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Original Article

Rootstock control of fruit dieldrin concentration in grafted cucumber (*Cucumis sativus*)

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We examined the effect of *Cucurbita* sp. rootstock on dieldrin concentration in grafted cucumber (*Cucumis sativus* L.) fruits grown in two types of contaminated soils by pot experiment. The two soils consisted of an Andosol and a Brown Lowland soil and contained 319 and 89 μg dieldrin/kg on a dry weight basis, respectively. Dieldrin concentration in cucumber fruits grafted on low-uptake rootstock (*ca*. 14–40 μg/kg on a fresh weight basis) decreased by 50–70% compared with those grafted on high-uptake rootstock, for each case of two scion cultivars used. Dieldrin concentration in grafted cucumber fruits basically depended on the content in the aerial part, and not on the dieldrin distribution or the water content in the fruits. Selecting low-uptake rootstock is a promising practical technique to reduce dieldrin concentration in cucumber fruits grown in contaminated fields.

Keywords: dieldrin, cucumber, *Cucurbita* sp., grafting.

Introduction

Drins (aldrin, dieldrin and endrin) have been categorized as a group of persistent organic pollutants (POPs) because of their high toxicity, high bioaccumulation and persistency in the environment.[1)] Drins were used extensively in cultivated land in Japan from 1954 to 1971. The Japanese Government banned drin use for food crops in 1971; however, these compounds are still found in soils.[2,3)] The half-life of dieldrin in soils is relatively long (5–12 years)[4)]; therefore, the risk of drin residues being present in crops cultivated in contaminated soils might continue for years or even decades. Although drins have not been used in Japan on cultivated land for the past 30 years, dieldrin at residual concentrations exceeding the limit set by the Food Sanitation Law of Japan (0.02 ppm, fresh weight basis) has been detected in cucumbers produced in some agricultural areas.[3,5)]

About 80% of cucumber producers in Japan have adopted grafted cultivation, usually using *Cucurbita* sp. as a rootstock.[6)] In our previous study, we showed that dieldrin concentrations in the aerial parts of the grafted plants of various combinations of *Cucurbita* sp. rootstocks and cucumber scions were influenced by rootstock cultivars at an early growth stage.[7)] The objectives of this study were to confirm the effect of low-uptake rootstock cultivars on decreasing dieldrin concentration in grafted cucumber fruits at the maturing stage, and to examine the factors influencing dieldrin concentration in the fruits.

Materials and Methods

1. Soil

Two types of dieldrin-contaminated soils were used in the present study. One was an Andosol (Acrudoxic Hapludand) with a pH (H_2O) of 5.6, carbon content of 98.6 g/kg, a loam texture and a water-holding capacity (WHC) of 0.95 kg/kg. The other was a Brown Lowland soil (Dystric Eutrudept) with a pH (H_2O) of 6.2, carbon content of 16.0 g/kg, a clay loam texture and a WHC of 0.34 kg/kg. Soils were classified according to the criteria adopted by the Cultivated Soil Classification Committee[8)] and Soil Survey Staff.[9)] These soils were collected from the upper layer (0–15 cm) of soils in fields in the Kanto area (Andosol) and the Hokuriku area (Brown Lowland soil) that had been cultivated with cucumbers. Precise application records were not available, but these areas of the farms had received a regular application of drins for insect control from the late 1950s to the early 1970s. Both types of soils were air-dried, passed through a 2-mm sieve, and used

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for pot experiment and soil analysis.

