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HORTSCIENCE 19(5): 705–707. 1984.

The Influence of Chlormequat and Daminozide on Net Photosynthesis, Transpiration, and Photorespiration of Hybrid Geranium

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Additional index words. *Pelargonium* ×*hortorum*, gas exchange, cycocel, B-nine, growth regulators

Abstract. **Foliar application of 0.3% CCC applied to geranium (*Pelargonium* ×*hortorum* Bailey) resulted in increased net photosynthesis (Pn), transpiration (Tr), chlorophyll concentration, and reduced photorespiration as measured by post lower illumination CO_2 burst (PLIB) compared with plants treated with 0.5% SADH. Pn and Tr rates were enhanced beginning 2 to 3 days after the CCC treatment compared with control plants and remained elevated for a least 4 to 5 more days.**

Growth regulators are used for the control of height in the production of hybrid geranium. Three of the major growth regulators used commercially in floriculture are succinic acid, 2-2 dimethylhydrozide (SADH, B-nine, alar, daminozide), 2 chloroethyl trimethylammonium chloride (CCC, chlormequat, cycocel), and α cyclopropyl-α-(4-methyoxyphenyl)-5-pyrimidine-methanol (A-rest, ancymidol). Ancymidol and CCC restricted internode elongation and overall height in many cultivars of hybrid geranium (1, 10, 13); however, CCC is less costly than ancymidol and is normally recommended for height control (4). One of the responses of hybrid geranium to foliar application of CCC is accelerated flowering (1, 8, 10) compared with control plants. Miranda (10) found that flowering was accelerated regardless of the number of applications, or the time of application of CCC.

Work with hybrid geranium has shown that time to 1st flower anthesis was correlated with the area of the 1st 6 to 8 leaves (3), and that high light intensity accelerated flower initiation (1, 12). The influence of light intensity on flowering time is thought to be correlated to increased carbon fixation, and this fixation might result in rapid initiation (2). Jensen (9) reported that CCC accelerated flowering in hybrid geranium by reducing the light requirement for flower initiation.

Ferree and Hall (6) found that a single application of SADH had no measurable influence on photosynthesis or transpiration of apples leaves. Halfacre et al. (7) reported that SADH treatment resulted in decreased photosynthesis rates.

The object of this research was to determine the influence of CCC and SADH on photosynthesis, transpiration and photorespiration in hybrid geranium 'Sprinter Scarlet'.

'Sprinter Scarlet' plants were grown in a glass greenhouse at 21 ± 3°C night and 28 ± 5° day temperature. Plants were grown in 1 peat: 1 vermiculite (v/v) medium and were watered to saturation with 200 ppm N of 15N–7P–12.5K at each irrigation. Soil was leached every 4th to 5th irrigation with tap water to reduce soluble salt accumulation. Plants were grown for 9, 10, or 11 weeks (1st, 2nd, and 3rd experiments) in the greenhouse prior to application of growth regulators. At that time, 5 plants in each treatment were sprayed to run off with 5000 ppm SADH, 3000 ppm CCC, or distilled water (control). First measurements were made as

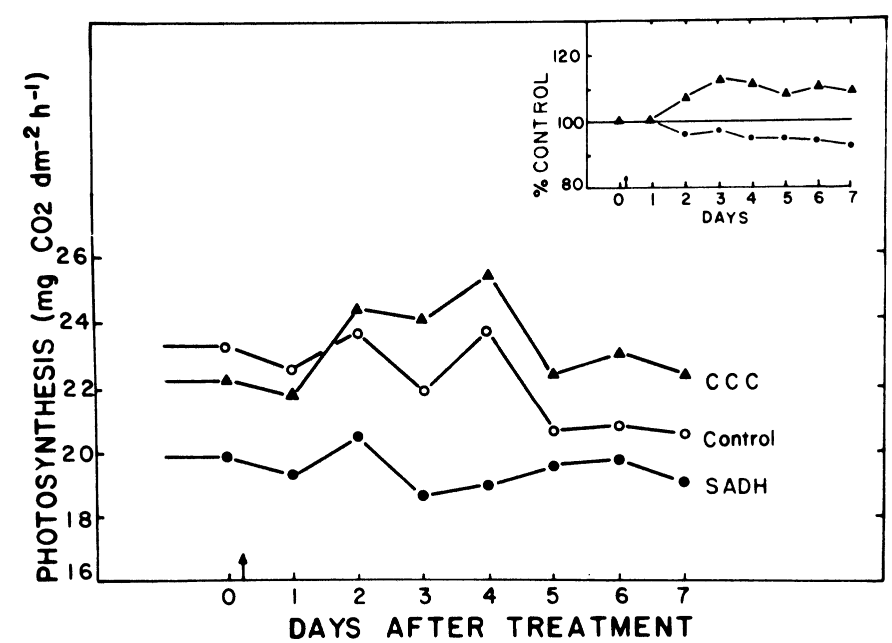

Fig. 1. The influence of CCC and SADH on net photosynthesis of 'Sprinter Scarlet'. Treatments were applied where arrow indicates.

