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Influence of Cobaltous Ion (Co^{2+}) on the Postharvest Behavior of 'Samantha' Roses[1]

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Abstract. **Cut flowers of rose (*Rosa hybrida* L. cv. Samantha) exhibited a longer vase life when opened in solutions containing cobaltous ion (Co^{2+}). The extended vase life in response to Co^{2+} was related to 1) an increased water uptake into the cut flower, 2) an improved water balance during opening, 3) a delay in loss of fresh weight, and 4) a prevention of the occurrence of bent-neck. A concentration of 1.5 mM Co^{2+} gave maximum beneficial effects without injury to the cut flower, while a 2.0 mM concentration induced some toxic symptoms on leaves.**

The short postharvest life of roses is often related to water stress characterized by neck droop and wilting of leaves and flowers (6, 18, 24), incomplete bud opening (6, 24), rapid loss of fresh weight (1), large water deficit (1, 20), and poor maintenance of turgidity (15, 20). The addition of several chemicals to holding solutions, including some of the trace elements, have been tried with varied success in attempts to extend the vase life of cut roses (13, 20, 23).

In a recent note (17), we reported that $Co(NO_3)_2$ unexpectedly prevented the occurrence of bent-neck in roses perhaps by increasing water uptake by stems. In the present work we will show that cobaltous ion (Co^{2+}) is the effective species. Application of Co^{2+} has been shown to increase water retention by leaves of melon (2) and tomato (5). We will also show that an overall improvement in plant-water relations in response to Co^{2+} is responsible for an extension of vase life, the prevention of bent-neck, and an increase in flower fresh weight.

Materials and Methods

Cultural practices, harvesting procedures and preparation of stems for bud opening were as described previously (17). After recording fresh weight, each flower was placed into a graduated cylinder containing 250 ml of deionized water or aqueous solutions of 0.5, 1.0, 1.5 and 2.0 mM cobalt-acetate, -chloride, -nitrate or -sulphate. Each treatment consisted of a minimum of 6 flowers, with each flower representing a replication. The buds were opened at 21 ± 1°C and 60 ± 5% relative humidity with a light intensity of 30 W m^{-2} at the top of the flowers.

At fixed times the weight of each cylinder plus solution with and without the flower was determined as were solution level in the cylinder, vase life, appearance of bent-neck and other visible conditions of the flowers. Appearance of bent-neck, wilting of outer petals, or bluing of the petals was considered to be the end of the useful vase life of the flower.

The difference between consecutive measurements of the cylinder + solution (without the flower) represents the water uptake, while the difference between consecutive measurements of cylinder + solution + flower represents the transpirational loss of water. The difference between the weight of cylinder + solution + flower and the weight of cylinder + solution represents the fresh weight of the flower on that particular day.

Evaporation of water from the surface of the solutions was insignificant and amounted to 0.5 – 0.75 ml/day. Therefore, no correction factor for evaporative water loss was made nor were precautions taken to control such losses. Previous studies on water uptake of cut roses have indicated that evaporative water loss under similar experimental conditions was negligible (12).

Results

Water uptake and water loss. The type of Co^{2+} salt had no significant influence on total water uptake, total water loss and water loss/water uptake ratio. However, total water uptake, total water loss and water loss/water uptake ratio were significantly affected by the concentration of Co^{2+} salt (Table 1). All concentrations of Co^{2+}, except the 1.0 mM level, significantly increased water uptake and water loss over the control. Although loss of water was increased as a result of Co^{2+} treatment, the water loss/water uptake ratio was significantly lowered by all the concentrations of Co^{2+} when compared to the water control.

A significant positive linear correlation was found between Co^{2+} concentration and total water uptake and total water loss. However, the water loss/water uptake ratio exhibited a curvelinear response to Co^{2+} (Fig. 1). Up to 1.0 mM Co^{2+} a significant linear decrease in water loss/water uptake ratio occurred in proportion to the increase in Co^{2+} while between 1.0 to 2.0 mM Co^{2+} the change was not significant nor linear. Nevertheless, the water loss/water uptake ratio at 1.5 mM Co^{2+} was significantly different from that of 0 and 0.5 mM Co^{2+} whereas 1.0 and 2.0 mM Co^{2+} were significant only from the control (Table 1).