2. Pot experiment

Plastic pots (volume 4.0 L; diam. 16 cm; height 20 cm) holding 1.8 kg of the Andosol and 3.3 kg of the Brown Lowland soil, respectively, were prepared. The soil in each pot was fertilized with a chemical fertilizer (0.4 g N as $(NH_4)_2SO_4$, 0.17 g P as $Ca(H_2PO_4)_2 \cdot H_2O$ and 0.33 g K as KCl) as basal dressing. Three cultivars of *Cucurbita* sp. (Shintosa-1gou, Hikaripower-gold and Yuyuikki-black) and two cultivars of cucumber (*Cucumis sativus* L.) (Sharp-1 and Natsubayashi) were included in the experiment. In our previous report,[7] dieldrin concentrations in the aerial tissues of *Cucurbita* sp. cultivars (Shintosa-1gou≥Hikaripower-gold>Yuyuikki-black) and cucumber cultivars (Sharp-1>Natsubayashi) grown in dieldrin-contaminated soil were quite different. Seeds of the test plants were germinated on perlite culture. Fourteen days (cucumber) and 11 days (*Cucurbita* sp.) after sowing, six grafted plants were created from the combination of three cultivars of *Cucurbita* sp. as rootstocks and two cultivars of cucumber as scions, and grown in perlite culture with nutrient solution (half the strength of Otsuka Chemical A-prescription (mg L^{-1}): N, 130; P, 26; K, 168; Ca, 82; Mg, 18; Mn, 0.6; B, 0.25; Fe, 1.35; Cu, 0.015; Zn, 0.045; Mo, 0.015) being applied every three days. Nineteen days after grafting, the grafted plants were transferred to pots (one plant per pot) of both soils on March 9, 2005. Three cultivars of *Cucurbita* sp. and two cultivars of cucumber with self-rooted (non-grafted) plants (one plant per pot) were also prepared. Twenty-two days after sowing followed by growing in perlite culture with nutrient solution in the same manner as described above, these were also transferred to soil pots on the same date. These grafted and non-grafted plants were then grown in a greenhouse at 25°C under natural light conditions. Three types of plants (grafted Sharp-1/Shintosa-1gou, and non-grafted Sharp-1 and Natsubayashi) were also grown in dieldrin-free Andosol. These soils were watered daily with tap water to about 60% of water-holding capacity. Additional fertilizer was applied fourteen times during the growing period to the soil in each pot as 300 mL of nutrient solution (one to two times the strength of Otsuka Chemical A-prescription). For example, the sum of the additional application of N was 1.65 g per pot. Test plants were pinched off at the eighteenth node on the main shoot, and then each first lateral shoot at the second node. Five cucumber fruits in each pot were harvested when they were of commercial size (about 100 g fresh weight), and the other young fruits were thinned as soon as possible. Fruits of the non-grafted *Cucurbita* sp. were harvested at the same time on May 12, 2005. Sixty-nine days after transferring the plants to the pots (on May 16, 2005), the aerial parts (leaf+stem) were harvested. All the plant experiments were replicated three times. Plant samples were chopped finely, mixed and divided into two subsamples. One was dried at 70°C to measure the moisture content, and the other was frozen and stored at −20°C until extraction for dieldrin content analysis. For every pot, fruit samples and leaf+stem composite samples were prepared separately. Each cucumber fruit was individually prepared, and all fruits of the non-grafted *Cucurbita* sp. per pot were composited.

3. Determination of transpiration amount

During the pot experiment described above, transpiration amounts of each pot were determined during a 24-hr period from April 18 to 19, and from April 27 to 28, 2005. After irrigation, each pot was weighed (including soil, test plant and supporting pole). Following the 24-hr period, each pot was weighed again before irrigation. Pots holding the same amount of soil without plants were prepared ($n=3$), watered to about 60% of water-holding capacity, and weighed in the same manner as above. The decrease in weight (kg) of each pot over 24 hr was measured. The transpiration amount (L) of each test plant per day was estimated by subtracting the decrease of pot weight (mean value) with the corresponding soil without plants from that of the cultivated pots.

4. Dieldrin analysis

Analytical methods for determining dieldrin concentration in soil and plant samples, and their quality control are described in detail in our previous report.[7] In brief, soil samples were Soxhlet-extracted with acetone for 16 hr. Plant samples were homogenized using a Polytron® PT3100 (Kinematica AG) with acetone. The soil and plant extracts were spiked with $^{13}C_{12}$-labeled dieldrin (Cambridge Isotope Laboratories) as the internal standard and were cleaned up with a florisil column (Mega Bond Elute FL, Varian) and a graphite carbon column (ENVI-Carb, Supelco). The cleaned-up samples were spiked with $^{13}C_{12}$-labeled 2,2′,4,4′,5,5′-hexachlorobiphenyl (Wellington Laboratories) as a syringe spike and were concentrated to 50 μL under a gentle stream of nitrogen.

The concentration of dieldrin in the soil and plant samples was determined with a gas chromatographic mass spectrometer (GC/MS) (HP6890-5973N, Agilent Technologies) equipped with an ENV-8MS column (30 m×0.25 mm i.d.×0.25 μm film thickness, Kanto Kagaku). The limits of quantitation (LOQs) for the dieldrin analyses were calculated according to the method of JIS K 0312.[10] The LOQ for the soils was 0.5 ng/g dry weight (dw). The LOQs for the fruits were 1.3 μg/kg fresh weight (fw) and 2.2 μg/kg fw for the leaf and stem parts.

5. Statistical analysis

All statistical analyses were performed using SPSS 12.0J for Windows® (SPSS Inc.). One-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test was used to determine which samples differed, using a pair-wise comparison matrix.

