both experiments plants grown on 100% NO$_3$-N tended to be lower in numerical score. At termination of both experiments, all plants were of good commercial quality and would have been salable with color and plant grades averaging 4.2 and 4.0, respectively.

Of tissue elements analyzed in brassaia, only P was influenced by N sources. However, results were variable; the difference between the highest and lowest levels was only 0.05 and did not seem to be related to whether N was derived from NH$_4$ or NO$_3$. Tissue levels of macro- and micro-nutrients were within recommended ranges (10). Unlike results observed on chrysanthemum (3, 11), light intensity appeared to have no effect on whether NH$_4$ or NO$_3$-N produced best growth (6 months data was taken at the end of the lowest light period and 9 months data at the peak of the high light period).

Growth of calathea was strongly influenced by N source, with poorest plant, root and color grades present on plants grown on 100% NO$_3$-N (Table 2). Best plant and color grades at 6 or 9 months were associated with plants that received 100% urea and 75% NH$_4$ and 25% NO$_3$-N. These data are very similar to observations on azalea (2) and blueberries (1) where N sources high in NO$_3$-N reduced growth and foliar color. Appearance of foliage on calathea that received higher NO$_3$-N levels was similar to Fe or Mn deficiency symptoms.

Although results of these experiments are variable, best overall calathea quality was produced where NH$_4$-N or urea-N sources provided 50% or more N, while N source had no effect on schefflera or philodendron. Based on these results it would be hard to substantiate a recommendation for 50% NH$_4$ and 50% NO$_3$ as suggested in the literature (7), especially since fertilizers high in NO$_3$-N are more expensive than NH$_4$-N or urea-based fertilizers.

**Reduced Water Application Rates and Cold Protection of Leatherleaf Fern**

In Florida, approximately 6,000 acres are currently devoted to cut foliage production and leatherleaf fern, *Rumohra adiantiformis* (G. Forst) Ching, accounts for about 80% of the volume shipped. The estimated leatherleaf fern crop value exceeds $43,000,000 at wholesale annually and one-third of the fern is exported to Europe, making it Florida's second highest farm export to the continent (8).

Leatherleaf fern is most commonly grown on well-drained sandy soils under 60-80% shade from polypropylene shade fabric. Visually detectable cold injury of immature fronds usually occurs after exposure to temperatures below 30°F (5). Almost all leatherleaf fern that is freeze protected in Florida is protected by use of overhead sprinkler irrigation, utilizing the latent heat of fusion of water. Freeze protection water application rate recommendations range from 0.3-0.44 inch/hr (3, 5, 6, 7) and appear to be based on recommendations for citrus (2). Dean (1), using conventional impact sprinklers (Rainbird® No. 20-A) with an average rotation rate of 1 rpm, concluded that maintenance of the necessary water-ice interface to protect fern under wooden slat shade, under cold, windy conditions, required 5/32 inch nozzle openings and wetting from at least 2 sprinklers operating.
operating at 45 psi. In that study, the lowest dry bulb temperature was 25°F and wind speeds 3 ft above the slat roof were 5-10 mph. A preliminary study (9) indicated that application rates as low as 0.21 inch/hr applied with rapidly rotating (6 rpm) freeze protection nozzles could successfully protect leatherleaf fern under 73% shade polypropylene fabric down to 11°F when wind conditions were fairly calm.

Reductions in water application rates could decrease soil erosion, incidence of root rots, and leaching of fertilizers and pesticides (3, 6). Leary (6) found that 60% of the ground water pumped in 1 yr in a fernery was for freeze protection. Reduced ground water withdrawals could reduce sinkhole activity and salt water intrusion (5, 7) as well as domestic well service interruptions due to water table drawdowns. This study was initiated to determine whether leatherleaf fern could be freeze protected using reduced water application rates by employing specialized freeze protection sprinklers and nozzles.

Each 100 x 100 ft plot contained 9 30-inch risers on square 30 ft centers in 3x3 configurations. One plot had Rainbird® 20AH sprinklers with 5/32 inch split nozzles on the outermost risers with Rainbird® 20A’s with 1/8 inch nozzles on the 6 interior risers, a common setup in commercial ferneries. Rainbird® L20VH frost protection sprinklers with 3/32 inch CDS™ (controlled droplet size) nozzles were used in the other plot. Water pressure at the nozzles was a constant 40 psi yielding perimeter water application rates of about 0.28 inch/hr and 0.11 inch/hr, and interior rates of 0.34 inch/hr and 0.18 inch/hr for the conventional and frost protection sprinklers, respectively. The plots were adjacent to each other and extended from the western perimeter of the fernery to a roadway in the fernery.

