# DIFFERENTIAL UPTAKE OF DIELDRIN FROM SOIL BY SEVERAL PLANT FAMILIES AND VARIETIES FOR CUCUMBER CULTIVATION

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**Abstract**
Dieldrin uptake of thirty two crops (including seventeen families) from a contaminated soil was examined. Among tested crops, cucurbits took up more dieldrin than the other families, and the uptake of zucchini (*Cucurbita pepo* var. *melopepo*) was the highest. Apart from the cucurbits, the uptake of the other sixteen families was negligible. These results suggest that cucurbits, especially zucchini, would make good candidates for phytoremediation, and non-cucurbits would make substitute crops in dieldrin contaminated fields. The effect of grafting on dieldrin uptake was also examined. Sixteen kinds of grafted plants were prepared by combining of four *Cucurbita* varieties as rootstocks and four cucumber (*Cucumis sativus* L.) varieties as scions, and then compared dieldrin uptake in the shoots. Dieldrin uptake by the grafting plants depended not on the scion varieties, but mainly on the rootstocks. We ensured the effect of rootstocks on dieldrin concentration in grafted cucumber fruits grown in a contaminated soil. Dieldrin concentration in cucumber fruits grafted on low-uptake rootstock decreased by 50–70 % compared with those grafted on high-uptake one, for each case of two scion varieties used. Selecting low-uptake rootstock is a promising practical technique to reduce dieldrin concentration in cucumber fruits grown in contaminated fields.

## Introduction
“Drins” (aldrin, dieldrin, and endrin), organochlorine pesticides included in the group of persistent organic pollutants (POPs), were used extensively in Japan. Because of the extreme persistence of drins in soils, and their accumulation in agricultural products poses a potential threat to human health, the Japanese Government banned drin use in food crops in 1971. However, because of the long half-lives (5–12 years) of dieldrin in soils[1], the risk of residue being in crops grown in contaminated soils might continue for years or decades yet. Although drins have not been used in Japan on arable lands for the past 30 years, dieldrin at concentrations exceeding the limit set by the Food Sanitation Law of Japan (dieldrin: 0.02 mg $kg^{-1}$-fw) have been detected in cucumber fruits produced in some areas[2]. Therefore, immediate measures need to be taken against this problem.

The objectives of this study were to compare dieldrin uptake ability among several crops grown in a contaminated soil in order to select candidates as substitute (low uptake) and phytoremediation (high uptake) crops. One of the strategies for reducing the risks of hazardous chemicals in food is to use varieties that accumulate less of the chemicals. About 80% of cucumber producers in Japan have adopted grafted cultivation, and usually *Cucurbita* spp. is used as a rootstock. It is important to know which is the main contributor to dieldrin uptake from the soil: the rootstock or the scion. Therefore, we determined varietal differences in the uptake of dieldrin among cucumber varieties used as scions and *Cucurbita* spp. as rootstocks, and to assess the comparative effect of scion vs. rootstock on the uptake of dieldrin from a contaminated soil.

## Materials and Methods
A contaminated soil (Andosol) with dieldrin collected from a field cultivated with cucumber was used for the small pot experiments. In the soil, dieldrin content was 594 µg $kg^{-1}$. Thirty two crops (including seventeen families) (see Fig. 1) were used for screening of high or low dieldrin uptake crops from the soil. Seeds were germinated in perlite culture. After 2-6 weeks of seedling growth, plants were transferred to small plastic pots (volume 400 mL) holding 270 g of the soil, grown for 25 days in a glasshouse at 25$^{o}$C under natural light condition, and harvested the shoots for dieldrin analysis.

