JARQ 30, 189-196 (1996)

Comparison of the Effect of Several Mulching and Shading Materials on Carnation Production

Takashi YAMAGUCHI*1, Akiko ITO*2, and Masaji KOSHIOKA*3

Department of Floriculture, National Research Institute of Vegetables, Ornamental Plants and Tea(Ano, Age, Mie, 514-23 Japan)

Abstract

We examined the properties of materials for a combination of reflective film mulching and shading treatments in carnation cultivation at high temperatures. We concluded that 2 properties of shading materials were important: one is the transmittance and the other is the rate of diffused solar radiation to the total transmitted light. Appropriate transmission percentage during summer ranged from 40 to 70%. In addition, light diffusiveness of shading materials exhibited an interactive effect on carnation growth. Shading materials with a lower transmittance around 40% required a higher light diffuseness of more than 70% to be effective. On the contrary for a relatively moderate shading of about 70% transmittance, the light diffusiveness did not affect appreciably the acceleration of early growth and flowering. Mulching materials were consistently effective when they reflected more than 80% of radiation. All the combinations of mulching and shading materials with the characteristics described above enabled to obtain yields 20 to 50% higher than in the non-shaded and non-mulched plots consistently over 3 years for 3 cultivars.

Discipline: Horticulture
Additional key words: light diffusiveness, light properties, transmittance

Introduction

Carnation is adapted to a comparatively high level of solar radiation. Low light intensity is reported to delay flower initiation associated with an increased number of leaves formed below the flower[1]. Even under high solar radiation in summer, shading treatments inhibited the development of primary branches and decreased the number of secondary branches, which led to the reduction of the weight and number of cut flowers[1,2,7]. The optimum temperature for photosynthesis and nutrient absorption of carnation is considered to be around 20°C[1,9]. These reports suggest that high reflectiveness of mulching with strong but not excessive shading could give the best results. In relation to the temperature, a balance between the reflectiveness of mulching and the intensity of shading should be achieved, as reflective film mulching (RFM) increases the air temperature[10] while shading conversely reduces the temperature[3,4]. However, there are only a few reports on the properties of shading materials and their effects on carnation growth. Sherry & Goldberry[5] who covered a carnation greenhouse with new corrugated fiberglass-reinforced plastic panels (FRP), single layer of UV-resistant polyethylene, double layer of polyethylene, and 8-year-old weathered FRP, reported that increased irradiance under the cover treatments increased stem length, fresh weight and quality. Weinard & Decker[6] and Yamaguchi[7] also noted that higher intensities of solar radiation increased the number of cut flowers. Kageyama et al.[2] reported that strong shading (more than 60%) delayed the development of branches, although 20% shading did not show an appreciable effect. They also stated that films which cut off UV radiation inhibited lateral shoot development.

Present address:
*1 Fukkaen Nursery & Bulb CO., LTD. (2167 Kitayama, Misato, Yokkaichi, Mie, 510-11 Japan)
*2 Department of Pomology, Fruit Tree Research Station (Tsukuba, Ibaraki, 305 Japan)
*3 To whom correspondence should be addressed.

In this report we investigated the effects of materials suitable for the combination of RFM and shading treatments on the growth of carnation.

Materials and methods

Seedlings of carnation used for the experiments were pinched at the 4th node and trained to hold 4 branches and subsequently only vigorous branches were pinched again. The experiments were carried out in a greenhouse located at the National Research Institute of Vegetables, Ornamental Plants and Tea (longitude 135°E, latitude 35°N). The temperature inside the greenhouse was maintained above 13°C. Carnation rooted cuttings were planted in 90 cm-wide benches filled with a mixture of soil and compost disinfected with dazomet before planting. Fertilizer was applied to the soil mixture at 3.5(N)-3.0(P)-3.5(K)-1.1 (Mg) kg/100 m^2 before planting. Liquid fertilizer consisting of N at 100 ppm was applied once a week after planting. Seedlings were planted at a density of 36.5 plants/m^2. Plants were watered as required. Anatomical data of standing plants included plant height and length of primary and secondary branches. Flowers were harvested twice a week at the 10th node level from the neck at full bloom. Then their length, weight, stem diameter and drooping grade of stem were measured according to the method of Yamaguchi[7].