Water balance. The daily water balance (water uptake minus transpirational loss of water) of cut roses was affected by Co^{2+} (Fig. 2). The water balance rapidly dropped to a negative value in flowers placed in deionized water between the second and third day, while a positive water balance was maintained for at least 4 days in flowers placed in Co^{2+} solutions, indicating that water retention was enhanced by Co^{2+}. There was no significant effect of Co^{2+} source on the water balance of cut rose flowers.

Table 1. Effect of Co^{2+} on total water uptake, total water loss and water loss/water uptake ratio in cut 'Samantha' roses.

Co^{2+} concentration (mM)	Total water uptake in 8 days (g/flower)	Total water loss in 8 days (g/flower)	Water loss/ water uptake ratio
0	82.7 b[zy]	83.2 c	1.015 a
0.5	95.6 a	95.4 a	0.991 b
1.0	85.3 b	84.0 bc	0.981 bc
1.5	96.6 a	94.3 ab	0.975 c
2.0	96.3 a	95.3 a	0.984 bc

[z]Mean separation within columns by Duncan's multiple range test, 5% level.
[y]Values for each concentration are means of all salts of cobalt.

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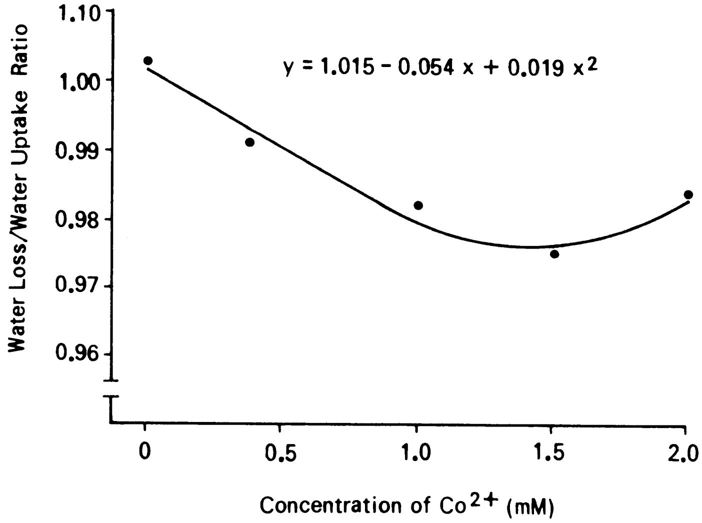

Fig. 1. Regression curve of data from Table 1 for effect of Co^{2+} concentration on water loss/water uptake ratio of 'Samantha' roses.

Fresh weight. There was no significant effect of Co^{2+} source on the fresh weight of the flower. However, the fresh weight was significantly affected by the concentration of Co^{2+} (Fig. 3). On any one day the fresh weight of the cut flower was less in deionized water than in Co^{2+} solution. Among the different

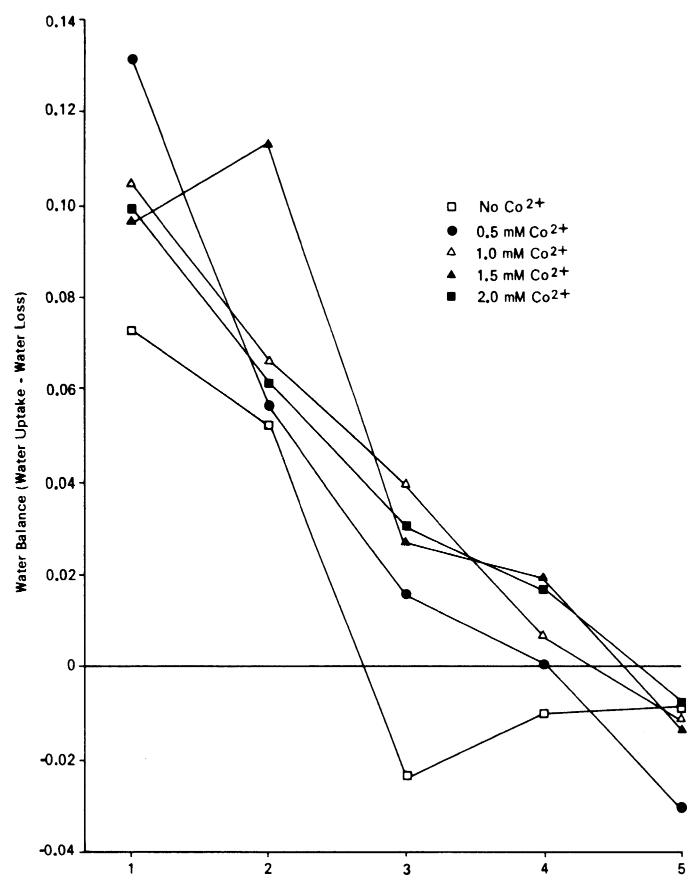

Fig. 2. Effect of Co^{2+} concentration on water balance of cut 'Samantha' roses.

