizer are significantly different at the 1% level with optimum fertilizer rate being 200 ppm N.

The response curves between chlorophyll and protein content and fertilizer are presented in Fig. 4 and 5, respectively. Content of chlorophyll and protein response to fertilizer rate when plants are watered weekly gives highly significant ($p < 1\%$) linear relationships. When plants were watered daily, only chlorophyll content had a significant ($p < 5\%$) linear response to fertilizer rate.

The diurnal fluctuation of titratable acidity in Crassulacean acid metabolism plants is a measure of the rate of metabolic activity (8). This difference between high acid in the morning and low acid in the late afternoon was greatest at the fertilizer rate of 100 ppm in both watering treatments (Fig 6).

Growing jade plants can be improved by changing the generally accepted commercial practice of low fertility and limiting water, to include weekly applications of fertilizer and adequate watering. The exact amount of fertilizer and the time and amount of water to apply for most rapid growth will depend on the soil type or growth media and pot size used in commercial practice. Daily watering in an amount sufficient to completely wet the entire growth media is recommended. Fertilizer at the rate of 100 ml of 250 ppm N from Peters' 20:20:20

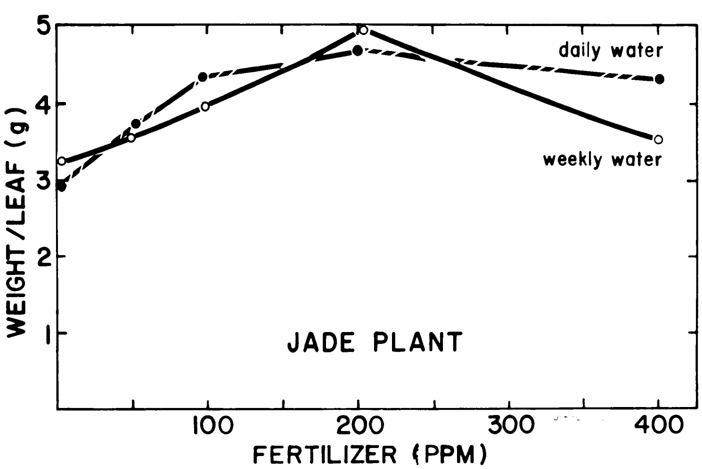

Fig. 3. Weight of jade leaves grown 6 months at specified fertilizer and water regimes.

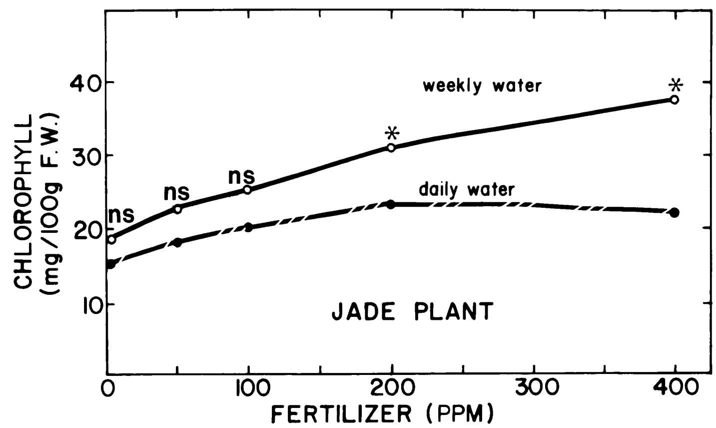

Fig. 4. Chlorphyll content on a fresh wt basis of jade plants grown 6 months at specified fertilizer and water regimes. Significance (*) or non-significance (ns) at 5% level of probability between water regimes at a given rate of fertilizer application.