Experiment 1: Light reflectance, transmission, and absorbance of several materials for shading and mulching uses

Shading materials used here consisted of Sun Rich (Kurare, Japan), Sunny Coat (Ube Nitto Kasei, Japan), High Cool (Toukan Kousan, Japan), Kure Cool (Kurare, Japan), Cheese clothes #100 and #200 (Kurare, Japan). Mulching materials included Neo PolyShine, PolyShine N, PolyShine L, PolyShine Mulch D (Hitachi AIC, Japan), Heiden (Shibataya Kakoushi, Japan), Taiyo Sheet 65-S, Taiyo Sheet #800 (Honshu Seishi, Japan), Tyvek 1025D, Tyvek 1422A (Dupon, USA), Shiro Kuro Mulch (Mikado Kakou, Japan), Silver Polytou (Toukan Kousan, Japan) and Pikasan (Sumitomo Kasei, Japan). Light reflectance, transmission and absorbance of radiation (400 to 700 nm, photosynthetic active radiation, PAR) were measured with a portable spectroradiometric research system (LI-1800, LI-COR). Neo PolyShine, PolyShine N, PolyShine L, PolyShine Mulch D, Taiyo Sheet 65-S, Taiyo Sheet #800 and Pikasan Film were aluminized films, Heiden and Silver Polytou were silver polyethylene films, Tyvek 1025D and Tyvek 1422A were white woven fabrics, and Shiro Kuro Mulch was a polyethylene film white in the front and black in the back. The properties of both surfaces were determined for Shiro Kuro Mulch while for all the other materials the properties of the front surfaces only were determined.

Experiment 2: Effects of 4 shading materials on the growth of carnation mulched with an aluminized film

Carnation cv. Soana was used here. The seedlings were planted on June 27, 1990 in benches mulched with an aluminized film (PolyShine Cloth Mulch) in 2.0 m^2 plots (1 replication). Five treatments were included in these experiments: (1) no-shading, (2) shading with Cheese cloth #200, (3) shading with a highly diffusive material (Sun Rich), (4) shading with a highly diffusive material (High Cool), and (5) shading with a highly diffusive material (Kura Cool). Shading was conducted from July 26 until September 29 for 2 months as described in the previous report[8]. Shading sheets were attached to the top portion of the wooden frame (1.5 m(H) × 2.2 m(L) × 1.2 m(W)) mounted over the canopy. The anatomical data were recorded on August 22 (8 weeks after treatment). PPFD (photosynthetic photon flux density of PAR), and diffused PPFD under shading were also recorded. Number of cut flowers and their qualities were observed from the onset of flowering until December 31, for approximately 3 months.

Experiment 3: Effects of combinations of 4 highly reflective mulching materials and 2 highly diffusive shading materials on the growth of carnation

Carnation seedlings cv. Francesco were planted on July 11, 1991 in 1.3 m^2 plots. Combination treatments of 2 shading sheets and 4 mulching materials were examined. The 2 shading materials used here which were highly diffusive, included Sun Rich and Sunny Coat. Mulching materials included PolyShine N, PolyShine Mulch D, Shiro Kuro Mulch (with a white surface) and silver Polytou. The 8 plots listed above plus the control plot (without shading or mulching treatment) were included in this experiment. Shading was conducted from July 19 until September 19. The anatomical data were recorded on September 19 (10 weeks after transplanting). Cut flower yield and their qualities were determined from the onset of flowering until May 10 in 1992.

Experiment 4: Effects of 3 highly reflective films on carnation yield and quality without shading treatment

Carnation seedlings cv. Nora were planted on March 29, 1992. The anatomical data were recorded on May 29 (2 months after transplanting). Four treatments were included in this experiment: (1) bare soil (control), (2) mulching with Neo PolyShine, (3) mulching with Taiyo Sheet 65-S, and (4) mulching with Tyvek 1422A. Flowers were harvested and their qualities were determined from the onset of flowering until February 28, 1993.