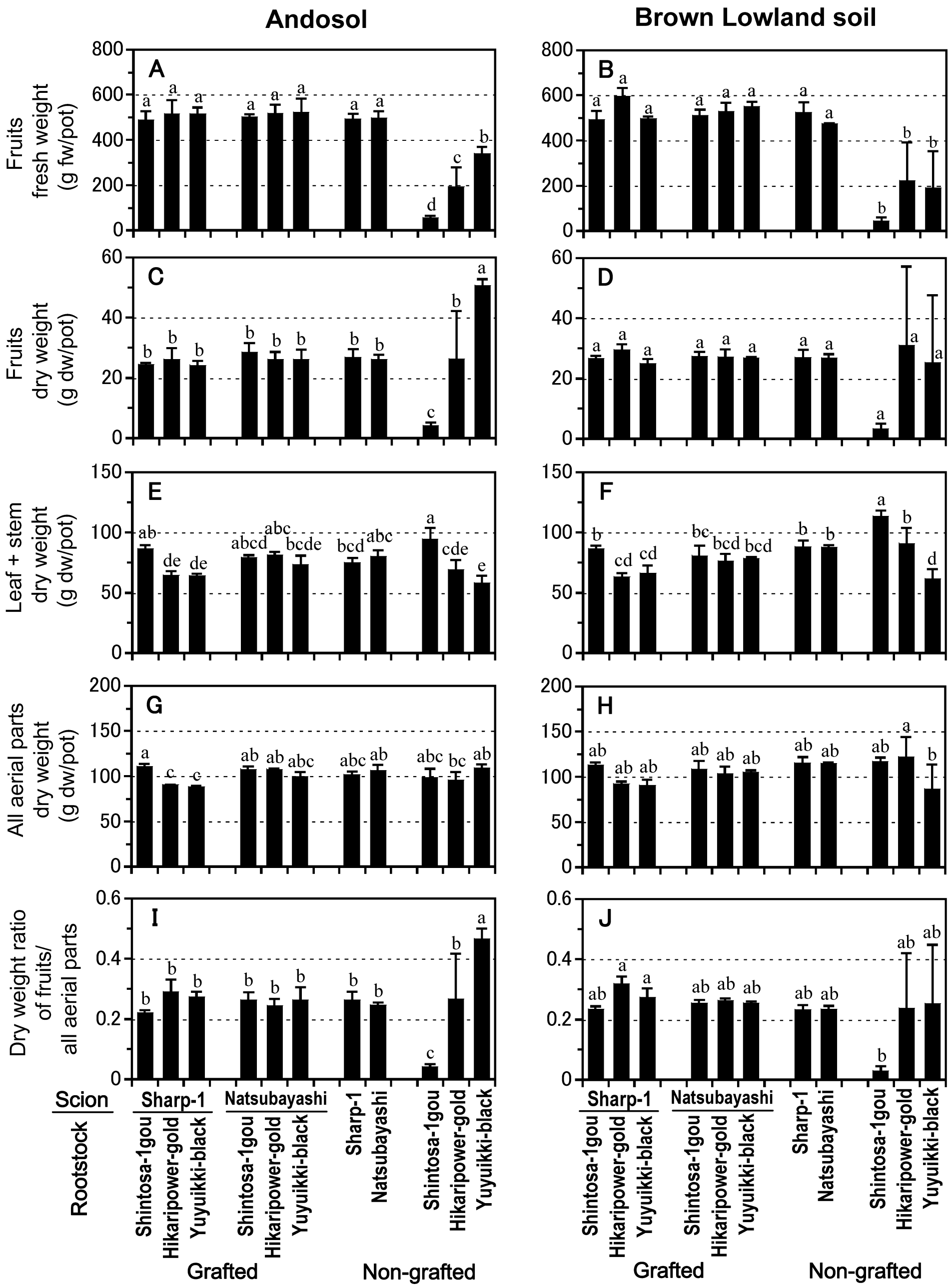

Fig. 1. (A, B) Fresh fruit weight, (C, D) dry fruit weight, (E, F) leaf and stem dry weight, (G, H) all aerial parts dry weight and (I, J) dry weight ratio of fruits per all aerial parts for six grafted and five non-grafted plants grown in Andosol (A, C, E, G, I) and Brown Lowland soil (B, D, F, H, J). Columns with the same letter are not significantly different at $P<0.05$ according to ANOVA/Tukey protected multiple range test. Error bars indicate standard deviations ($n=3$).

Results

1. Soil

Dieldrin concentrations of test soils were: Andosol 319 μg/kg dw and Brown Lowland soil 89 μg/kg dw, so the initial dieldrin amount of Andosol per pot was 574 μg and that of Brown Lowland soil was 294 μg.

