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Effect of Reflective Film Mulching on Leaf Temperature and Nutrient Absorption in Carnation

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Abstract

We examined in the paper the interaction between carnation growth and air and soil temperatures to clarify the effect of the combination of reflective film mulching (RFM) and shading treatments on carnation growth. Dry weight and nutrient absorption of carnation were influenced more strongly by the air temperature than by the soil temperature, although favorable effect of cooler soil was noticed when the air temperature increased. RFM effect on the lowering of the soil temperature may contribute to higher nutrient absorption. Combination of RFM and shading treatments reduced the leaf temperature by 5.3°C compared with the untreated plot. The response was enhanced by the increase of the air temperature. The treatments also reduced the soil temperature in the daytime although the response was less evident than that to the increase of the air temperature. As shown above, since RFM and the shading treatments reduced the air and soil temperature, they alleviated high temperature stress in carnation plants and activated nutrient uptake, resulting in a larger plant size.

Discipline: Horticulture
Additional key words: high temperature, soil temperature

Introduction

The optimum temperature for carnation growth was reported to range from 15 to 20°C[1,9,11]. However, when carnation grows in warmer areas as in southwestern Japan, the temperature during the summer season is high. Since the temperature inside the greenhouse sometimes exceeds 40°C, carnation is exposed to heat stress. We reported previously that the application of shading treatment for cooling combined with RMF was effective[10]. The treatments promoted vegetative growth under high temperature, and subsequently induced early flowering and also yields higher by 15% compared with the plot without mulching and shading. The treatments reduced soil and air temperatures and increased the amount of solar radiation in the middle to lower parts of the plants where leaves are closely located. In this paper, we analyzed the effect of the combination of RFM and shading treatments on nutrient absorption and leaf temperature.

Materials and methods

Exp. 1: Single and interactive effects of air and soil temperatures on dry weight, nutrient absorption and root activity of carnation

Potted seedlings of cvs. Scania and Kibou no Hikari were pinched at the 5th node, then transferred into a greenhouse with 6 identical compartments. Combinations of 2 air temperature regimes and 3 soil temperature regimes were examined. Air temperature regimes were as follows: 1) air temperature was set at 30°C and ranged from 37 to 23°C and 2) temperature was set at 20°C and ranged from 23 to 17°C. Soil temperature regimes were as follows: 1) 30°C, 2) 25°C and 3) 20°C. Plant height, primary branch length, number of secondary branches, number of unfolded leaf pairs and percen-

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tage of seedlings at visible bud stage were determined 11 weeks after the treatment. After 11 weeks of the temperature treatment, seedlings were separated into leaves, stems and roots, and their dry weight, inorganic nutrient contents (N, P, K, Ca and Mg) and root activity were determined. Content of inorganic nutrients was determined by the Kjeldahl method (N), colorimetry according to the Truog-Meyer method (P) and atomic absorption spectrophotometry (K, Mg and Ca). Root activity was expressed by the reducing power of triphenyl tetrazolium chloride (TTC), measured by colorimetry.

Exp. 2: Effect of RFM combined with shading using diffusive material and soil temperature on leaf temperature

The seedlings of cv. Nora were planted on July 1, 1993 on a bench in a greenhouse at the rate of 36.5 plants·m^{-2} (1.2 m^2 for 1 plot), then pinched at the 4th node. The bench which was 0.9 m wide and 4.0 m long, was divided into 3 individual compartments with an insulation material. Ten uniform plants per plot in which the number of unfolded leaf pairs ranged from 6 to 8 were selected. Average plant height was 27 cm. The uppermost leaf pair that made an angle of more than 60° with the stem was used for the measurements, which were conducted on the clear days of August 12 (Exp. 2-1) and August 16 (Exp. 2-2). Leaf temperature was measured with an infrared thermometer (Minolta) and 1 measurement took 15 min. Air temperature, soil temperature and solar radiation (photosynthesis photon flux density, PPFD) were recorded in the middle of the measurement of the leaf temperature (7.5 min). PPFD was measured with a portable spectroradiometric research system (Li-1800, LI-COR). Exp. 2-1 was conducted using the seedlings of the following 2 plots: 1) plot with mulching and shading (RFM + S) and 2) plot without mulching and shading (untreated plot). In neither of the plots was the soil temperature controlled. Sixteen measurements were performed from 8:00 to 18:00 on August 12. Exp. 2-2 was conducted using the seedlings of the following 3 plots: 1) plot with mulching, shading, and soil temperature set at 20°C (RFM + S + SC), 2) plot with mulching and shading without soil temperature control (RFM + S) and 3) plot without mulching, shading and soil temperature control (untreated plot). Measurements were conducted 10 times from 10:00 to 17:00 on August 16. The reflective film used for mulching was Neo Poly-Shine (Hitachi Condenser), and the shading material used was SunRich whose high diffusiveness was reported in the previous paper[10]. Soil cooling was achieved by running refrigerated water through pipes buried in soil.