Results

Experiment 1: Light reflectance, transmission, and absorbance of several materials for shading and mulching uses

Averaged values of reflectance, transmission and absorbance of PAR of each material are shown in Table 1. The shading materials affected the percentage of transmission of radiation. Sun Rich, Sunny Coat and Cheese cloth #200 transmitted more than 80% of total available radiation, while 65.8 and 67.0% of the radiation were transmitted by High Cool and Cheese cloth #100, respectively. There was also a clear difference in the percentage of reflectance of radiation among the mulching materials. Tyvek 1025D and Tyvek 1422A reflected more than 90% of total radiation, and Taiyo Sheet 65-S, Heiden, Neo PolyShine and PolyShine N reflected more than 85%. Percentages of radiation reflected by Taiyo Sheet #800, Pikasan and PolyShine L ranged from 80 to 85% while those of PolyShine Mulch D, white and black surfaces of Shiro Kuro Mulch and Silver Polytou were 75, 58, 5 and 49%, respectively. Percentage of transmittance by mulching films was less than 3% of total radiation in all the materials but more than 7% in the case of Tyvek 1025D and Tyvek 1422A, which were white woven fabrics. The percentages of reflectance of almost all the mulching materials decreased and the absorbance percentages increased with the increase of the wavelength of radiation.

Experiment 2: Effect of 4 shading materials on the growth of carnation mulched with an aluminized film

The glass roof of the greenhouse transmitted 82% of outside solar radiation measured on September 10 and 11. Transmittance percentages of shading

Table 1. Light reflectance, transmission and absorbance percentages of 19 materials for shading and mulching uses

Materials	Reflection (%)	Transmission (%)	Absorbance (%)
Cheese cloth (#100)	30.12	67.01	2.87
Cheese cloth (#200)	14.75	82.49	2.76
Heiden	86.28	0.32	13.40
High Cool	21.88	65.75	12.37
Kura Cool	24.59	56.78	18.63
Neo PolyShine	85.12	0.34	14.54
Pikasan	81.93	2.64	15.43
PolyShine L	80.23	0.70	19.07
PolyShine Mulch D	74.82	1.12	24.06
PolyShine N	85.08	0.97	13.95
Shiro Kuro Mulch (white surface)	58.21	1.29	40.50
Shiro Kuro Mulch (black surface)	5.43	1.22	93.35
Silver Polytou	48.97	0.12	50.50
Sun Rich	11.65	86.35	2.00
Sunny Coat	15.45	82.59	1.96
Taiyo Sheet (#80)	83.85	1.81	14.34
Taiyo Sheet (65-S)	86.45	0.64	12.91
Tyvek 1025D	94.42	7.71	-2.13
Tyvek 1422A	91.30	7.87	0.83

Average values of wavelength from 400 to 700 nm measured with a spectroradiometric research system (LI-1800, LI-COR).

Table 2. Effect of 4 shading materials with reflective film mulching (RFM) on the photosynthetic active photon flux densities (μmol m^2/s, PPFD), diffused PPFD and light diffusion rate (%) above the soil surface

Shading materials	PPFD RFM		Diffused PPFD RFM		Light diffusion rate (%) RFM	
	Yes	No	Yes	No	Yes	No
No shading	1032	939	364	314	35.3	33.4
Cheese cloth (#20)	683	689	290	293	42.5	42.5
Sun Rich	531	547	472	461	88.9	84.3
High Cool	412	398	300	273	72.8	68.3
Kura Cool	526	496	217	183	41.3	36.9

Data were taken from 13:00 to 14:00 on clear day of September 11, 1990 with a spectroradiometric research system (LI-1800, LI-COR).

Table 3. Effect of 4 shading materials with reflective film mulching (RFM) on the growth of carnation cv. Soana

Shading materials	Plant height (cm)	Primary branch		Secondary branch	
		Length (cm)	No. (/m^2)	Length (cm)	No. (/m^2)
No shading	40.4	29.1	184	11.5	71.3
Cheese cloth	42.9	33.8	188	11.3	95.0
Sun Rich	52.6	39.2	191	10.9	86.3
High Cool	57.2	42.3	179	11.4	97.5
Kura Cool	47.8	35.9	171	9.5	62.5

Data were collected on August 22, 1990 (8 weeks after treatment).

