A-5.2.2 Study on the evaluation of effects of increased UV-B radiation on growth of vegetables and ornamental crops

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Abstract

The effects of increased UV-B radiation due to ozone layer depletion on the growth and yield of green and root vegetables in Brassica are investigated. Two hundreds thirty cultivars of cabbages, Chinese cabbages, and Japanese radishes were evaluated. UV-B was supplemented for several months until the harvest in 12 cultivars of cabbage, broccoli, cauliflower, and Japanese radishes and for about 2 - 4 weeks in the others. For UV-B supplement, automatic UV-B supplement apparatuses were placed in the field, and fluorescent sunlamps were adjusted so that the biological effect of UV-B in treatment plots is constantly twice that in control plots (4 times the value causing the estimated degree of ozone layer depletion in the middle latitude zone). Under these UV-B supplement conditions, no visible damage was observed in any cultivar. In the short-term UV-B supplement experiments, a total of 145 cultivars including those repeatedly examined were statistically analyzed. The dry matter increase significantly differed in 16 cultivars; being reduced in 13 cultivars but increased in the other 3. Though 14 of the 16 cultivars were repeatedly examined, none of them showed a significant difference of twice or more. Of the 12 cultivars in the long-term UV-B supplement experiments, 1 cauliflower cultivar showed a decrease in yield, and 1 broccoli cultivar showed an increase. Thus, the effects of increased UV-B radiation were not growth inhibition alone but sometimes growth promotion. Comparison of the effects of UV-B supplement on growth among cultivar groups revealed no marked differences. These results suggest that the effects of about 10% ozone layer depletion on the yield of vegetables are slight and can be ignored.

Key Words : Ozone layer depletion, UV-B, Brassica, Growth, Yield

1. Introduction

With recent progression of ozone layer depletion[5], concern has been raised about the effects of increased UV-B radiation on the growth and yield of vegetables. However, since these effects have been evaluated mainly by indoor experiments[2,3], investigation in the field is necessary. In addition, vegetables have many cultivars that markedly differ in ecotypes.

Therefore, we investigated the effects of increased UV-B radiation on the growth and yield of cultivar groups with various ecotypes in Brassica vegetables, which are important not only in Japan but also in the world, in an experimental system in which UV-B environments under ozone layer depletion are artificially created. Based on the results, the effects of future ozone layer depletion on the yield of Brassica crops were estimated.

2. Research methods

(1) Artificial creation of the UV-B environment under ozone layer depletion in the field

Automatic UV supplement apparatuses [4] (Fig. 1) were placed in the field. Fluorescent sunlamps were adjusted so that the biological effect of UV-B[1] in treatment plots under the UV-B supplement apparatuses is constantly twice that in control plots under the open field conditions (4 times the value causing the estimated degree of ozone layer depletion).

(2) Short-term UV-B supplement experiments

Various cultivars of Brassica green and root vegetables were used (cabbages, 113 cultivars; Chinese cabbages, 73; and Japanese radishes, 44). As short-term UV-B supplement experiment I, two experiments were performed using all available VU-B supplement apparatuses in the treatment plots. Seedlings were raised in plug-trays in a plastic house, and cultivars that reached the stage with 2 - 3 leaves, i.e., the transplanting stage, were transplanted one after another in pots (capacity, 500 cm^3) and treated with UV-B for 2 - 4 weeks.

In short-term UV-B supplement experiment I, the difference in the solar intensity between the treatment and control plots resulted in a marked difference in growth. Therefore, apparatuses with the same shape as that of the UV-B supplement apparatuses were also placed in the control plots so as to produce the same solar environments. Under these conditions, 11 experiments were performed as short-term UV-B supplement experiment II. In 8 experiments, cabbages and Chinese cabbages were used, and seedlings were transplanted in pots and treated with UV-B for 2 - 4 weeks. In 3 experiments, Japanese radishes were used. In 1 of the 3 experiments, seeds were directly sown on the field. In the other 2 experiments, seeds were directly sown on planters, and UV-B treatment was initiated immediately after seeding.

(3) Long-term UV-B supplement experiments

UV-B was supplemented on 4 cabbage cultivars, 2 broccoli cultivars, 2 cauliflower cultivars, and 4 Japanese radish cultivars for several months from seeding or transplanting to harvesting. During treatment, light environments other than UV-B such as UV-A and visible radiation were adjusted to the same between the treatment and control plots. To produce these environments, fluorescent sunlamps were covered with cellulose acetate films that allow transmission of a wavelength range of 290 nm or more in the treatment plots while sunlamps were covered with lumirror films that allow the wavelength range of 320 nm or more in the control plots.