2. Plant growth

Fresh weights of cucumber fruits per pot grown in both soils were nearly the same among tested plants (Fig. 1; A, B) as the sampling number was fixed to five fruits per pot and the size of the fruits was as uniform as possible. In practice, the fresh weight of the sampled cucumber fruits showed little variation (mean, 102.86 g; SD, 18.13 g; CV, 17.62%; $n=240$). The water content of the cucumber fruit was nearly the same among the tested plants (mean, 94.8%; SD, 0.7%), so the dry

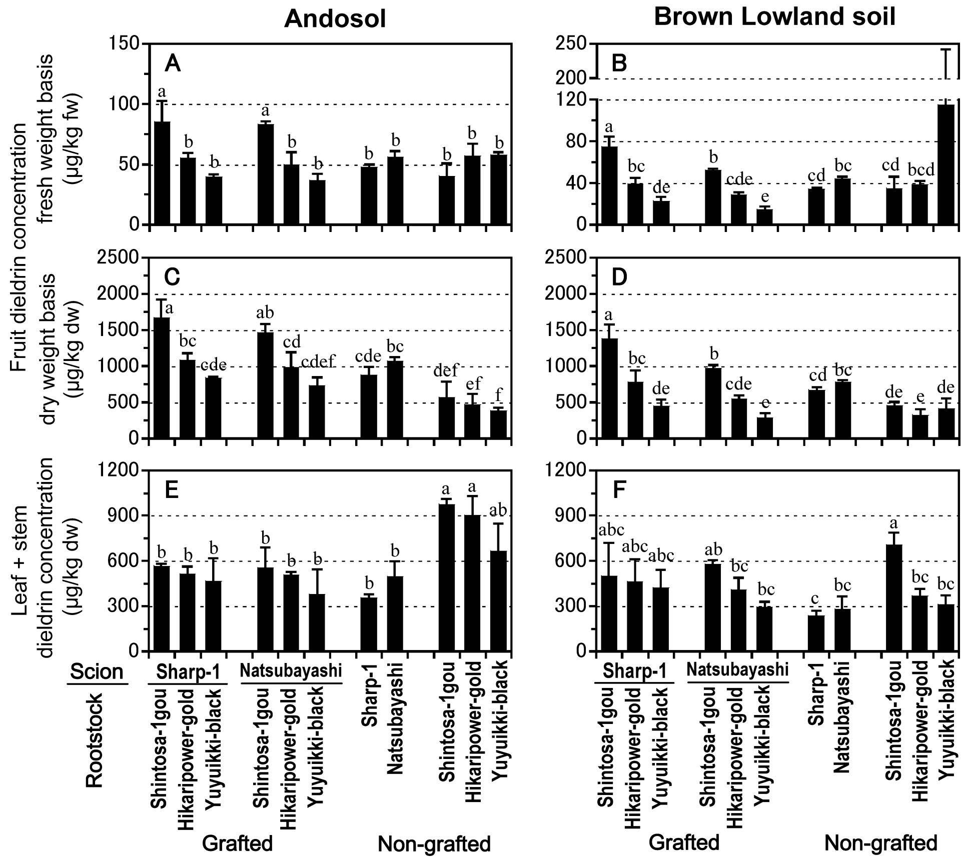

Fig. 2. Dieldrin concentrations of (A, B) fresh weight-based fruits, (C, D) dry weight-based fruits and (E, F) dry weight-based leaf and stem parts for six grafted and five non-grafted plants grown in Andosol (A, C, E) and Brown Lowland soil (B, D, F). Columns with the same letter are not significantly different at $P<0.05$ according to ANOVA/Tukey protected multiple range test. Data of non-grafted Yuyuikki-black in (B) were not used for statistical analysis. Error bars indicate standard deviations ($n=3$).

weights were also the same (Fig. 1; C, D). The dry weights of the leaf and stem parts, and those of all aerial parts (fruit+leaf and stem) in Sharp-1/Hikaripower-gold and Sharp-1/Yuyuikki-black were a little lower (Fig. 1; E–H). The dry weight ratios of fruit per all aerial parts were the same among grafted and non-grafted cucumber plants (Fig. 1; I, J). Though fruit fresh and dry weights of non-grafted *Cucurbita* sp. were different among the three cultivars, the dry weights of all aerial parts were nearly the same as those of the grafted and non-grafted cucumber plants. Thus, the growth of the aerial parts among all tested plants grown in both soils was nearly uniform, and the fruiting condition among grafted and non-grafted cucumber plants was also uniform.