Table 4. Effect of 4 shading materials with reflective film mulching (RFM) on the yield and quality of carnation cv. Soana

Shading materials	Flower number (/m^2)	Percentage grade of flower length[a)]			Percentage grade of flower weight[b)]			Percentage grade of stem diameter[c)]			Percentage grade of drooping[d)]	
		M	L	XL	M	L	XL	M	L	XL	M	IF
Control	70.9	73.9	26.1	0	29.3	36.8	33.9	3.0	58.8	38.2	44.1	55.9
Cheese cloth	84.0	36.9	63.1	0	29.3	47.6	23.1	10.7	52.4	36.9	43.1	56.9
Sun Rich	106.0	45.1	53.7	1.2	43.9	40.3	15.8	15.8	54.9	29.2	28.4	71.6
High Cool	88.4	42.4	57.6	0	37.9	34.8	27.3	18.2	60.6	21.2	29.8	70.9
Kura Cool	72.4	37.6	62.4	0	32.0	37.6	30.4	9.0	53.6	37.4	22.1	77.9

Data were collected for the flowers harvested from the onset of the flowering (early October) until December 31, 1990.

Cut flowers were classified according to the standard cultural practices in Japan.

a): M (medium); less than and equal to 65 cm, L (large); 66 to 80 cm, XL (extra large); more than 80 cm.

b): M (medium); less than and equal to 25 g, L (large); 26 to 30 g, XL (extra large); more than 30 g.

c): M (medium); less than 3.4 mm, L (large); 3.5 to 4.0 mm, XL (extra large); more than 4.0 mm.

d): M (medium); less than and equal to 20°, IF (low quality); more than 20°.

materials increased in the order of High Cool, Kura Cool, Sun Rich, and Cheese cloth #200 (Table 2). Reflective mulches increased the diffused PPFD and led to higher percentages of diffused PPFD to the total PPFD on reflective mulches than those on bare soil surface. There were differences in the growth of carnation such as length and number of branches among the shading materials. Cheese cloth, Sun Rich and High Cool enhanced the growth compared with the control, but the effect of Kura Cool was comparable to that of the control (Table 3). Transmittance percentages of Sun Rich, Kura Cool and High Cool were similar, but the percentage of diffuseness of radiation was influenced by the shading materials.

The percentages of diffusion of Sun Rich, High Cool and Kura Cool were 88.9, 72.8 and 41.3%, respectively (Table 2). Shading treatments with reflective mulching enhanced flowering, resulting in higher yields of flowers harvested in the first 3 months of the harvest period (Table 4). Yields increased in the order of control, Kura Cool, Cheese Cloth, High Cool and Sun Rich. All the shading treatments resulted in longer but more drooping flowers. Although this phenomenon was observed more frequently as shading became stronger, stronger shading also produced a larger number of early harvested flowers.

Experiment 3: Effects of combinations of 4 highly reflective mulching materials and 2 highly diffusive shading materials on the growth of carnation

Transmittance percentages of Sun Rich and Sunny Coat were 86.4 and 82.6%, respectively. Reflectance percentages of PolyShine N, PolyShine Mulch D, Shiro Kuro Mulch (white surface) and Silver Polytou were 85.1, 74.8, 58.2 and 49.0%, respectively

Table 5. Effect of shading treatments with diffusive films and reflective film mulching (RFM) on early growth of carnation cv. Francesco

Treatment		Plant height (cm)	Primary branch length	
Shading materials	Mulching materials		Average (cm)	Cumulative (cm/plant)
Sun Rich	PolyShine N	37.3	30.3	69.9
	PolyShine Mulch D	39.4	31.1	71.8
	Shiro Kuro Mulch[a)]	37.6	28.1	73.1
	Silver Polytou	35.0	27.5	66.1
	Average	37.3	29.3	70.2
Sunny Coat	PolyShine N	38.0	30.5	75.6
	PolyShine Mulch D	40.5	31.5	85.4
	Shiro Kuro Mulch	40.5	31.3	74.2
	Silver Polytou	32.4	24.7	60.9
	Average	37.9	29.5	74.0
No shading	No mulching	28.8	19.7	29.9

Data were collected on September 19, 1991 (10 weeks after transplantation).
a): White surface was used for mulching.