3. Results

(1) Short-term UV-B supplement experiments

No visible damages were observed in any of the 230 cultivars. No effects on the leaf color or the shape were observed. The increase in the number of leaves during the treatment period did not significantly differ between the treatment and control plots.

In UV-B supplement experiment I, the mean dry matter increase of cabbages according to the cultivars was 0.88 - 3.10 g/plant in the treatment plots and 0.94 - 3.33 g/plant in the control plots, the difference being -0.60 - 0.32 g/plant. The dry matter increase ratio (treatment plots/control plots) for each cultivar is shown in Fig. 2. The black circles indicate the ratio according to each cultivar, and the inside area of the ellipse drawn by a broken line belongs to the same cultivar group. The ratio was lower in the treatment plots than in the control plots for 62 of the 72 cultivars. The mean dry matter content was 8.1% in the treatment plots and 7.7% in the control plots. The mean dry matter increase in Chinese cabbages according to the 53 cultivars was 2.90 - 5.83 g/plant in the treatment plots and 3.29 - 6.53 g/plant in the control plots, the difference being -1.09 - 0.01 g/plant. The dry matter increase ratio for each cultivar is shown in Fig. 3. The ratio was lower in the treatment plots than in the control plots in all 53 cultivars. The mean dry matter increase ratios according to the cabbage cultivar groups were distributed between 0.89 and 1.01, each showing deviation of 0.02 - 0.09. The mean dry matter increase ratios in Chinese cabbages according to cultivar groups distributed between 0.90 and 0.94; each showing deviation of 0.07 - 0.09. Therefore, no marked differences due to increased UV-B radiation were observed among the cultivar groups. Similar trends were observed in the fresh weight increase and the dry matter content.

In UV-B supplement experiment II, the dry matter increase of a total of 111 cabbage cultivars according to cultivars was 0.97 - 7.37 g/plant in the treatment plots and 0.89 - 7.52 g/plant in the control plots; the difference was -0.47 - 0.57 g/plant, and the standard error was 0.03 - 0.31 g/plant. Significant differences were observed in 15 cultivars, which accounted for 14% of the total number of cultivars. Of the 15 cultivars, 12 (6 cultivars of cabbage, 1 of Brussels sprouts, 1 of cauliflower and 4 of broccoli) showed a reduction in the dry matter weight increase, while 3 (1 of cabbage, 1 of Brussels sprouts, and 1 of cauliflower) showed its increase. Fig. 4 shows the distribution of the incidences of the dry matter increase ratios expressed as class marks at 0.05 increments. The ratio distributed between 0.86 and 1.18 with a mean of 0.99. The mean ratio (treated plots/control plots) of dry matter content in all cultivars in the 7 experiments was 0.99. When the solar environment was the same, the dry mater content became similar. The dry matter increase in the 27 Chinese cabbage cultivars was 3.00 - 4.62 g/plant in the treatment plots and 3.10 - 4.82 g/plant in the control plots; the difference being -0.60 - 0.67 g/plant, and the standard error was 0.09 - 0.24 g/plant. No significant difference was observed in any cultivar. Fig. 5 shows the distribution of the incidences of the dry matter increase ratios expressed as class marks at 0.05 increments. The mean ratio was 0.98.

In UV-B supplement experiment II, the dry matter increase in the 44 Japanese radish cultivars period in the first experiment according to the cultivars was 13.1 - 27.3 g/plant in the treatment plots and 12.6 - 26.8 g/plant in the control plots, the difference being -6.9 -

3.1 g/plant. As shown in Fig. 6, the dry matter increase ratio distributed between 0.68 and 1.18 with a mean of 0.98. The dry matter increase markedly varied due to regional excessive soil moisture because the experiment was performed in a field with poor water drainage. Therefore, in the following 2 experiments, planters were used, and 5 cultivars from the lowest dry matter increase ratio and 1 cultivar showing a moderate ratio in the first experiment were evaluated. The mean dry matter increase in these experiments according to the cultivars was 12.8 - 25.8 g/plant in the treatment plots and 17.4 - 26.5 g/plant in the control plots; the difference was -4.6 - 0.5 g/plant, and the standard error was 0.5 - 1.0 g/plant. A significant difference was observed in 1 cultivar, which was observed in an inappropriate environment for growth. This suggests that growth inhibition by increased UV-B radiation is more marked in an inappropriate environment for growth.