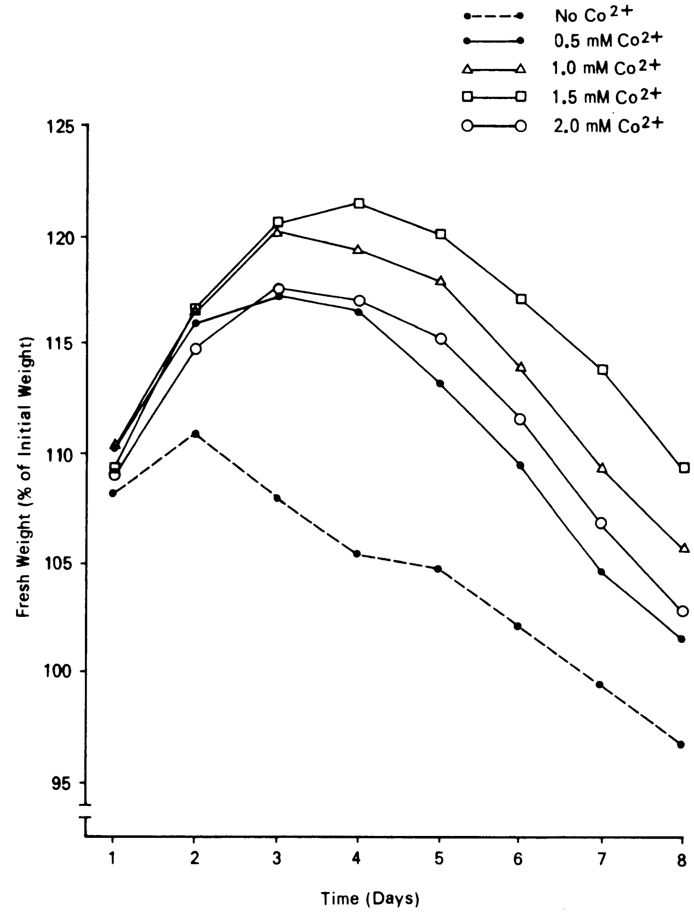

Fig. 3. Effect of Co^{2+} concentration on the fresh weight of cut 'Samantha' roses.

concentrations of Co^{2+}, the lowest fresh weights occurred in the 0.5 and 2.0 mM solutions. In general, the fresh weight of flowers held in Co^{2+} increased by 17-21% during the first 4 days, then decreased at a rate comparable to the control. Flower fresh weight increased slightly in the water control during the first 2 days and decreased to a value below the initial weight by the 7th day (Fig. 3). Fresh weight of flowers in Co^{2+} always remained higher than initial fresh weight.

Vase life and bent-neck. The source of Co^{2+} did not significantly affect the vase life, % bent-neck, or time to appearance of bent-neck. However, the concentration of Co^{2+} significantly affected bent-neck and, hence, vase life (Table 2). The mean

Table 2. Effect of Co^{2+} on vase life, time to appearance of bent-neck and percent bent-neck in cut 'Samantha' roses.

Co^{2+} concn (mM)	Vase life (days)	Bent-neck (%)	Time to bent-neck (days)
0	5.0 c[zy]	92.3 a	5.3 d
0.5	8.3 b	88.1 a	8.1 c
1.0	9.8 a	53.4 b	9.8 b
1.5	10.5 a	18.2 c	11.3 a
2.0	9.6 a	25.9 c	11.0 ab

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

[y]Values for each concentration are means of all salts of cobalt.

vase life for flowers held in water was 5 days and all concentrations of Co^{2+} increased vase life by about 1.5 to 2-fold. Among the various concentrations of Co^{2+}, flowers in 0.5 mM Co^{2+} exhibited the shortest vase life, the greatest occurrence of bent-neck and the shortest time to appearance of bent-neck. Bent-neck appeared as early as the 3rd day in deionized water, whereas in Co^{2+} treatments bent-neck appeared between day 8 and day 11.