Table 6. Effect of shading treatments with diffusive films and reflective film mulching (RMF) on yield and quality of carnation cv. Francesco

Treatment		Flower number ($/m^2$)	Percentage grade of flower length[b)]			Percentage grade of flower weight[c)]			Percentage grade of drooping[d)]	
Shading materials	Mulching materials		M	L	XL	M	L	XL	M	IF
Sun Rich	PolyShine N	339.1	1.9	83.0	15.2	22.9	57.0	20.1	97.2	2.8
	PolyShine Mulch D	342.2	2.3	78.1	19.6	29.2	53.9	16.9	96.8	3.2
	Shiro Kuro Mulch[a)]	326.6	2.9	80.4	16.7	35.9	49.3	14.8	93.8	6.2
	Silver Polytou	354.7	1.3	89.0	9.7	32.6	49.8	17.6	92.0	8.0
Sunny Coat	PolyShine N	373.4	1.3	74.9	21.9	29.7	57.3	13.0	98.3	1.7
	PolyShine Mulch D	356.3	2.6	84.6	12.7	32.0	50.9	17.1	95.6	4.4
	Shiro Kuro Mulch	360.9	3.9	82.2	13.9	37.7	45.5	16.9	94.7	5.3
	Silver Polytou	298.4	4.7	76.9	18.3	32.4	52.3	15.2	93.4	6.6
No shading	No mulching	109.4	5.8	89.9	4.3	31.4	65.7	2.8	98.5	1.5

Data were collected for the flowers harvested from the onset of flowering (early October 1991) until May 10, 1992.
Cut flowers were classified as follows:
a): White surface was used for mulching.
b): M (medium); less than and equal to 50 cm, L (large); 51 to 65 cm, XL (extra large); more than 65 cm.
c): M (medium); less than and qual to 25 g, L (large); 26 to 30 g, XL (extra large); more than 30 g.
d): M (medium); less than and equal to 20°, IF (low quality); more than 20°.

(Table 1). The anatomical data are presented in Table 5. The length of the primary branches of carnation on RFM exceeded 200% of that on the control, but no significant differences were observed among the shading materials. A slight difference was observed among the mulching materials as Silver Polytou, whose reflectance was the lowest in the used materials, suppressed the growth. This suppression by Silver Polytou was greater when the plants were covered with Sunny Coat than with Sun Rich. Total flower yield increased by the combination of any shading and RFM materials except for the above combination of Sunny Coat and Silver Polytou. The effect of the latter combination was similar to that of the control, while the other combinations were similarly effective and increased the flower yields by approximately 50% of the values of the control (Table 6). Mulching materials exerted a more pronounced effect on the yield and early growth of carnation than the shading ones. However, Sunny Coat shading corresponded more clearly to the characteristics of mulching films than Sun Rich, and it gave a lower flower yield when combined with materials with a lower radiation reflectance.

Experiment 4: Effect of 3 highly reflective films on carnation yield and quality without shading treatment

Early growth of carnation was clearly enhanced by RFM. There were significant differences in the plant height and primary branch length between the mulching materials and the control (Table 7). A proportion of 100% of the seedlings reached the visible bud stage at 16 weeks after treatment in 3

Table 7. Effect of 4 reflective film mulching (RFM) materials on the growth of carnation cv. Nora

Mulching materials	Plant height (cm)	Primary branch		Secondary branch
		Length (cm)	No. ($/m^2$)	Cumulative length (cm)
No mulch	24.5b*	97.5b	4.8 ns	1.6
Neo PolyShine	32.7a	127.5a	5.0	34.7
Taiyo 65-S	30.7a	129.7a	4.9	20.7
Tyvek 1442A	31.8a	130.4a	5.0	20.7

Data were collected on May 29, 1992 (2 months after treatment).
* Mean separation between treatments by Duncan's multiple range test at $P \leq 0.05$.