3. *Dieldrin concentration in cucumber fruits*

Among the grafted plants that used Sharp-1 as the scion cultivar, fresh weight-based dieldrin concentration of cucumber fruits was highest in plants grafted on Shintosa-1gou, medium in those grafted on Hikaripower-gold and lowest in those grafted on Yuyuikki-black, grown in Andosol and Brown Lowland soil (Fig. 2; A, B). The dieldrin concentration of non-grafted Sharp-1 plants was nearly the same as that of plants grafted on Hikaripower-gold. Among the grafted plants using Natsubayashi as a scion cultivar, the concentration was also highest in plants grafted on Shintosa-1gou, medium in those grafted on Hikaripower-gold and lowest in those grafted on Yuyuikki-black, grown in both soils. The concentration of non-grafted Natsubayashi plants was ranked between those grafted on Shintosa-1gou and those grafted on Hikaripower-gold. Between the two cultivars of non-grafted cucumber, the concentration of Natsubayashi was a little higher than that of Sharp-1, though there was no significant difference ($P<0.05$). The dieldrin concentrations of non-grafted *Cucurbita* sp. fruits were nearly the same among the three cultivars except for Yuyuikki-black grown in Brown Lowland soil. Among the three non-grafted Yuyuikki-black plants, one plant bore very poor fruits that did not thicken and dried up, continuing in such condition until the plant harvest. The concentration of dieldrin in non-grafted Yuyuikki-black plants was not reliable because the water content of the fruits showed large variation among the replications; therefore, statistical analysis of fresh weight-based dieldrin concentration was performed without the data of non-grafted Yuyuikki-black plants. The dry weight-based dieldrin concentration of cucumber fruits

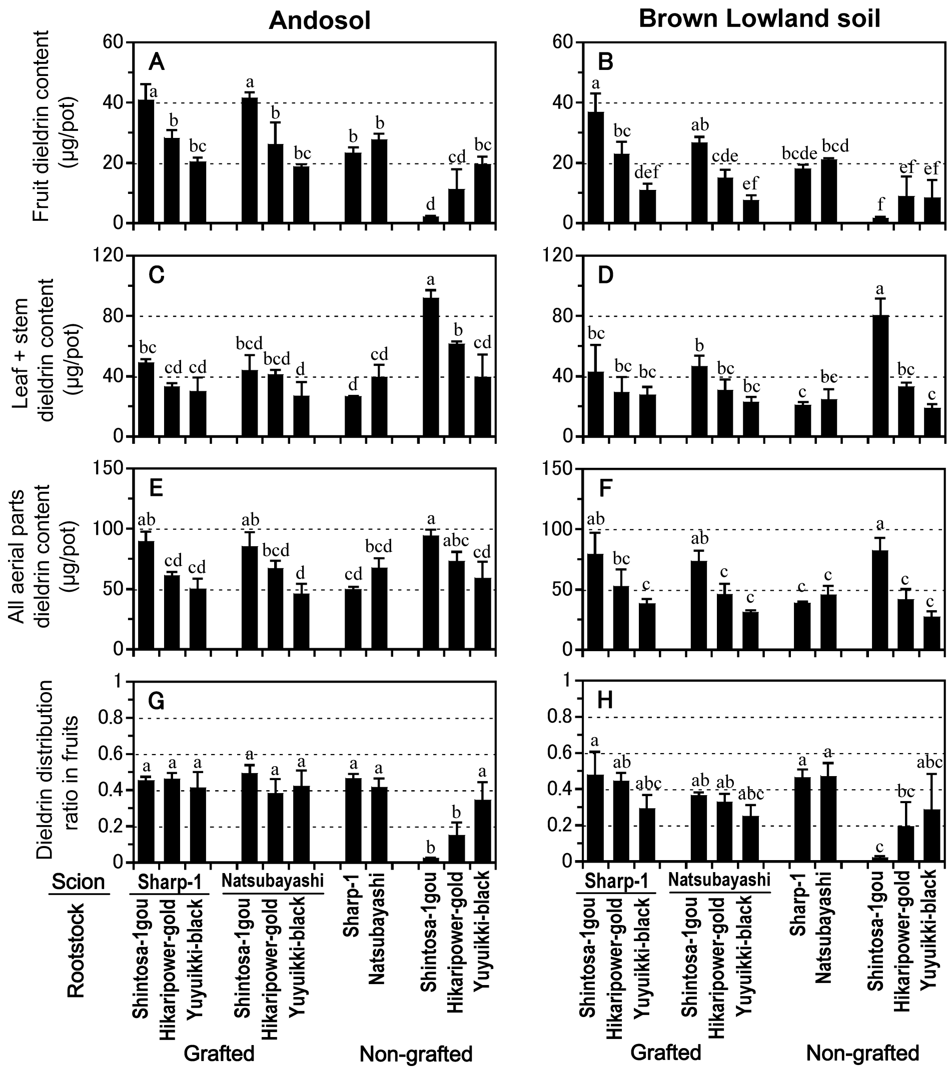

Fig. 3. Dieldrin contents in (A, B) fruits, (C, D) leaf and stem parts and (E, F) all aerial parts, and dieldrin distribution ratio in (G, H) fruits for six grafted and five non-grafted plants grown in Andosol (A, C, E, G) and Brown Lowland soil (B, D, F, H). Columns with the same letter are not significantly different at $P<0.05$ according to ANOVA/Tukey protected multiple range test. Error bars indicate standard deviations ($n=3$).

showed the same trend as that of fresh weight-based concentration, because the water content was almost the same (Fig. 2; C, D). The dieldrin concentration of the *Cucurbita* sp. fruits was not much different among the three cultivars.