(2) Long-term UV-B supplement experiments

The growth and yield of cabbages at harvest are shown in table 1. The growth and yield are normal. The yield in the treatment plots was 1.03 times higher than that in the control plots for "Akimaki-Gokuwase Nigo", 0.96 times higher for "Fuji-Wase", 0.99 times higher for "Akimaki-Nakawase", and 1.09 times higher for "SE". But, no significant difference was observed in the yield between the treatment and control plots for any of the 4 cultivars.

The growth and yield of Japanese radishes at harvest are shown in table 2. Since the cropping season was delayed compared with the normal, the growth state was considerably poorer than normal. The yield in the treatment plots was 1.10 times that in the control plots for "Shijunichi-Daikon", 0.82 times for "Suikomi-Ninengo", 0.95 times for "Taibyo-Sobutori", and 1.00 times for "Kono-Shogoin". No significant difference was observed between the two plots in any cultivar.

The results of 2 broccoli cultivars and 2 cauliflower cultivars are shown in Table 3. Since the cropping season was delayed, growth was slightly poorer than normal. The yield of "Masamidori 67 go" in the treatment plots was 1.30 times higher than that in the control plots, showing a significant increase. The yield of "Haitsu" and that of "Bridal" were 0.78 times and 1.05 times, respectively, that in the control plots, showing no significant difference. The yield of "Shiratama" was 0.88 times that in the control plots, showing a significant decrease.

4. Discussion

In short-term UV-B supplement experiment I, the solar radiation in the treatment plots decreased by 12% compared with the control plots because the plots were in the shade of the UV-B supplement apparatuses. In UV-B supplement experiment II, the solar radiation was similar between the treatment and control plots. In experiment I, the mean dry matter increase ratio (treatment plots/control plots) was 0.93 in the 72 cabbage cultivars and 0.92 in the 53 Chinese cabbage cultivars. In experiment II, the mean dry matter increase ratio was 0.99 in the total of 111 cabbage cultivars and 0.98 in the 27 Chinese cabbage cultivars. When these results are compared, the dry matter increase ratio in experiment I was lower than that in experiment II by 0.06. This difference between experiments I and II may be associated with the difference in solar radiation, considering the differences in the dry matter content and specific leaf weight. Therefore, the effects of a 2-fold increase in UV-B radiation on the growth of seedlings of cabbages and Chinese cabbages are estimated to be smaller than the effects of a 12% decrease in solar radiation.

Of 92 cultivars (a total of 145 cultivars) statistically evaluated in the short-term experiments, 16 showed a significant difference between the treatment and control plots. This number accounts for 11% of the total number of cultivars evaluated; growth was inhibited in 9% but promoted in 2%. However, when the same cultivars were evaluated, the highest deviation of the dry matter increase ratio was 14 points. Therefore, when results showing a difference of less than ± 10% were excluded from the results of statistical tests, 10 cultivars remained. Of the 16 cultivars showing a significant difference, 14 were examined 2 - 4 times in experiments, but none of them showed a significant difference twice or more. Therefore, the effects of increased UV-B radiation appear to be slight. In addition, the effects of other environments are estimated to be large. Evaluation of the effects of UV-B according to cultivar groups revealed similar response, indicating no difference among the cultivar groups. These results suggest that even if growth inhibition by UV-B is observed in some cultivars under 10% ozone layer destruction, other cultivars in the same cultivar group that are negligibly affected can be selected.

Increased UV-B radiation did not significantly affect the yield of cabbages or Japanese radishes. However, the yield significantly increased in 1 broccoli cultivar and significantly decreased in 1 cauliflower cultivar. In this study, only 12 cultivars were evaluated in the long-term experiments, and the experiments were not repeated. Therefore, evaluation of the effects on the yield was not sufficient. Further studies are necessary for accurate evaluation. However, the results in this study suggest that the effects of increased UV-B radiation on the yield of Brassica crops are negligible.

References

1)Caldwell,M.M., 1971, Solar UV radiation and the growth and development of higher plants, In Photophysiology. Edited by Giese,A.C., Vol. 6, 131-177, Academic Press, New York

2)Caldwell,M.M.,Flint,S.D. and Searles,P.S., 1994, Spectral balance and UV-B sensitivity of soybean: a field experiment, Plant Cell and Environment, 17, 267-276.

3)Krupa,S.V. and Kickert,R.N., 1989, The greenhouse effect: Impact of ultraviolet-B (UV-B) radiation, Carbon Dioxide (CO2) and Ozone (O3) on vegetation, Environmental Pollution, 61, 263-393.