At a 2.0 mM cobalt salt concentration slight toxicity in the form of a red-brown pigmentation on the lower leaves was noted. The red-brown pigmentation of the leaves was similar to that reported for white bean in response to excess cobalt and other trace elements (19).

Discussion

Water balance is recognized as a major factor affecting the quality and longevity of cut roses (1, 15, 20). Water deficit has a direct effect on turgor of cut flowers and will accelerate their senescence (8). In the present study it has been demonstrated that Co^{2+} not only effectively increased water uptake but also increased transpirational water loss. Although the total quantity of water uptake and water loss was greater in Co^{2+} treatments, a significant decrease in the water loss/water uptake ratio indicated improved water retention by those cut flowers treated with Co^{2+}.

One of the major requirements for an increased vase life of cut flowers is that water uptake should take place unhindered (1). Some workers regard stem blockage as the major cause of water deficit and wilting of cut flowers (13, 20) and it has been reported that water flow through the stem is inversely correlated with microbial growth at the stem base (10). Since Co^{2+} increased water uptake of cut 'Samantha' roses, Co^{2+} might act to inhibit vascular blockage by suppressing microbial growth as shown with tomato (16).

A striking effect of Co^{2+} was a delay in the decline of fresh weight of cut roses. The time the fresh weight of the cut rose was equal to or greater than its initial weight was also increased and was found to be associated with a reduced water loss/water uptake ratio, an increased total water uptake, an extension of vase life, and a delay in time to occurrence of bent-neck. Similar observations of an association of fresh weight with vase life of cut roses have been reported (21).

One of the most important effects of Co^{2+} was a significant reduction in the occurrence of bent-neck in cut roses. A similar prevention of bent-neck by cobalt nitrate has been reported (17). In the present work we found a close relationship of bent-neck to water loss/water uptake ratio indicating an association of bent-neck with poor water relations.

As a consequence of the changes in water balance shown in the present study, possible changes in abscisic acid (ABA) content and its role in senescence of cut roses cannot be overruled. A deterioration in the water balance of plant organs leads to a rise in endogenous ABA content, but when water balance improves ABA levels fall (3). The role attributed to ABA in rose petals is that of regulating the process of senescence (4, 8, 14). Since rose flowers in water developed a negative water balance as early as the 2nd or 3rd day and flowers in Co^{2+} solutions developed a negative water balance only on or after the 5th day, the improved water balance of flowers held in Co^{2+} solutions may have prevented an increase in endogenous ABA levels and, thereby delayed senescence. Furthermore, cobalt is a known inhibitor of ethylene synthesis (7, 9, 11, 22). Significant amounts of ethylene are produced by rose petals 48-72 hr after cutting and this increase in ethylene production was shown to stimulate synthesis of an ABA-like inhibitor (14). It is possible then, that Co^{2+} exerts a dual effect in delaying senescence of cut roses: first, by improving water balance and preventing a water stress-induced increase in ABA, and second, through an inhibition of ethylene-induced changes in ABA levels.

The observed similarity of effect for all cobalt salts suggests that Co^{2+} is the active species which influences the postharvest behavior of cut flowers. This is further supported by unpublished work with carnations (D. P. Murr and D. Shoemaker), in which equimolar concentrations of salts such as KCl, KNO_3, K_2SO_4, and NH_4NO_3 were no more effective than deionized water and were much less effective than cobalt salts in prolonging shelf life and maintaining good water balance.

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Some Influences of Potassium Nutrition on Growth and Quality of 'Tifgreen' Bermudagrass[1]

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Abstract. **The effect of 9 potassium (KCl) treatments were compared in 1974, 1975 and 1977 on a United States Golf Association (USGA) golf green planted with 'Tifgreen' Bermudagrass** *(Cynodon dactylon* **(L.) Pers. x** *C. transvaalensis).* **The rate of applied K or number of applications had no significant influence on turfgrass quality, yield, or foliar N or P concentration. Plots receiving a single application of 0.5 kg of available K_2O per 100 m^2 exhibited lowest quality while those on which a total of 9.0 kg of K_2O was applied in 3 applications had maximum evaluation scores. Foliar K levels were also lowest and highest in these treatments, as were the amounts of extractable K in the medium. Yearly variations in rainfall influenced turfgrass quality, yield, foliar N and K concentrations, and level of extractable K. Turf quality and foliar N levels were positively associated.**