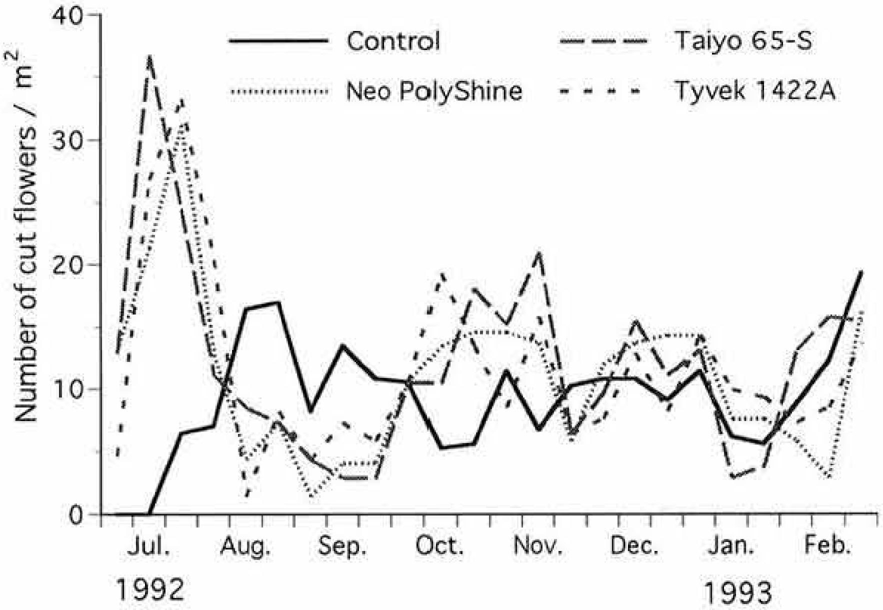

Fig. 1. Effect of 3 highly reflective films on the seasonal changes of the yield of carnation cv. Nora

Table 8. Effect of 4 reflective film mulching (RFM) materials on the growth of carnation cv. Nora

Mulching materials	Flower number ($/m^2$)	Percentage grade of flower length[a]			Percentage grade of flower weight[b]			Percentage grade of drooping[c]	
		M	L	XL	M	L	XL	M	IF
No much	218.8	13.5	70.6	15.9	42.5	48.2	9.4	67.8	32.2
Neo PolyShine	261.5	11.0	82.0	7	40.8	55.1	4.1	62.3	37.7
Taiyo 65-S	284.1	11.5	80.5	7.9	44.9	50.8	4.3	60.3	39.7
Tyvek 1422A	275.3	10.0	83.1	7.0	38.5	58.2	3.3	59.4	40.6

Data were collected for the flowers harvested from the onset of flowering (early July 1992) until February 28, 1993.
a): M (medium); less than and equal to 45 cm, L (large); 46 to 65 cm, XL (extra large); more than 65 cm.
b): M (medium); less than and equal to 20 g, L (large); 21 to 30 g, XL (extra large); more than 30 g.
c): M (medium); less than and equal to 20°, IF (low quality); more than 20°.

mulching plots instead of 20 weeks in the control. Reflective film mulching shortened the vegetative growth duration by 4 weeks, resulting in the prolongation of the harvest period and increase of yield (Fig. 1). Numbers of cut flowers on Neo PolyShine, Taiyo Sheet 65-S and Tyvek 1422A were 119.5, 129.8 and 125.8% of the control, respectively, and no differences were observed between the mulching materials, nor was the seasonal pattern of flowering influenced by the materials. RFMs increased the number of flowers of medium class quality but not those of high quality (Table 8). As for the drooping grade of stem, RFMs were less effective than the control. There was no difference in the flower quality among the film materials.

Discussion

The effects of shading on carnation growth included delayed development of primary branches, a smaller number of secondary branches and lower cut flower yield[1,2,7]. However, the previous report[8] showed that a 2-month shading period combined with reflective film mulching enabled to achieve vegetative growth and resulted in a higher yield than in the non-shaded plot. Exp. 2 indicated that Sun Rich, High Cool, Cheese cloth #200 were equally effective, suggesting that suitable transmittance percentage for shading during summer ranged from 40 to 70%. In addition, the percentage of diffused solar radiation to the total transmitted light also affected the carnation growth. The shading materials with a lower transmittance around 40% needed to have a diffuseness of more than 70% to be effective, and conversely a material with a relatively moderate shading of about 70% transmittance exerted a less appreciable effect on the acceleration of early growth and flowering. It was reported that the use of 20% shading (80% transmission) for carnation grown during summer did not exert an adverse effect although stronger shading (40% or less of transmitted light) delayed markedly the development of lateral shoots[2]. On the contrary, transmitted solar radiation of 3 effective materials in Exp. 2 ranging from 42 to 73% of that of the control (measured under the glass roof of a greenhouse), was estimated to provide a shading strong enough to cause adverse effects on carnation growth and development. However, these 3 shading plots produced a larger number of branches than the control, presumably due to the higher diffused solar radiation of 87 to 147% compared with the control plot, and due to their effect on the decrease of the temperature[8]. Diffused light could more easily reach the leaves in the middle to lower parts of the plant community than direct light. Therefore, higher diffused solar radiation tended to increase the radiation on the leaves at middle to lower positions than on those at a higher position in the plant community. Supplemental illumination applied to light-starving leaves is much more effective than illumination applied to light-rich ones for the increase of the photosynthesis of a plant community. As a result higher diffuseness unexpectedly exerted a beneficial effect on plant growth.