4)Nouch,I. and Kobayashi,K., 1995, Effects of Enhanced Ultraviolet-B Radiation with a Modulated Lamp Control System on Growth of 17 Rice Cultivars in the Field, J. Agric. Meteorol., 51(1), 11-20.

5)Shomura,T., 1996, Ozone layer depletion, Research and Information Office, Global Environment Department, Environment Agency, p17-20

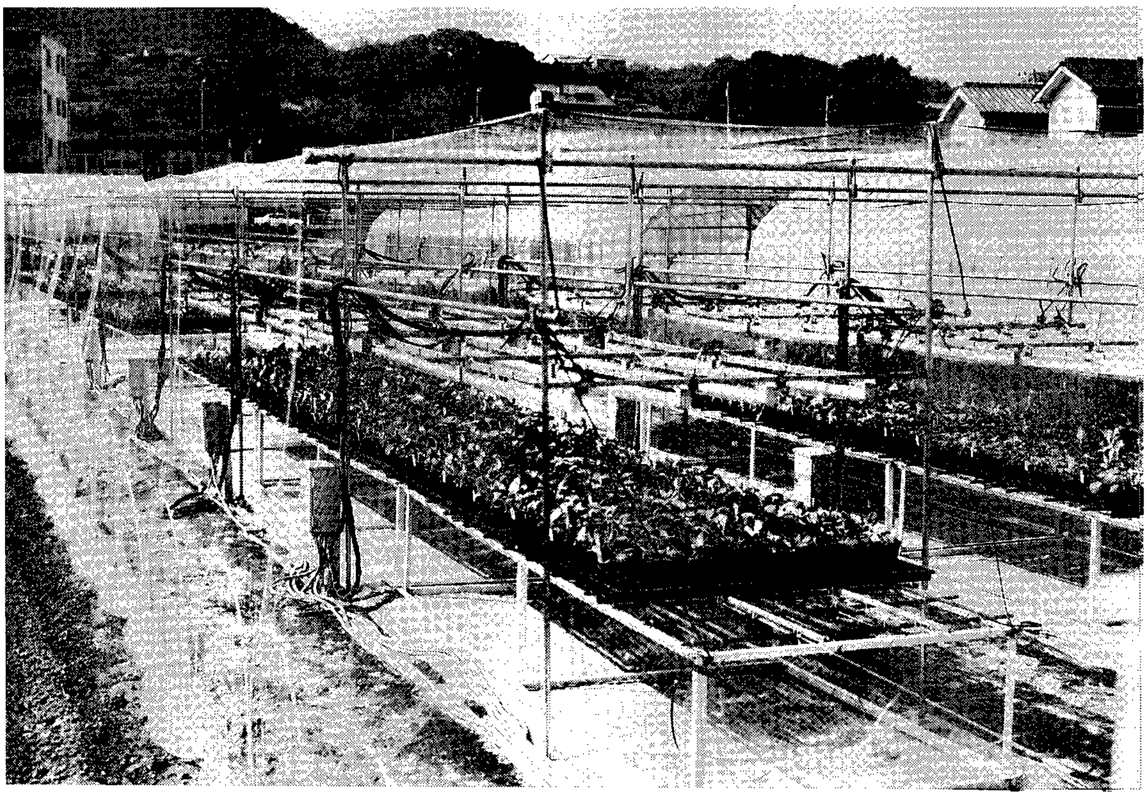

Fig.1 The outdoor UV-B supplementation system

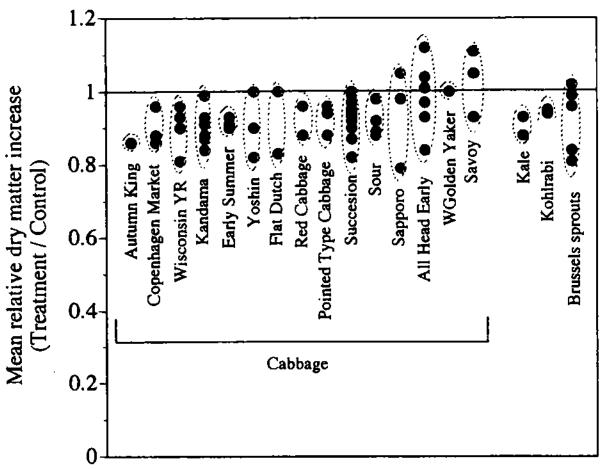

Fig.2 Effect of the treatment on dry matter increase of seedlings of *Brassica oleracea* (cabbage, Brussels sprouts, kale and kohlrabi) in Exp. I-1. One data point shows one cultivar. Data points in a same circle with Brake line belong to a same cultivar group of cabbage or a same species.