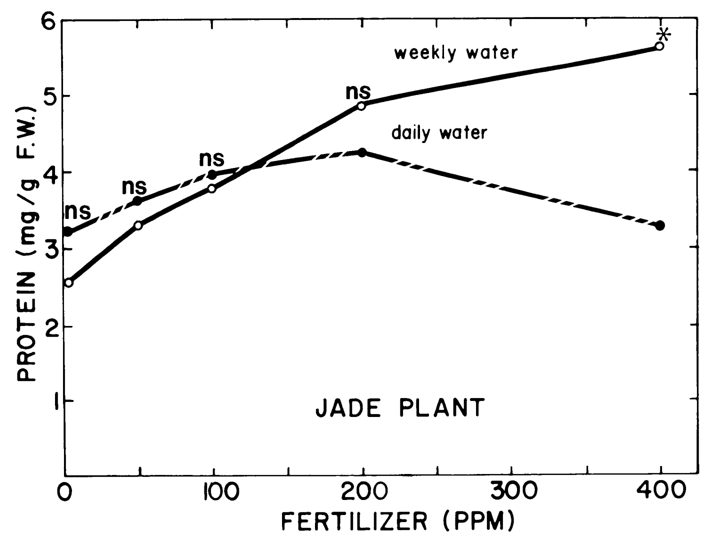

Fig. 5. Protein content on a fresh wt basis of jade plants grown for 6 months at specified fertilizer and water regimes. Significance (*) or non-significance (ns) at 5% level of probability between water regimes at a given rate of fertilizer application.

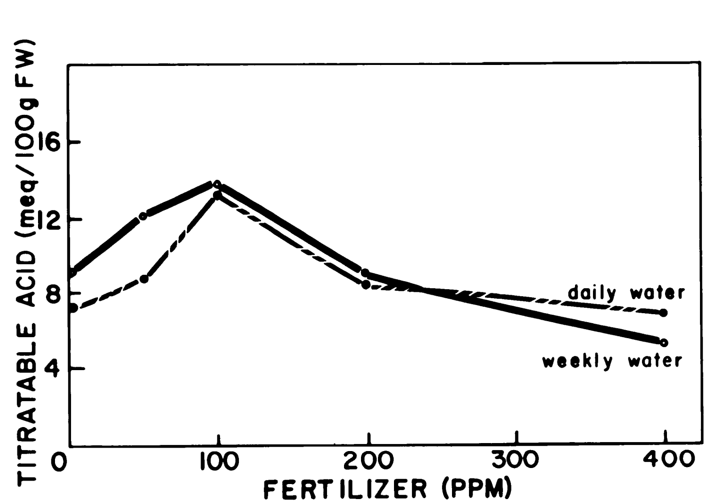

Fig. 6. Difference in diurnal titratable acid (meq/100 g fresh wt) between high acid at dawn and low acid at late afternoon among 5 fertilizer treatments and 2 irrigation schedules.

fertilizer per 10 cm pot per week, is suggested. Commercial growers benefit by daily watering and fertilizer input to maximize plant size and plant quality per unit of greenhouse space. The fertilizer rate of 400 ppm N caused salt burn of the stem at the soil surface. However, caution is needed if one is to extend these results in areas where phytopathological factors are not under control, and for species not studied here. It is also suggested that watering be limited to once a week for a 2 week period prior to sale to increase the plant's disease resistance.

Literature Cited

1. Arnon, D. 1949. Copper enzymes in isolated chloroplasts. Polyphenol oxidase in *Beta vulgaris*. *Plant Physiol.* 29:1-15.
2. Bailey, L. and E. Bailey. 1941. Hortus second: a concise dictionary of gardening and general horticulture. MacMillan, New York, p. 713-715.
3. Baker, J. 1973. Make friends with your house plants. Simon & Schuster, New York.
4. Boarder, A. 1972. Cultural notes. *Cactus & Succ. J. Great Britain* 34(1):5, 6.
5. Bradford, M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem.* 72:248-254.
6. Chidamian, C. 1958. The book of cacti and other succulents. American Garden Guild, Doubleday, Garden City, N. Y., p. 68-72, 139-148, 196-205.
7. Crater, D. 1975. Ornamental timely topics. Univ. of Georgia Coop. Ext. Serv., Athens, Ga.
8. Crews, C. S. Williams, M. Vines, and C. Black. 1975. Changes in the metabolism and physiology of Crassulacean acid metabolism plants grown in controlled environments. *In* Burris and Black (eds.) p. 235-250. *CO_2 metabolism* and *plant productivity*. Univ. Press, Baltimore, Md.
9. Crockett, J. 1972. Foliage house plants. Time Inc., New York, p. 72-79, 122, 293.
10. Doney, V. 1976. Doney do's and don'ts. *Cactus & Succ. J.* (U.S.) 48:25-26.
11. Fitch, C. 1972. The complete book of house plants. Hawthorne Books, New York, p. 33-39, 76, 247-248.
12. Rainbow, A. 1974. The times they are a changing. Cactus & Succ. J. Great Britain 36(1):10-11.