Results

Exp. 1: Single and interactive effects of air and soil temperatures on dry weight, nutrient absorption and root activity of carnation

Table 1. Single and interactive effects of air and soil temperatures on the development and growth of carnation cvs. Scania and Kibou no Hikari

Cultivar	Temperature (°C)		Plant height (cm)	Primary branch length (cm)	Leaf number[a)]	Rate of flowering[b)] (%)	Dry weight (g/plant)				
							Leaf		Stem	Flower	Root
	Air	Soil					Green	Died			
Scania	30	30	38.0	19.0	9.9	0	4.47	0.41	1.52	0	0.75
	30	25	39.2	22.5	10.7	0	4.58	0.58	1.67	0	0.84
	30	20	46.2	28.6	11.8	0	5.58	0.37	1.96	0	0.74
	20	30	72.0	37.9	11.7	14.3	6.02	0.05	4.01	0.45	1.21
	20	25	73.8	41.3	12.6	15.4	7.91	0.20	4.60	0.30	1.77
	20	20	82.2	52.1	14.0	29.2	8.17	0.17	6.08	1.11	1.20
Kibou no Hikari	30	30	31.4	16.6	9.4	0	2.50	0.14	1.09	0	0.58
	30	25	34.5	20.2	10.9	0	2.67	0.28	0.97	0	0.57
	30	20	39.5	25.2	12.0	0	4.15	0.07	1.55	0	0.81
	20	30	75.2	48.3	12.5	65.0	4.85	0.16	4.25	1.17	1.00
	20	25	79.2	49.3	12.4	31.3	4.66	0.07	3.72	1.22	0.98
	20	20	85.3	55.4	12.5	46.0	6.68	0.08	5.61	1.54	1.08

Measurements were conducted 11 weeks after treatment.
a): Averaged values of primary branches.
b): Rates of flowering of primary branches to the total number of primary branches.

The growth of carnation under the higher air temperature and/or soil temperature regimes was suppressed after 11 weeks of treatment (Table 1). Higher air temperature markedly reduced the plant height and branch length and delayed leaf unfolding and flowering. Soil temperature did not affect appreciably the development and growth unlike air temperature, but exerted a relatively pronounced effect under the high air temperature regimes. Soil temperature decrease from 30 to 25°C was obviously sufficient to enhance the growth and development of cv. Kibou no Hikari, whereas cooling of soil temperature to 25°C was not effective for the growth and development of cv. Scania. On the other hand, soil temperature decrease to 20°C was effective. Dry weight of the seedlings was affected in the same way as the growth and development. High air temperature decreased the dry weight of seedlings, but favorable effects of low soil temperature appeared at high air temperatures. Greenness of the stems and leaves decreased by high temperature treatment. High air temperature also strongly decreased root weight, and soil temperature suppressed the effect under lower regimes. The contents (g/g D.W.) of inorganic nutrients were also affected by the temperature in the same way as indicated above; high air temperature decreased the contents but low soil temperature improved the conditions under the high air temperature regimes. This effect could be observed for all the organs, in particular stem and leaves (Table 2) because of their higher contents than in the other organs. Nitrogen content increased to a larger extent than that of the other nutrients by the decrease of the temperature. The difference in the content of each nutrient among the treatments became greater on a seedling basis because lower air and soil temperatures increased the dry weight of the seedlings. Root vigor expressed by the reduction power of TTC decreased by the high air and/or high soil temperatures, but was mainly influenced by the soil temperature rather than the air temperature. Air temperature did not affect appreciably the root vigor when the soil temperature was 30°C, but exerted a more pronounced effect when the soil temperature was 20°C.