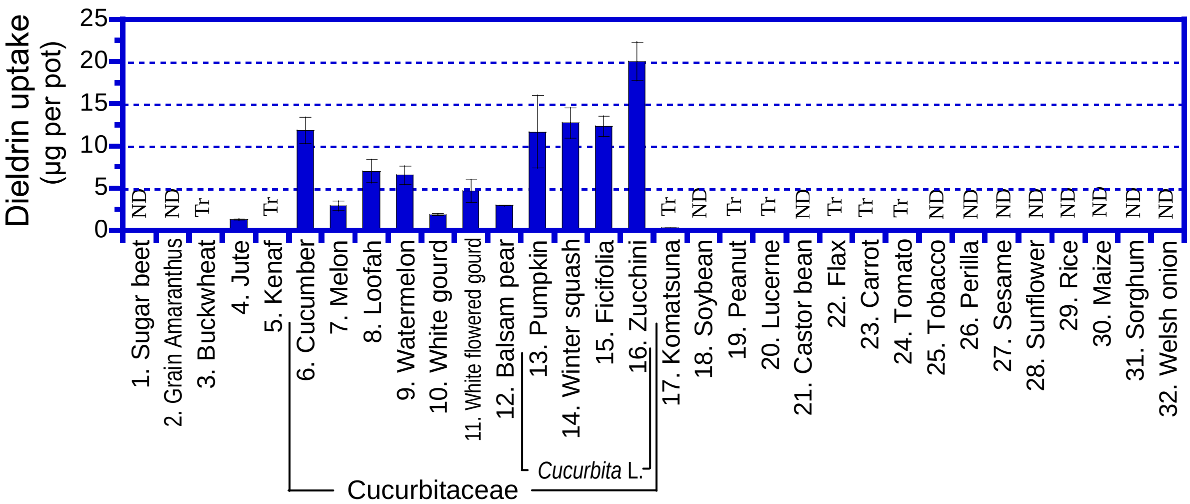
Four varieties of *Cucurbita* L. and *Cucumis sativus* L. (cucumber), respectively (see Fig. 2a), were used for examining of dieldrin uptake effect in grafting. Seedlings of eight varieties were germinated, and sixteen kinds of grafting plants were made up of the combination of four varieties of *Cucurbita* L. as rootstocks and four varieties of cucumber as scions (see Fig. 2b) in perlite culture. After 18 days of the grafting seedlings growth, these plants were transferred to plastic pots filled with the contaminated soil as previously described, grown for 18 days, and harvested the shoots for dieldrin analysis. To confirm the effect of low-uptake rootstock varieties in decreasing dieldrin concentration in fruits of grafted cucumber at the maturing stage, six grafted plants were created from the combination of three varieties of *Cucurbita* sp. as rootstocks and two varieties of cucumber as scions (see Fig. 3), transferred to plastic pots (volume 4.0 L) holding 1.8 kg of the other contaminated Andosol (dieldrin 319 µg $kg^{-1}$), and grown for 69 days in a glasshouse at 25°C under natural light condition. Five cucumber fruits in each pot were harvested for dieldrin analysis when they were of commercial size (about 100 g fresh weight).

Plant samples (shoots or fruits) were extracted with acetone. The extract was dissolved in *n*-hexane, purified with florisil and graphited carbon black, and dieldrin was measured with a gas chromatograph equipped with a mass spectrometer[3].

**Results and Discussion**

*Screening of crops with high or low dieldrin uptake ability*

In our screening of plants of 17 families, only cucurbits (Cucurbitaceae) took up considerable amounts of dieldrin in their shoots (Fig. 1). Jute (Tiliaceae) took up a little, and the other families absorbed them negligibly. Zucchini, which took up the most, took up 20 µg dieldrin per pot. This amount corresponded to 12.5 % of the dieldrin (160 µg per pot) in the soil. Therefore, cucurbits, especially zucchini, would be candidates as cleaning crops for phytoremediation in contaminated fields. But because this result was obtained from a small scale pot experiment using young plants, we must confirm the effect in field experiments. It was reported that dieldrin residues in edible parts of non-cucurbit vegetables were minor[4]. Our results are in agreement with the study, and it is important that various crops of 15 families were confirmed to be non-accumulator of dieldrin in their shoots. Therefore, it appears to be safe to grow non-cucurbit crops (although nalta jute [*Corchorus olitorius* L.], known as *mulukhiya*, is grown as an edible crop) in dieldrin-contaminated fields.