J. Amer. Soc. Hort. Sci. 103(3):308–310. 1978.

Respiration and Ethylene Production in Mammee Apple (*Mammea americana* L.)[1]

Ernest K. Akamine and Theodore Goo
Department of Botany, University of Hawaii, Honolulu, HI 96822

Additional index words. bioassay, climacteric

Abstract. **Gas chromatography and bioassays were used to identify ethylene (C_2H_4) in fruit emanations of mammee apple (*Mammea americana* L.). C_2H_4 production probably triggered the respiratory rise in preclimacteric fruit and its relationship to respiration was typical of that for a climacteric fruit. C_2H_4 production was however, independent of respiration in immature and postclimacteric fruits. C_2H_4 production increased to a peak and then declined with deterioration of fruit in spite of nearly constant rates of respiration in immature fruit and declining rates in postclimacteric fruit. Peak production of C_2H_4, 408 μl per kg per hr, from preclimacteric fruit is probably the highest reported among fruits.**

An unusually high production of what appeared to be C_2H_4 was discovered in the emanations of mammee apple in storage in the course of determining C_2H_4 production in various species of fruits. This paper reports the identification of the gas and its relationship to respiration.

Materials and Methods

Fruits of mammee apple (also known as mamey, apricot of Santo Domingo, etc.) were obtained from a single tree on the grounds of Poamoho Farm, Hawaii Agricultural Experiment Station.

Immature (about 85% developed), preclimacteric, mature and postclimacteric (just past ripe stage), fruit were individually sealed in gas-tight 3,250 ml glass containers for 1 hr at 27.5°C for C_2H_4 identification. One ml samples of the atmosphere surrounding the fruit were withdrawn with gas-tight syringe for gas chromatography analyses with a hydrogen flame ionization unit (Aerograph Hy-Fi 600-D) and alumina column. Emanations of the fruit were also bubbled into $Hg(ClO_3)_2$ solution (0.25 M red mercuric oxide in a 2.0 M perchloric acid) for 1 to 2 hr. The trapped gas after being liberated with 4.0 N LiCl (11) was similarly analyzed for C_2H_4. The gas released was also scrubbed with brominated (23%) activated charcoal (4) and crystals of $KMnO_4$ (7, 9), materials known to be C_2H_4 inactivators, and again tested for C_2H_4. Bioassays were also utilized to verify the presence of C_2H_4 in the fruit emanations. Blossoms of vanda orchid (*Vanda* Miss Agnes Joaquim) and carnations (*Dianthus caryophyllus* L.); young seedlings of soybean [*Glycine max* (L.) Merr.] and papaya (*Carica papaya* L.); excised terminal shoots of weed species (*Amaranthus spinosus* L., *Portulaca oleracea* L., *Euphorbia hirta* L. and *Bidens pilosa* L.); and green fruit of tangerine (*Citrus reticulata* Blanco) were exposed to 50 ml per min streams of air passing through containers with mammee apples for 1 to 3 days.

Immature, preclimacteric, and postclimacteric fruits were tested within 2 hr after harvest. Four or more fruit of each stage of development were used for studies on the relationship between C_2H_4 production and respiration. Each fruit was weighed before sealing in a gas-tight 3,250 ml glass container for CO_2 respiration and C_2H_4 determinations at 27.5°C. Separate 1-ml samples of the atmosphere surrounding each fruit were withdrawn after 1 hr with a gas-tight syringe for gas chromatographic analyses of CO_2 and C_2H_4. A thermal conductivity detector unit (Varian Aerograph 90-F) with a silica gel column was used for CO_2 analysis and the hydrogen flame unit previously described was used for C_2H_4 determination. Sampling was performed at the time the experiments were begun and daily thereafter until the fruit deteriorated, i.e. showed physiological breakdown without decay. Fruit were aerated between samplings with a continuous flow of air bubbled

[1]Received for publication October 4, 1977. Journal Series No. 2192 of the Hawaii Agricultural Experiment Station.