Cheese cloth #200 and Sun Rich transmitted a higher solar radiation than High Cool. Shading with Cheese cloth #200 or Sun Rich produced a larger number of lateral branches but the quality of the cut flowers was lower than when High Cool was used for shading. Excessive shading showed a thinning-like effect on carnation at early vegetative growth, resulting in reduced competition for nutrients and assimilates between young branches, which in turn led to the production of fewer flowers with a higher quality.

Exp. 3 supported the results of Exp. 2, and showed that any combination was equally effective for carnation growing on mulching materials with a reflection percentage of more than 60% and shading materials with a transmittance of more than 80% with high diffusiveness. However, as shown in Exp. 2, when the shading materials displayed either a lower diffusiveness or lower transmittance percentages than the percentages mentioned above, it was necessary to use mulching materials with a reflectiveness of at least 80% to obtain consistent results.

In Exp. 4, we compared the effects of aluminized films and white woven fabrics for mulching on carnation growth. All the films used in Exp. 4 reflected more than 80% of total solar radiation and were equally effective on cultivation. Since Tyvek with a white woven fabric reflected solar radiation diffusively, it was more useful for transplanting under high solar radiation, when the reflective surfaces are exposed for a long time to solar radiation with limited screen of plant canopy. However, the material also transmitted air and solar radiation more readily than aluminized films and the growth of weeds under the mulching materials could not be controlled.

In conclusion, good results were obtained consistently over 3 years by the use of mulching materials with a reflection percentage of more than 80% and shading materials with a transmittance of more than 80% with a high diffusiveness. Such combinations enabled to increase the total yield by 20 to 50% compared with the absence of mulching or shading.

References

1) Abou Dahab, A. M. (1967): Effects of light and temperature on growth and flowering of carnation (*Dianthus caryophyllus* L.). *Mededelingen Landbouwhogeschool Wageningen*, **67**(13), 1–76.
2) Kageyama, Y., Okamoto, N. & Konishi, K (1985): Effects of light, soil moisture and plant density on lateral shoot development in carnations. *Sci. Rep. Fac. Agric. Okayama Univ.*, **65**, 15–21 [In Japanese with English summary].
3) Kurozumi, T. et al. (1988): An effect on summer spinach of minimizing rise in temperature by shading. *Bull. Nara Agric. Exp. Stn.*, **19**, 31–37 [In Japanese with English summary].
4) Roberts, B. W. & Anderson, J. A. (1994): Canopy shade and soil mulch affect yield and solar injury of bell pepper. *HortScience*, **29**, 258–260.
5) Sherry, W. J. & Goldsberry, K. L. (1980): Carnation production responses to solar radiation transmitted through plastic greenhouse covers. *J. Am. Soc. Hort. Sci.*, **105**, 579–582.
6) Weinard, F. F. & Decker, S. W. (1930): Yield and quality of roses and carnations as affected by position on the bench. *Am. Soc. Hort. Sci.*, **27**, 454–456.
7) Yamaguchi, T. (1987): Stimulating effects of some chemical and physical treatments on the growth of carnation. *Acta Horticulturae*, **216**, 281–288.
8) Yamaguchi, T., Ito, A. & Koshioka, M. (1995): Effect of combination of reflective film mulching and shading treatments on the growth of carnation. *JARQ*, **30**, 181–188.
9) Yasui, K., Kuroki, M. & Konishi, K. (1980): Optimum macro-nutrient levels and temperature for growth of greenhouse carnation. *Sci. Rep. Fac. Agric. Okayama Univ.*, **56**, 73–80 [In Japanese with English summary].
10) Zalom, F. G. (1981): Effects of aluminum mulch on fecundity of apterous *Myzus persicae* on head lettuce in a field planting. *Ent. Exp. & Appl.*, **30**, 227–230.

(Received for publication, November 2, 1995)