Received for publication 3 Feb. 1984. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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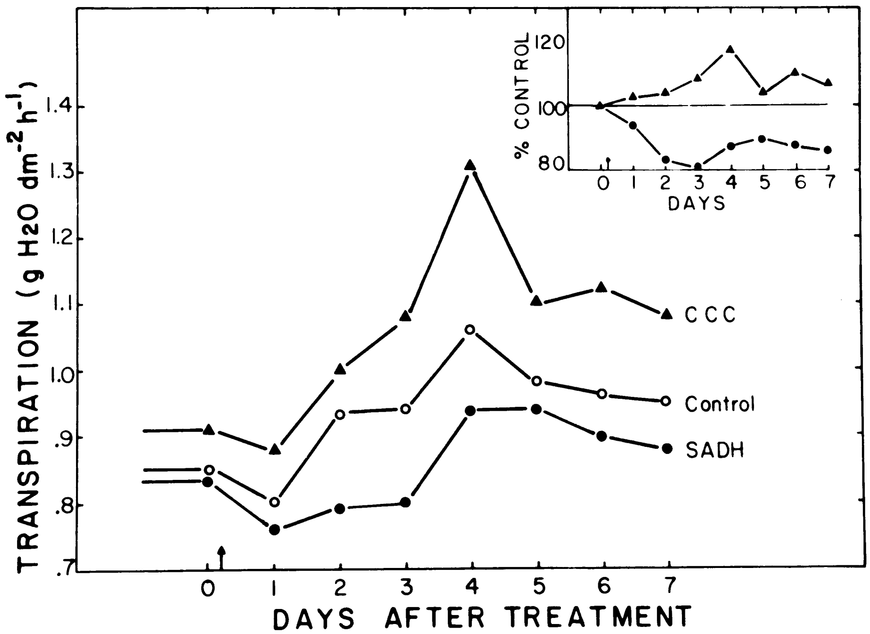

Fig. 2. The influence of CCC and SADH on transpiration of 'Sprinter Scarlet'. Treatments were applied where arrow indicates.

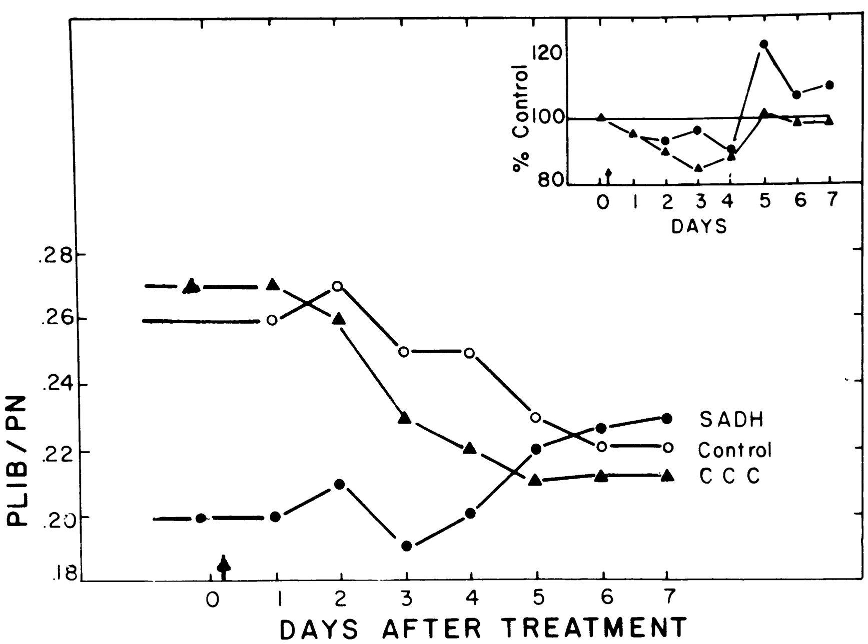

Fig. 3. The influence of CCC and SADH on post lower illumination CO_2 burst of 'Sprinter Scarlet'. Treatments were applied where arrow indicates.

soon as leaves were dry. To attempt to have all sample leaves in each of the 3 experiments at the approximate same physiological age, a fully expanded newly matured leaf in each plant was marked to be used for daily net photosynthesis (Pn), transpiration (Tr), and post lower illumination CO_2 burst (PLIB) measurements. All measurements were made at 25° ± 1°C and 600 ± 10 μmol $s^{-1}m^{-2}$ in the morning for 7 consecutive days using a flow through system with 320 μl l^{-1} CO_2 and 21% O_2. The system consisted of 2 identical round leaf chambers each fitted with air circulating fans, copper/constantan thermocouples, quantum sensor (LI-COR 190SB), and cooled with a temperature controlled water bath. The irradiation source was 400W metal halide high intensity discharge lamps. Rate of gas flow from premixed pressure tanks was controlled with rotameters (Matheson), and humidity was controlled by directing dry air through a humidity chamber. Transpiration was measured by the difference in dew point (EG + G hygrometer, model 880) before and after passing over the leaf. The CO_2 concentration was measured to an accuracy of 1 μl l^{-1} using a Beckman infrared non-dispersion CO_2 analyzer model 865 fitted with a water vapor filter. Leaf area was measured with a Lambda LI-3000 leaf area meter. When not being measured, the plants were placed in environment controlled chambers at 350 ± 20 μmol $s^{-1}m^{-2}$ quantum flux density provided by fluorecent and incandescent source (80:20). A 17°/21° ± 2° night/day temperature and 16 hr photoperiod were maintained.