1. Chenopodiaceae, 2. Amaranthaceae, 3. Polygonaceae, 4.Tiliaceae, 5. Malvaceae
6-16. Cucurbitaceae
[6,7. *Cucumis* L., 8. *Luffa* Mill., 9. *Citrullus* Schrad., 10. *Benincasa* Savi, 11. *Legenaria* Ser., 12. *Momordica* L., 13-16. *Cucurbita* L. (13. *C. moschata*, 14. *C. maxima*, 15. *C. ficigolia*, 16. *C. pepo*) ]
17. Brassicaceae, 18-20. Leguminosae, 21.Euphorbiaceae, 22.Linaceae, 23.Umbelliferae
24,25. Solanaceae, 26. Labiatae, 27. Pedaliaceae, 28. Compositae, 29-31. Gramineae, 32.Liliaceae

Fig. 1. Dieldrin uptake by crops grown in a contaminated soil.
Bars denote standard deviations (*n*=3). ND, under detection limits ; Tr, above detection limits and under quantitation limits.

Although there were significant differences in dieldrin uptake among cucurbits, every eleven species including seven genera could take up dieldrin more or less. This result suggests that cucurbits in common have characteristic ability to absorb dieldrin from soils. Cucurbits also take up other organochlorine pollutants, such as heptachlor[5], chlordane[6], DDE (metabolite of DDT in soils)[7], and polychlorinated dibenzo-*p*-dioxins and dibenzofurans[8]. Therefore, cucurbits seem to have characteristic mechanisms facilitating the uptake of hydrophobic chemicals such as POPs from soils.

*Effect of grafting on dieldrin uptake in cucumber*

For a grafting experiment, four varieties of *Cucurbita* L. (A, B, C, D) as rootstocks and *Cucumis* sativus L. (cucumber) (a, b, c, d) as scions, respectively, were used (Fig. 2a). The ability of dieldrin uptake from the contaminated soil was significantly different among *Cucurbita* (about three times) and cucumber (two times) varieties, respectively. The effect of grafting on dieldrin uptake was examined by using combination of four *Cucurbita* varieties as rootstocks and four cucumber varieties as scions (4 x 4 = 16 grafting plants). Dieldrin uptake by the grafting plants tended to depend not on scions but on rootstocks (Fig. 2b). On dieldrin uptake, interaction effect between two factors, one was rootstock varieties and another was scion ones, was not significant ($p > 0.05$) by two-way ANOVA. And then differences among means of dieldrin uptake by the rootstock varieties and that by the scion ones were analyzed using Turkey's test (Fig. 2c). On the effect of four *Cucurbita* varieties using as rootstocks on dieldrin uptake by grafting plants, the tendency was similar (A > B ≥ C ≥ D) to that of *Cucurbita* varieties themselves. As for scions, on the other hands, the differences in the four scions could not be regarded as significant. This result indicated that dieldrin uptake on grafting plants was controlled not by scion parts but by rootstock parts.