Materials and Methods

Wind speed and temperature data were recorded using an Esterline Angus PD-2064 key programmable data acquisition system. WEATHERtronics Model 2535 anemometers were located outside, 4 ft above ground, and inside 6 ft above ground, a 63% shade polypropylene fabric covered fernery in DeLeon Springs, FL (Fig. 1). A cloth windbreak 4 ft high extended around the outside of the fernery. Thermocouples made from 0.01 inch copper/constantan wire were taped to the top of fronds inside the fernery or supported 4 ft above ground outside the fernery. Temperatures were measured near the perimeter (9 ft from the windbreak) and in the center of each experimental plot (Fig. 1). The perimeter and interior thermocouples received water from 3 and 5 sprinklers, respectively. Additional wet and dry bulb temperatures for dewpoint determinations were taken outside the fernery using a Bendix Model 566 psychrometer.

Results and Discussion

The coldest weather during the 1981-82 winter occurred in mid-January. Winds were out of the west during all periods reported. Air temperatures dropped to 18°F and wind speed reached 16.5 mph outside the fernery on January 11 (Figs. 2, 3). Dewpoint temperatures as low as 2°F were recorded and the dewpoint at 7 AM was 10°F. All wind speeds recorded inside the fernery were 56% or less of those outside and the highest wind speed recorded inside the fernery was 6.8 mph. Neither conventional nor frost protection sprinklers protected immature fronds under these conditions (Figs. 2, 3). After this time, both sprinkler setups maintained temperatures at interior locations above ambient except on 3 occasions, 3:30 AM, 4:30 AM and 5:30 AM for frost protection sprinklers and in the conventionally irrigated plot (Fig. 2). These temperature drops were probably due to evaporation, with the drops in the conventionally irrigated plots being greater because of the relatively slow rotation rate (average = 1.1 rpm) of the conventional sprinklers which allowed more time between wettings than the faster rotating (average = 2.9 rpm) frost protection sprinklers. Perimeter locations had slightly higher tempera-
duced wind speed due to the windbreak and in the conventional plots also due to the larger (5/32 inch) nozzle size. The 2.5 times greater water application rate in the conventional plots effected only modest gains in frond temperature at the lower ambient temperatures and, again, neither setup provided adequate protection for immature fronds. After ice started forming, frond temperatures dropped below ambient near the perimenter in the conventionally irrigated plot.

Both set ups successfully freeze protected fern at interior locations the nights of January 11-12 when winds were calm and minimum recorded air and dewpoint temperatures were 18.7 and 10°F respectively (Fig. 4). The higher application rate at the perimeter of the conventional setup again maintained higher frond temperatures than the reduced rate setup (Fig. 5). The higher application rate kept temperatures above the critical 30°F temperature but the low rate did not. The CDS nozzles had a more ring-shaped and less uniform distribution pattern than the circular pattern of the conventional split nozzles and this reduced their effectiveness along the perimeter. Visual evidence for this was that the only areas where "milky-white" ice without icicles formed, indicating too low application rate (4) was between the outermost frost protection sprinkler risers and the perimeter of the fernery. These were the only areas where severe damage to mature fronds occurred. Clear ice formed everywhere else.

Visual ratings of cold damage to fronds were made January 19, 1982. Comparisons of paired subplots showed no differences between the two setups. In the conventional and frost protection sprinkler setups, 85.6 and 98.9% of mature fronds were undamaged. Comparisons of damage to immature fronds were not made because a 5.5 hr power failure at the test site on January 14 damaged immature fronds but not mature fronds.

Under low wind conditions, conventional application rates (0.34 inch/hr) and reduced rates (0.18 inch/hr) applied using faster rotating frost protection sprinklers protected leatherleaf fern from cold damage. Research has shown that under windborne freeze conditions, other factors remaining constant, increased water application frequencies increase the effectiveness of sprinkling in frost protection (10). Larger orifice nozzles or nozzles that could more evenly distribute the water are beneficial along the perimeter of the fernery, especially when reduced application rates are used. Polypropylene shade fabric reduced wind speeds inside the fernery by about 50% but, even so, both water application setups were equally ineffective in cold protecting immature fronds under low dewpoint, high wind conditions. Reduction of air movement, using windbreaks, ice, polyethylene sheeting or methyl cellulose sprays, would allow reduced water application rates to effectively cold protect leatherleaf fern. Reduced water application setups might require more maintenance due to clogging of the smaller orifices used but such systems would conserve energy and water.

Literature Cited