Dieldrin concentration (dry weight basis) of the leaf and stem parts of the grafted cucumber plants showed the same trend as that of fruits, that is, highest in plants grafted on Shintosa-1gou, medium in plants grafted on Hikaripower-gold and lowest in plants grafted on Yuyuikki-black, though they were not significantly different ($P<0.05$) (Fig. 2; E, F). Among the non-grafted *Cucurbita* sp. plants, the dieldrin concentration tended to decrease in the order of Shintosa-1gou≥Hikaripower-gold≥Yuyuikki-black. In all of the plants grown in dieldrin-free Andosol, the concentrations of dieldrin in the fruits, and leaf and stem parts were below the LOQs.

4. *Dieldrin content of aerial parts*

Similar patterns were observed for the dieldrin contents of the fruits (Fig. 3; A, B), leaf and stem parts (Fig. 3; C, D), and all aerial parts (Fig. 3; E, F) among grafted and non-grafted cucumber plants, because the plant biomass was nearly the same among the tested plants (Fig. 1); that is, the dieldrin contents of the fruits, leaf and stem parts, and all aerial parts were highest in plants grafted on Shintosa-1gou, medium in plants grafted on Hikaripower-gold and lowest in plants grafted on Yuyuikki-black, using either Sharp-1 or Natsubayashi as a scion cultivar, grown in both Andosol and Brown Lowland soil. The aerial dieldrin content of non-grafted Sharp-1 was nearly the same as that of Sharp-1/Yuyuikki-black, and that of non-grafted Natsubayashi was nearly the same as that of Natsubayashi/Hikaripower-gold. Among the non-grafted *Cucurbita* sp., the fruits dieldrin content of Shintosa-1gou was low

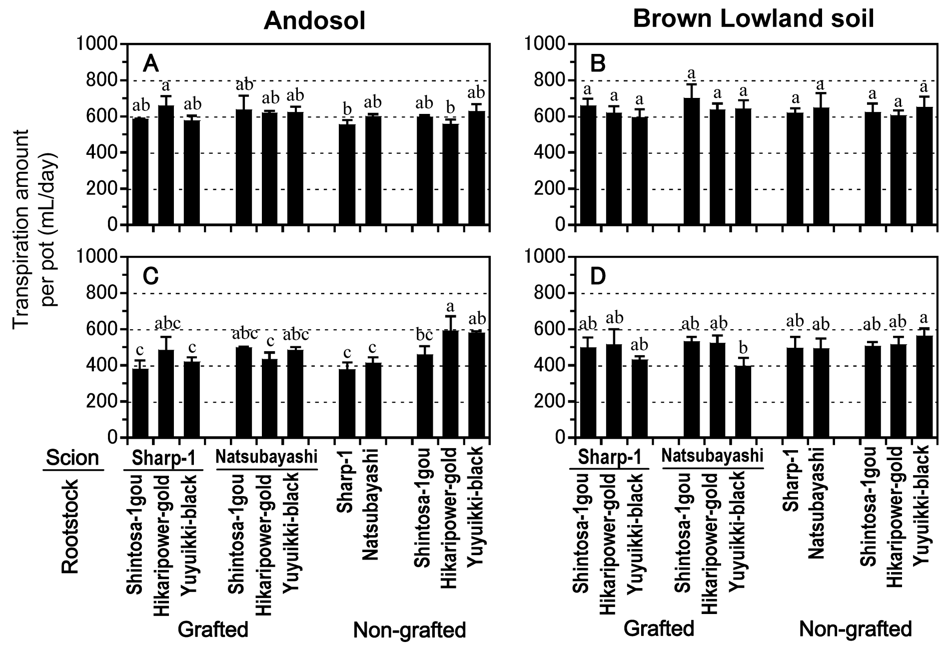

Fig. 4. (A, B) Transpiration amounts per 24 hr from April 18 to 19 and (C, D) from April 27 to 28 for six grafted and five non-grafted plants grown in Andosol (A, C) and Brown Lowland soil (B, D). Columns with the same letter are not significantly different at $P<0.05$ according to ANOVA/Tukey protected multiple range test. Error bars indicate standard deviations ($n=3$).

because of poor fruit yield; however, leaf and stem dieldrin content was the highest because of good growth. Consequently, all aerial dieldrin contents tended to decrease in the order of Shintosa-1gou≥Hikaripower-gold≥Yuyuikki-black.