Exp. 2: Effect of RFM combined with shading using diffusive material and soil temperature on leaf temperature

Air temperatures were lower in the day time in the RFM + shading plot than in the untreated plot for every measurement on both August 12 and 16 (Fig. 1). The largest difference among the treatments was approximately 10°C, which was observed when the temperature in the greenhouse exceeded 40°C. The shading treatment was considered to lower the air temperature. Soil temperatures were lower in the untreated plot than in the RFM plot in the morning,

Table 2. Combined effects of air and soil temperatures on the absorption of inorganic nutrients and the root activity (TTC reducing power) of carnation cv. Scania

Organ	Temperature (°C)		Inorganic nutrient concentration (%, D.W.)					TTC reducing power ($mg \cdot g^{-1} h^{-1}$)
	Air	Soil	N	P	K	Ca	Mg	
Stem and leaf	30	30	2.19	0.32	3.27	1.05	0.24	–
	30	25	2.41	0.34	3.37	1.31	0.20	–
	30	20	3.96	0.47	4.02	1.35	0.29	–
	20	30	3.55	0.35	3.52	1.24	0.39	–
	20	25	4.29	0.41	3.64	1.32	0.40	–
	20	20	4.09	0.51	4.98	1.56	0.49	–
Root	30	30	1.20	0.32	0.75	0.83	0.15	0.159
	30	25	1.14	0.30	1.13	0.92	0.25	0.162
	30	20	1.63	0.47	1.72	0.93	0.27	0.193
	20	30	1.59	0.32	1.58	0.91	0.27	0.156
	20	25	1.43	0.41	1.45	1.17	0.25	0.216
	20	20	1.83	0.39	1.74	1.23	0.28	0.331
Flower	30	30	–	–	–	–	–	–
	30	25	–	–	–	–	–	–
	30	20	–	–	–	–	–	–
	20	30	1.91	0.28	1.70	0.38	0.18	–
	20	25	2.21	0.31	2.10	0.37	0.17	–
	20	20	2.83	0.45	2.82	0.69	0.25	–

Measurements were conducted 11 weeks after treatment.

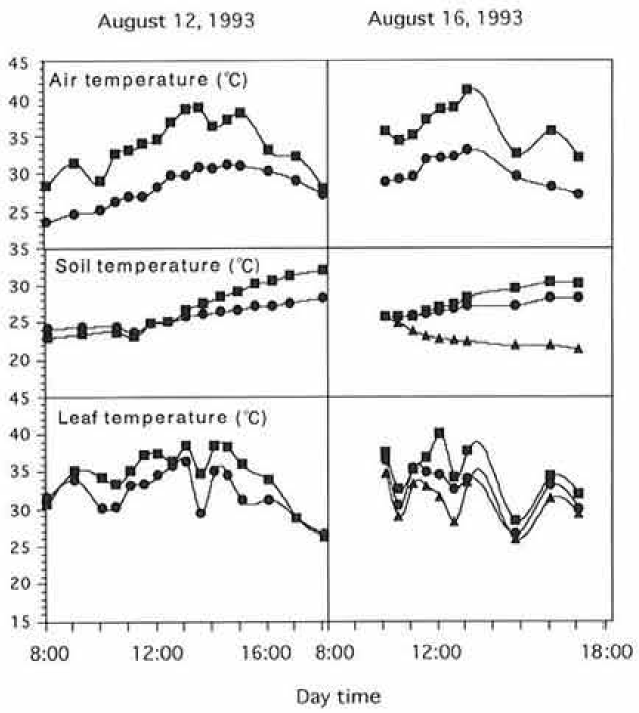

Fig. 1. Effect of reflective film mulching combined with shading and soil temperature cooling treatment on the temperatures of air, soil and carnation leaf

Measurements were conducted on the clear days of August 12 and 16, 1993.

Plots include control (■), reflective film mulching + shading (●) and reflective film mulching + shading + soil temperature control (▲).