A soil analysis survey of 1150 Louisiana golf greens (1973 to 1977) (0-15 cm deep) showed that 91% contained from 25 to 200 ppm of extractable K[4]; 63% of the samples had 25 to 100 ppm of K, while 7% exceeded 200 ppm, and 23% ranged from 100 to 200 ppm. The pH of 60% of the greens was 6.5 or lower, with extractable Ca[4] varying from 250 to 1500 ppm in 75% of the samples and over 2000 ppm in 15% of the samples. Extractable P[5] levels varied from 100 to 400 ppm in 52% of the greens, with 33% higher than 400 ppm. Extractable Mg[4] in 70% of the soils varied from 51 to 400 ppm, with 15% above and 15% below these concentrations (4).

Relatively large amounts of K are required for increased root, stolon, and rhizome development in turfgrasses, and heat, cold, wear, and drought tolerance are influenced by K levels in the plant (1, 3, 9, 11, 14, 15, 16). K sources, rates, and frequencies of application affect turf quality (5, 6, 8). Foliar analysis has been used to diagnose the nutrient status of a turfgrass (10, 13, 15).

The large proportion of sand required in proper construction of putting greens, along with the high moisture requirements of turfgrass with a limited root system results in considerable K loss from leaching during the long growing season. Thus, the efficiency of utilization of applied K is thought to be relatively low. This research was designed to study these problems on a 'Tifgreen' Bermudagrass golf green in a warm, high rainfall environment.

Materials and Methods

Two golf greens, each 69.7 m^2, were constructed at Baton Rouge in 1973, following USGA specifications (7). Materials used and procedures followed have been previously described (2).

Financial limitations somewhat restricted the size of each green. Therefore, provisions were made to eliminate possible experimental error resulting from this source. Nine plots 0.9 m wide and 4.6 m long (4.2 m^2) each were constructed per replication, with 4 replications of treatments provided. Plots were separated by 20 cm wide borders, and fiberglass dividers placed between them to a depth of 30 cm. Turfgrass between plots was killed regularly by the application of a contact herbicide to prevent growth from one plot to another. Replications were also separated from one another by fiberglass dividers. Shoulders of the greens were composed of topsoil alone (Cascilla silt loam) and planted to the same turfgrass cultivar as the greens.

The pH of the mixed medium was adjusted from 4.9 to between 6.5 and 7.0 by the addition of agricultural lime (100 mesh) during 1973 and maintained in that range. Analyses of the medium showed 14 and 15 ppm of extractable P and K, respectively. Consequently, a pre-plant starter fertilizer was applied at the rate of 2.5 kg of available P_2O_5 (single superphosphate), 2.5 kg of available K_2O (potassium chloride) and 1.0 kg of N (ammonium nitrate) per 100 m^2 one month prior to planting and incorporated into the medium to a depth of about 10 cm. Plots were planted with 'Tifgreen' Bermudagrass in September 1973 by sprigging at the rate of 0.2 m^3 per 100 m^2.

Growing medium samples were taken periodically to monitor nutrient levels. Elements other than K were applied as necessary to maintain extractable P, Ca, and Mg at about 200, 1200, and 100 ppm, respectively. N was applied from NH_4NO_3 at the rate of 1 kg per 100 m^2 monthly from April to September. Ryegrass was overseeded in November each year. N (1.0 kg) per 100 m^2 was applied by-monthly during the winter from isobutylidene diurea (IBDU). Although rainfall fluctuated considerably, about 5.1 cm of moisture per week was provided during the growing season by rainfall supplemented with a controller-operated underground irrigation system.

K treatments (KCl) were applied initially in 1974. The same source, rates and frequencies were continued from May to October in 1975 and 1977 (Table 1). The turfgrass was cut

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[3]The authors thank Kenneth L. Koonce for statistical analyses.

[4]Extracted with 1 N NH_4OAc buffered at pH 7.0 at a soil extractant ratio of 1:20.

[5]Extracted with 0.1 N HCl + 0.03 N NH_4F at a soil to extractant ratio of 1:20.