The dieldrin content of all aerial parts was nearly equal among plants with the same cultivar root part (grafted Sharp-1, grafted Natsubayashi, or non-grafted *Cucurbita* sp.): plants grafted in Andosol (Fig. 3; E) on Shintosa-1gou (*ca*. 90 μg/pot), Hikaripower-gold (*ca*. 60–70 μg/pot) and Yuyuikki-black (*ca*. 50–60 μg/pot); and plants grafted in Brown Lowland soil (Fig. 3; F) on Shintosa-1gou (*ca*. 70–80 μg/pot), Hikaripower-gold (*ca*. 40–50 μg/pot) and Yuyuikki-black (*ca*. 30–40 μg/pot). The contents in plants grown in Andosol tended to be 1.2–1.5 times greater than in the corresponding plants grown in Brown Lowland soil.

The dieldrin distribution ratio in fruits was calculated based on the proportion of dieldrin contents in fruits to the contents in all aerial parts (Fig. 3; G, H), and was found to be nearly the same, about 40–50% of the dieldrin contents in all aerial parts among grafted and non-grafted cucumber plants grown in Andosol. The same trend was observed in plants grown in Brown Lowland soil, except that the dieldrin content of plants grafted on Yuyuikki-black was a little lower.

5. *Transpiration amount*

Over a 24-hr period from April 18 to 19, 2005, transpiration amounts per pot were nearly the same (*ca*. 600–700 mL/day) among tested plants grown in both soils (Fig. 4; A, B). Over a 24-hr period from April 27 to 28, 2005, the amounts were a little lower (*ca*. 400 mL/day) in some plants, Sharp-1/Shintosa-1gou, Sharp-1/Yuyuikki-black, Natsubayashi/Hikaripower-gold, and non-grafted Sharp-1 and Natsubayashi grown in Andosol (Fig. 4; C) and Sharp-1/Yuyuikki-black and Natsubayashi/Yuyuikki-black grown in Brown Lowland soil (Fig. 4; D), compared to that of the others (*ca*. 500–600 mL/day). Among plants grafted on the same rootstock, the transpiration amounts were not significantly different for either measurement period or soil.

Discussion

We already reported that dieldrin concentration in the aerial parts of grafted cucumber plants mainly depended on the rootstock cultivars in the early growth stage.[7] In this study, using the scions of two cucumber cultivars, Sharp-1 and Natsubayashi, fresh weight-based dieldrin concentration in the fruits was highest in plants grafted on Shintosa-1gou, medium in those grafted on Hikaripower-gold and lowest in those grafted on Yuyuikki-black, grown in both Andosol and Brown Lowland soil (Fig. 2; A, B). This order of rootstock *Cucurbita* sp. cultivars matched well the results of our former study using grafted plants in the early growth stage[7]; therefore, the phenomenon of rootstock controlling dieldrin concentration in the shoots of young grafted plants is also applicable to controlling dieldrin concentration in the fruits in the maturing stage. These results suggest that the comparison of dieldrin uptake in young grafted plants is a useful way to screen for and select rootstock effective for reducing dieldrin concentration in cucumber fruits.

Three factors affecting fresh weight-based dieldrin concentration in cucumber fruits were considered, namely, 1) plant dieldrin uptake in the aerial parts, 2) dieldrin distribution in the fruits, and 3) water content in the fruits. Among these potential factors, the effect of water content on cucumber fruits was unlikely because the amounts were the same among the tested plants. In practice, dry weight-based dieldrin concentration of cucumber fruits showed the same trend as for fresh weight-based concentration (Fig. 2; C, D). Therefore, the differences in fresh weight-based dieldrin concentration in cucumber fruits were not caused by differences in fruit water content.