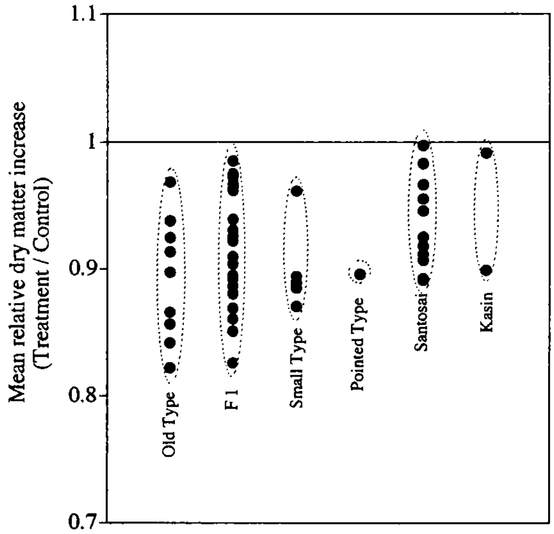

Fig. 3 Effect of the treatment on dry matter increase of seedlings of *Brassica campestris* (Chinese cabbage) in Exp. I-2. One data point shows one cultivar. Data points in a same circle with Brake line belong to a same cultivar group.

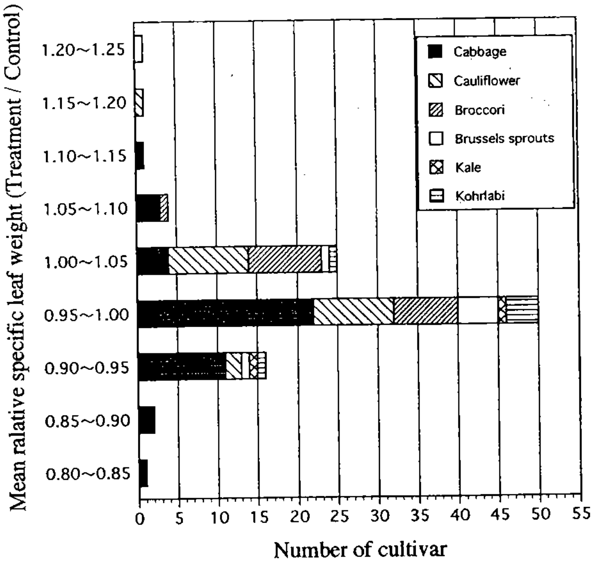

Fig.4 Effect of the supplemental UV-B on spesific leaf weight of seedlings of *Brassica oleracea* (cabbage, cauliflower, broccoli, Brussels sprouts, kale and kohlrabi) in Exp. II-1-1~6

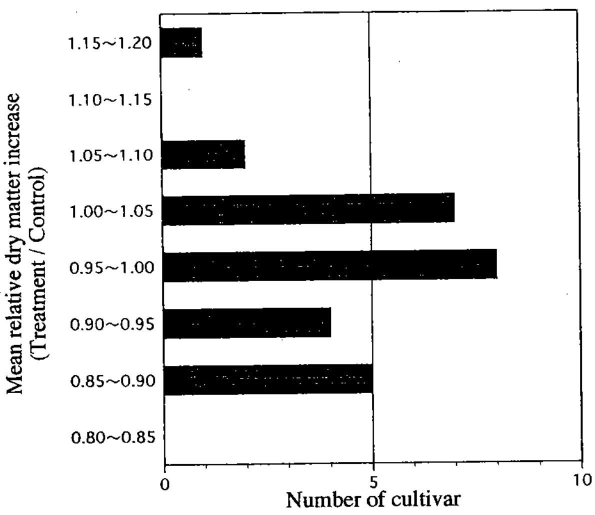

Fig. 5 Effect of the supplemental UV-B on dry matter increase of seedlings of *Brassica campestris* (Chinese cabbage) in Exp. II-2