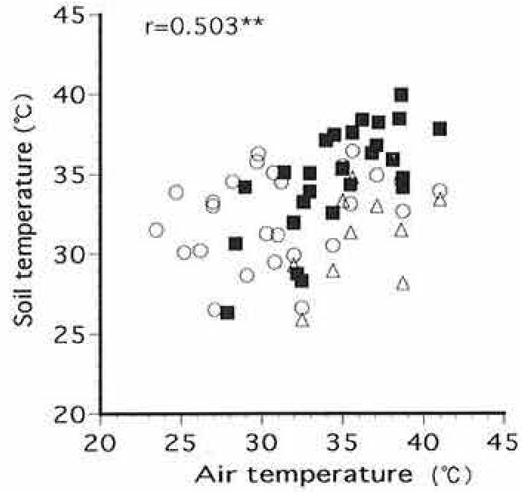

Fig. 2. Interaction between air temperature and leaf temperature in carnation cv. Nora

Temperature measurements were carried out on the clear days of August 12 and 16, 1993.

Plots include control (■), reflective film mulching + shading (○) and reflective film mulching + shading + soil temperature control (△).

and those in both treatments increased toward noon, then at dusk the temperature in the untreated plot began to decrease while that in the RFM plot remained stable or even increased (Fig. 1). Soil temperature control in the RFM + S + SC plot was not effective enough to decrease the temperature to 20°C of the set point, but it enabled to keep a lower temperature than in the other plots (Fig. 1). Leaf temperature was reduced in the RFM + S plot regardless of whether the soil temperature decreased compared with the untreated plots in both Exp. 2-1 and 2-2 (Fig. 1). The largest differences in leaf temperature between the RFM + S plot and the untreated plot were 5.3°C and 5.4°C in Exp. 2-1 and 2-2, respectively. The response became larger by additional treatment of soil cooling to the RFM + S plot, and the difference between the RFM + S + SC plot and the untreated plot was 8.4°C.

Lower leaf temperature in the RFM + S plot was due to the lower air temperature brought about by shading. Leaf temperature increased linearly as the air temperature increased (Fig. 2, r = 0.503**). Moreover, the shading material had minimized the variations of leaf temperatures at each measurement.

Discussion

Reflective film mulching was reported to modify environmental factors through the increase of the light intensity by the reflection of downward light[5,8], reduction of soil temperature[2,6] and increase of air temperature above the reflective surface[12].

Either growth or development of carnation was influenced by air and soil temperatures, and the optimum temperature of both air and soil was estimated to be 20°C. Air temperature exerted a more pronounced effect than the soil temperature, but favorable effect of the low soil temperature appeared under a higher air temperature regime. Some authors reported findings similar to our data and optimum air temperature for carnation ranged from 15 to 20°C[1,9,11]. The growth and development were markedly influenced by the air temperature, while the soil temperature exerted a negligible effect and carnation was able to grow well over a wide range of soil temperatures[7]. Nutrient absorption was also influenced by air and soil temperatures. The effect of the air temperature was greater than that of the soil temperature. Nutrient distribution was also controlled by the air temperature, and organs at lower air temperatures received a larger amount of nutrients regardless of whether the organs were under or above the ground. In solution culture it was reported that favorable temperatures for carnation nutrient absorption ranged from 15 to 25°C and the optimum temperature was 20°C. Above 30°C on the other hand, the amount of nutrients absorbed decreased as well as dry matter production[11]. Our results agreed with the report, indicating that the optimum temperature for both nutrient absorption and growth was around 20°C rather than 30°C. In spite of the effect of the air temperature on nutrient absorption, the root vigor expressed by the reducing power of TTC was affected by the soil temperature and increased when the soil temperature decreased. The large amount of nutrients absorbed was considered to be caused not only by root vigor controlled by the soil temperature but also by the requirement of the above-ground parts controlled by the air temperature.

It was obvious that the shading treatment in addition to RFM alleviated the increase of the leaf temperature (Exp. 2). The leaf temperature of carnation at high temperatures was always lower when RFM was combined to shading than in the untreated plots, presumably due to the effect of shading on the alleviation of the negative impact of high temperature[4,5]. The optimum air temperature for carnation growth was reported to range from 15 to 20°C, and the photosynthetic activity decreased rapidly when the temperature exceeded the optimum value[1,9,11]. In our previous report[3] we also showed that the photosynthetic rate of carnation plant was related to the leaf temperature and rapidly decreased when the leaf temperature was above 26°C. These results suggested that lowering of leaf temperature at high air temperature would reduce the decrease when the air temperature inside the glasshouse sometimes exceeds 40°C. Leaf temperature was influenced not only by the air temperature but also by the soil temperature, suggesting that RFM contributed to the decrease of the leaf temperature through the decrease of the soil temperature.

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