Four 7 mm diameter leaf disks were used for chlorphyll determination from each of the sample leaves immediately after the last gas exchange measurement. Chlorophyll content was assayed according to the method of Moran and Porath (11). The experiment was repeated 3 times and data given are the means of the 3 experiments.

Net photosynthesis. Plants treated with CCC exhibited increased Pn on the 2nd day after treatment compared to day 0 (Fig. 1). Pn of CCC treated plants remained elevated for at least 5 more days, and Pn of plants treated with SADH decreased on day 3 and remained rather constant throughout the experiment. Pn of control plants exhibited random changes throughout the experiment but decreased slowly below the original rate.

Plants were selected randomly for the various treatments, but the Pn values prior to application were not the same (Fig. 1). When Pn values of control plants were normalized to 100% each day, the Pn of treated plants were calculated based on their relative differences from control (Fig. 1-inset). CCC treated plants had Pn values from 109% to 120% compared with control plants (100%) throughout the whole experiment, whereas Pn of SADH treated plants were 93% to 97% at the control (Fig. 1-inset). The decrease in Pn associated with SADH application is similar to that found by Halfacre et al. (7) with apples.

Some of the differences in Pn associated with the growth regulator treatments may be explained by changes in chlorophyll levels (Table 1). Plants treated with CCC had an increased chlorophyll content, and leaves seemed greener than those from the SADH treatment. These results are similar to those of Semeniuk and Taylor (13). Cathy and Marth (5) found the same effect due to treatment with another trimethylammonium chloride, Amo-1618. The reason for the decrease in chlorophyll levels with SADH applications is not clear. These data may partially explain the reduction in Pn associated with the SADH treatment.

Transpiration. Transpiration was affected in a manner similar to Pn (Fig. 2). Transpiration in all plants exhibited a tendency to increase from day 0 to day 7, but Tr rates were consistently higher in the CCC treated plants compared with either control of SADH treated plants. When daily fluctuations in Tr of control plants were accounted for, Tr of CCC treated plants were 2% to 18% greater than the control plants, and SADH treated plants were 5% to 19% less (Fig. 2-inset). The growth regulators may be influencing Pn and Tr by regulating stomatal opening.

PLIB/Pn ratio. The ratio of PLIB (14, 15) to Pn in many C_3 plants has been reported to be between 5% to 34% (14). The PLIB/Pn ratio in this study ranged from 20% to 27% for all plants prior to treatment (Day 0) (Fig. 3). In general, the daily trend for CCC treated plants was similar to control plants. SADH treated plants, however, showed higher PLIB/Pn rates compared with the other treat-

Table 1. Chlorophyll concentration in leaves of geranium 'Sprinter Scarlet' 7 days after treatment with growth regulators.

Treatment	Chl a	Chl b	Total Chl
CCC	3.73 a[z]	1.06 a	4.80 a
Control	3.33 ab	0.92 ab	4.25 ab
SADH	3.11 b	0.83 b	3.94 b

[z]Numbers followed by the same letter are not significant at the 5% level (Duncan's multiple range test).

ments (Fig. 3). When daily fluctuations in control plants were accounted for, CCC treated plants ranged from 83% to 101% compared with control plants, whereas SADH treated plants were lower than control for the 1st 4 days (93% to 95% of control) but rose dramatically after the 4th day and remained elevated (121% to 108% of control) for the next 3 days (Fig. 3-inset). A high PLIB/Pn ratio can be well correlated with high photorespiratory rates (14, 15). In general, CCC treated plants exhibited lower rates of photorespiration compared with control and SADH treated plants.

The data from this work may be summarized in the following manner: 1) Pn and Tr of hybrid geranium leaves were enhanced 2 to 3 days after treatment with CCC and remained elevated for at least 4 to 5 more days; 2) Treatment with SADH resulted in either the same or lower values of Pn and Tr when compared with control plants; 3) Treatment with CCC elevated chlorophyll content compared with SADH treatment; and 4) Treatment with CCC was beneficial in lowering PLIB/Pn ratio compared with control or SADH treatment.

Although there were definite physiological differences in plants compared to the control, these data do not entirely explain the reduction in flowering time associated with CCC applications. There are likely a number of mechanisms associated with the CCC mediated reduction in flowering time, such as its influence as an anti-gibberellin. Experiments are now underway to investigate this avenue of research.

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