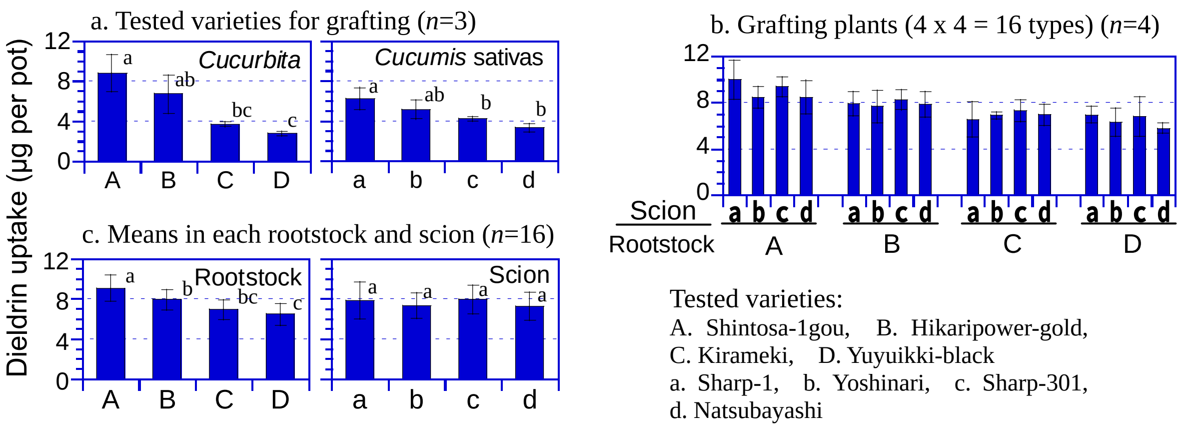



Fig. 2. Dieldrin uptake by individual varieties using for grafting (a), grafting plants (b), and means of uptake in each variety of rootstocks and scions (c). Bars denote standard deviations. Means with the same letter (a, b, c) beside bars tops in each graph are not significantly different ($p < 0.05$) according to an ANOVA-protected Tukey's multiple range test.

Then we ensured the effect of rootstock on dieldrin concentration in fruits of grafted cucumber grown in a contaminated soil by a pot experiment. Dieldrin uptake in the shoots of grafted plants mainly depended on the rootstock varieties in the early growth stage as described above. In this experiment, using the scions of two cucumber varieties, fresh weight based dieldrin concentration in the fruits was highest in plants grafted on A, medium in those grafted on B and lowest in those grafted on D grown in a dieldrin contaminated Andosol (Fig. 3). This order of rootstock *Cucurbita* sp. varieties matched well the results of our former observation using grafted plants in the early growth stage (Fig. 2b, c). Therefore, the phenomenon of rootstock controlling dieldrin uptake in the shoot of young grafted plants is also applicable to controlling dieldrin concentration in the fruits in the maturing stage. These results suggest that 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. 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 mg $kg^{-1}$) even in the plants grafted on D. Therefore, the selection of rootstock for reducing dieldrin contamination in cucumber fruits seems appropriate where soil contamination is slight. Because the technique, only changing rootstock varieties 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[9], selecting low-uptake type of rootstock varieties is a promising practical technique to reduce dieldrin concentration in cucumber fruits grown in the contaminated fields.

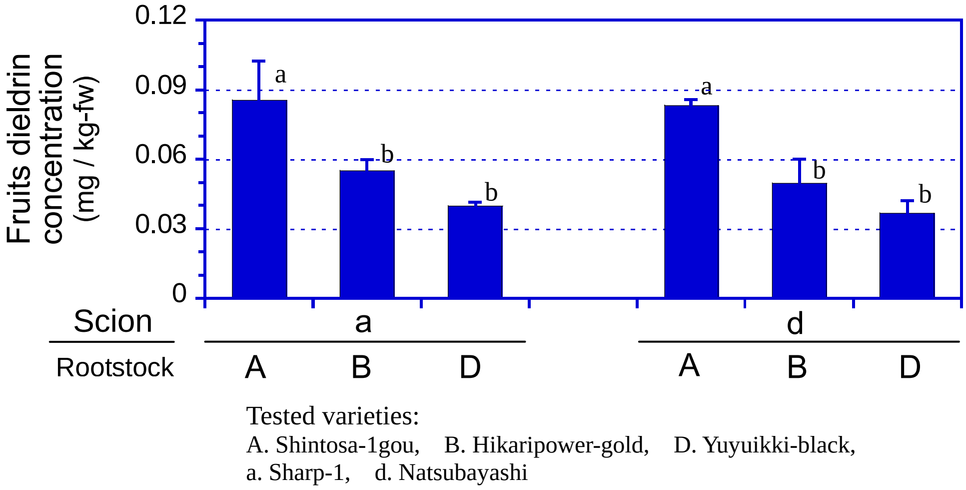



Fig. 3. Dieldrin concentrations of fresh weight based cucumber fruits for six grafted plants grown in a contaminated soil. Columns with the same letter are not significantly different at $P < 0.05$ according to ANOVA/Tukey protected multiple range test. Error bars indicate standard deviation ($n$=3).

**Acknowledgements**

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