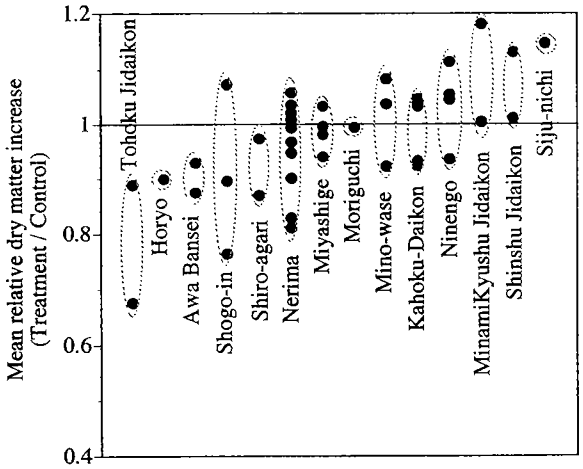

Fig.6 Effect of the supplemental UV-B on dry matter increase of seedlings of *Raphanus sativus* (radish) in Exp. II-3-1. One data point shows one cultivar. Data points in a same circle with Brake line belong to a same cultivar group.

Table 1 Effects of the supplemental UV-B on the yield and growth of cabbage

cultivar	plot	yield(fresh weight of leafy head,g)	total dry weight (g)	dry matter allocation (leafy head/total)	leaf area(cm²)
Akimaki-gokuwase 2	treatment	1248±56	148±4	0.54±0.01	8821±434
	control	1216±51	140±4	0.53±0.01	8659±344
	ratio	1.03	1.06	1.02	1.02
Fuji-wase	treatment	1774±44	145±2	0.54±0.01	9492±250
	control	1849±64	142±3	0.59±0.02	9125±358
	ratio	0.96	1.02	0.91	1.04
Akimaki-nakawase	treatment	1218±39	154±5	0.45±0.01	11144±360
	control	1235±35	147±2	0.47±0.01	10056±245
	raatio	0.99	1.05	0.97	1.11
SE	treatment	1242±46	196±6	0.40±0.01	12155±386
	control	1137±49	224±3	0.36±0.01	12282±260
	ratio	1.09	0.87	1.09	0.99

Mean±S.E.

Table 2 Effects of the supplemental UV-B on the yield and growth of radish

cultivar	plot	yield(fresh weight of edible root,g)	total dry weight (g)	root length (mm)	leaf area (cm²)
Shijunichi-daikon	treatment	383±16	41.6±1.9	307±10	2800±213
	control	350±17	39.7±2.3	298± 9	2723±237
	ratio	1.10	1.05	1.03	1.03
Taibyo-sobutori	treatment	559±22	52.8±1.3	257±18	4036±123
	control	586±27	54.6±1.7	263±18	4028± 90
	ratio	0.95	0.97	0.98	1.04
Kono-shogoin	treatment	367±26	55.3±2.6	109± 4	5354±298
	control	365±23	57.5±2.3	113± 4	5243±177
	ratio	1.00	0.96	0.97	1.02
Suikomi-ninengo	treatment	436±40	52.3±4.8	280±12	2940±197
	control	530±49	56.7±4.4	290± 7	3551±321
	ratio	0.82	0.92	0.96	0.83

Mean±S.E.

Table 3 Effects of the supplemental UV-B on the yield and growth of broccoli and cauliflower

cultivar	plot	yield(fresh weight of flower bud,g)	height of flower bud (mm)	diameter of flower bud (mm)	total dry weight (g)	leaf area (cm²)	specific leaf weight(mg/cm²)	No. of leaf
Masa-midori	treatment	205±20	123± 5	114±7	89.2±3.5	5710±247	8.9±0.2	20.6±0.4
	control	158±10	117± 4	106±3	86.2±1.8	5842±166	9.0±0.1	20.7±0.4
	ratio	1.30	1.05	1.08	1.04	0.98	0.99	0.99
Haitsu	treatment	80± 6	73± 3	96±4	115.8±4.4	6936±239	11.6±0.2	28.0±0.4
	control	103±16	75± 6	102±7	118.5±4.2	7999±175	10.4±0.3	27.4±0.4
	ratio	0.78	0.97	0.94	0.98	0.87	1.12	1.02
Bridal	treatment	161±20	72± 3	107±6	66.6±3.6	–	–	36.4±1.2
	control	154±15	90±14	108±6	61.5±4.6	–	–	35.7±0.5
	ratio	1.05	0.80	0.99	1.08	–	–	1.02
Shira-tama	treatment	100± 4	55± 1	100±1	18.3±1.1	–	–	25.1±0.6
	control	114± 4	56± 1	102±2	20.9±1.7	–	–	23.4±0.4
	ratio	0.88	0.98	0.98	0.87	–	–	1.07

Mean±S.E.