Considering the other two possibilities, dieldrin contents in all aerial parts (fruits+leaf and stem parts) followed the same trend as for the dieldrin concentration of cucumber fruits among the grafted plants (Shintosa-1gou≥Hikaripower-gold≥Yuyuikki-black). On the other hand, dieldrin distribution in the fruits was similar (*ca*. 40–50% of all aerial parts) among grafted and non-grafted cucumber plants grown in Andosol (Fig. 3; G) and also those grown in Brown Lowland soil except for plants grafted on Yuyuikki-black, which showed low distribution (*ca*. 30%) (Fig. 3; H); however, even in exceptional cases, fruit dieldrin concentration seemed to be much more affected by the differences in dieldrin content in all aerial parts than the distribution; that is, for plants grown in Brown Lowland soil, fresh weight-based dieldrin concentration of cucumber fruits in Sharp-1 (22.4 μg/kg) and Natsubayashi (14.2 μg/kg) grafted on Yuyuikki-black was 70% less than that in Sharp-1 (74.7 μg/kg) and Natsubayashi (52.3 μg/kg) grafted on Shintosa-1gou, respectively. On the other hand, dieldrin content in all aerial parts of Sharp-1 (38.5 μg) and Natsubayashi (30.8 μg) grafted on Yuyuikki-black was about 50% less than that in Sharp-1 (79.5 μg) and Natsubayashi (73.4 μg) grafted on Shintosa-1gou; however, the difference in dieldrin distribution in fruits was 10–20% at most in these cases. Therefore, dieldrin concentration in grafted cucumber fruits basically depended on the contents in the aerial parts. The agreement of the rootstock effect on controlling dieldrin concentration in the shoots of young grafted plants with that on fruit dieldrin concentration is consistent with the result that fruit dieldrin concentration is not affected by distribution in the aerial parts.

It was noteworthy that the dieldrin content of all aerial parts was nearly equal among plants with the same cultivar root parts (grafted Sharp-1, grafted Natsubayashi and non-grafted *Cucurbita* sp.). This result suggests that dieldrin uptake in aerial parts is dependent on the characteristics of the root cultivars, regardless of the aerial cultivars. As dieldrin concentrations in the fruits, and the leaf and stem parts were below the LOQs in all of the plants grown in dieldrin-free Andosol, the influence of airborne dieldrin on the aerial parts was negligible; thus, dieldrin determined in the aerial parts of the plants was absorbed and translocated from the contaminated soil *via* the roots. Consequently, the ability of dieldrin uptake (absorption from soil and translocation to the aerial parts) seems to be different among root part cultivars, and the dieldrin content in the aerial parts and the concentration in fruits strongly depended on the root part cultivars. In our previous report, some cultivars were observed with lower dieldrin uptake than Yuyuikki-black (a low-uptake type of rootstock) in screening using 34 *Cucurbita* sp. cultivars[11]; thus, it is promising that a rootstock for grafting cucumber with very low uptake of dieldrin can be created by breeding.

Cucurbits demonstrated superior dieldrin uptake ability from soil among various plant families.[11] Cucurbits also take up other organochlorine pollutants, such as heptachlor,[12] chlordane,[13] DDE (a metabolite of DDT in soils),[14] and polychlorinated dibenzo-*p*-dioxins and dibenzofurans[15]; therefore, cucurbits seem to have characteristic mechanisms facilitating the uptake of hydrophobic chemicals such as POPs from soil. Though the mechanisms are unclear at present, it has been speculated that the high transpiration ability of cucurbits is related to their high dieldrin uptake ability.[16] In our results, however, the transpiration amounts were almost the same, being not as much in Shintosa-1gou plants of as root parts which showed the highest dieldrin contents among the tested cultivars (Fig. 4); therefore, transpiration ability could not explain the differences in dieldrin contents in the aerial parts among tested plants.

It was interesting that plants grown in Andosol have only 1.2 to 1.5 times greater dieldrin content than those grown in Brown Lowland soil (Fig. 3; E, F), although the dieldrin of Andosol is 3.6 times the concentration in soil and two times the content in pots of Brown Lowland soil. This result suggests that dieldrin bioavailability (in this case, plant uptake) of Andosol is lower than that of Brown Lowland soil. It is known that soil organic matter affects the reduction in the bioavailability of hydrophobic organic contaminants in soils.[17] Because of the six times greater carbon content in Andosol than in Brown Lowland soil, Andosol held the dieldrin much more strongly and seemed to restrict transferability to the tested plants, even though there was a higher concentration of dieldrin; therefore, the risk of dieldrin contamination in cucumber plants may be greater in soil which has a low carbon content with the same dieldrin concentration.

Dieldrin concentration in cucumber fruits grafted on Yuyuikki-black (*ca*. 14–40 μg/kg on a fresh weight basis) decreased by 50–70% compared with those grafted on Shintosa-1gou, and by 30–50% compared with those grafted on Hikaripower-gold. In our study, fresh weight-based dieldrin concentration in cucumber fruits was over the limit set by the Food Sanitation Low of Japan (0.02 ppm) even in plants grafted on Yuyuikki-black; therefore, the selection of rootstock for reducing dieldrin contamination in cucumber fruits seems appropriate where soil contamination is slight. Moreover, the technique, only changing rootstock cultivars to the low-uptake type, is an inexpensive way compared to soil dressing, plowing to replace surface soil with subsoil, and applying active carbon or organic matter to soil.[18] In conclusion, selecting low-uptake rootstock cultivars is a promising practical technique to reduce dieldrin concentration in cucumber fruits grown in contaminated fields.

Acknowledgments

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