temporary translation

NEA International Workshop on Post-Accident Food Safety Science

Mechanisms of Radioactive Material Absorption and Measures for Fruit Trees

Fukushima Agricultural Technology Centre-
National Institute of Fruit Tree Science

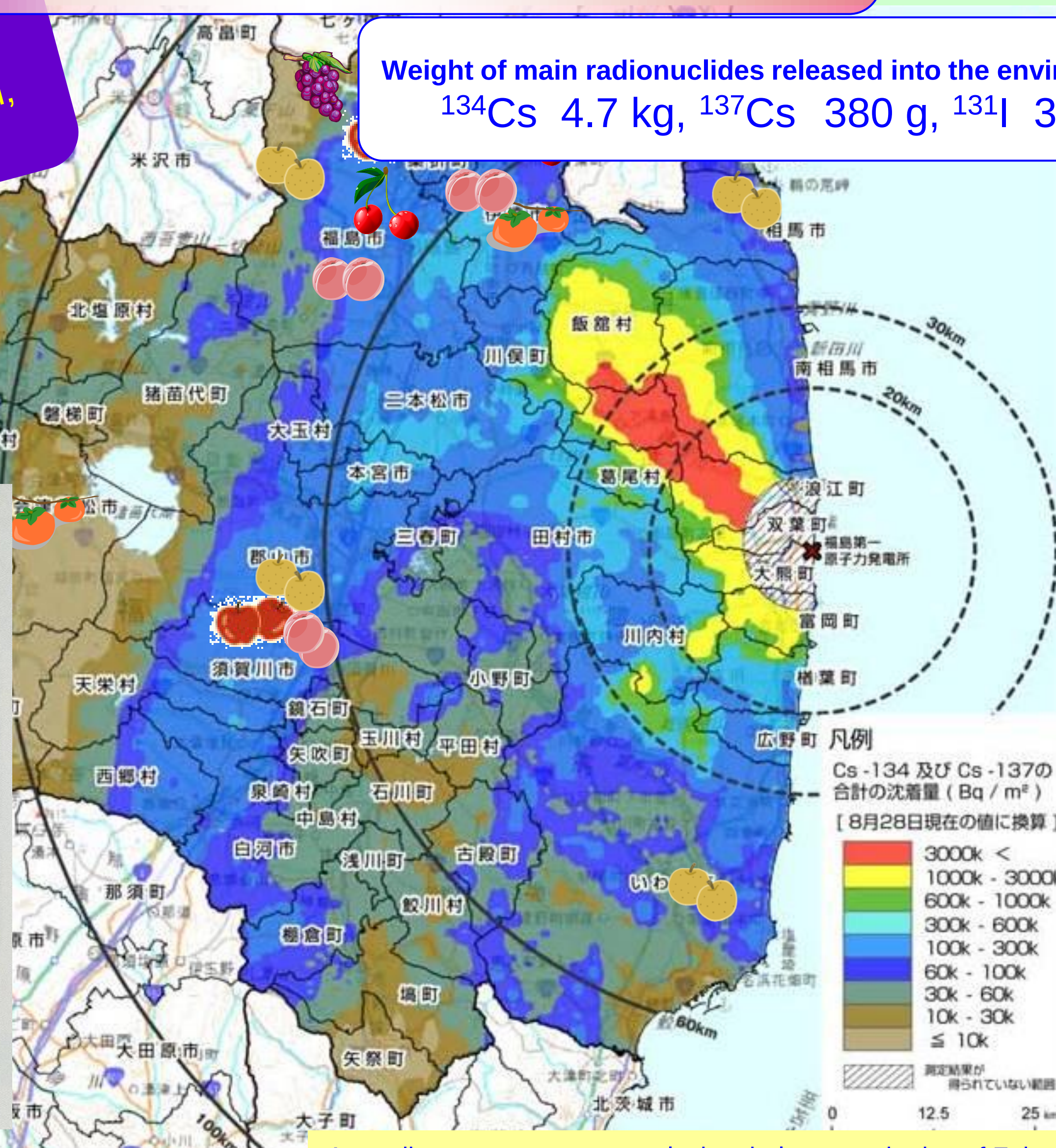
Radiation pollution status of major fruit production areas in Fukushima

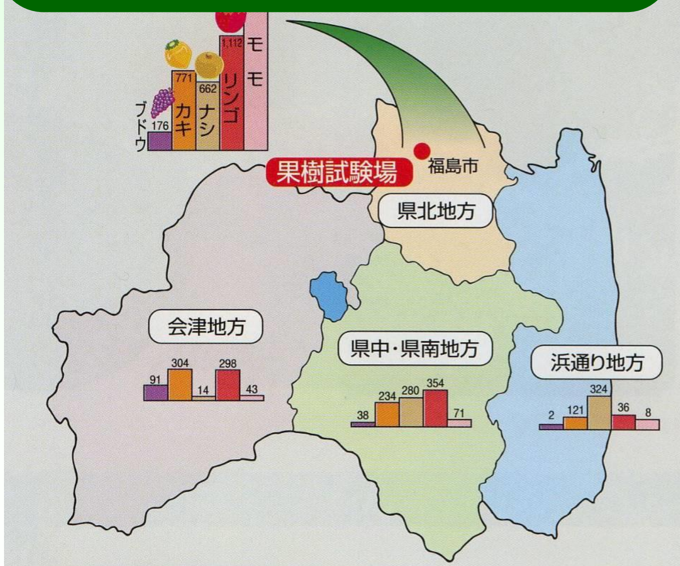
Fukushima is a major production prefecture of deciduous fruit trees following Aomori, Nagano, Yamanashi, and Yamagata

Weight of main radionuclides released into the environment
^{134}Cs 4.7 kg, ^{137}Cs 380 g, ^{131}I 35 g

Ranking of fruit by prefecture

Peach	2nd	Persimmon	4th
Apple	6th	Sweet Cherry	6th
Japanese Pear	3rd	Grape	12th





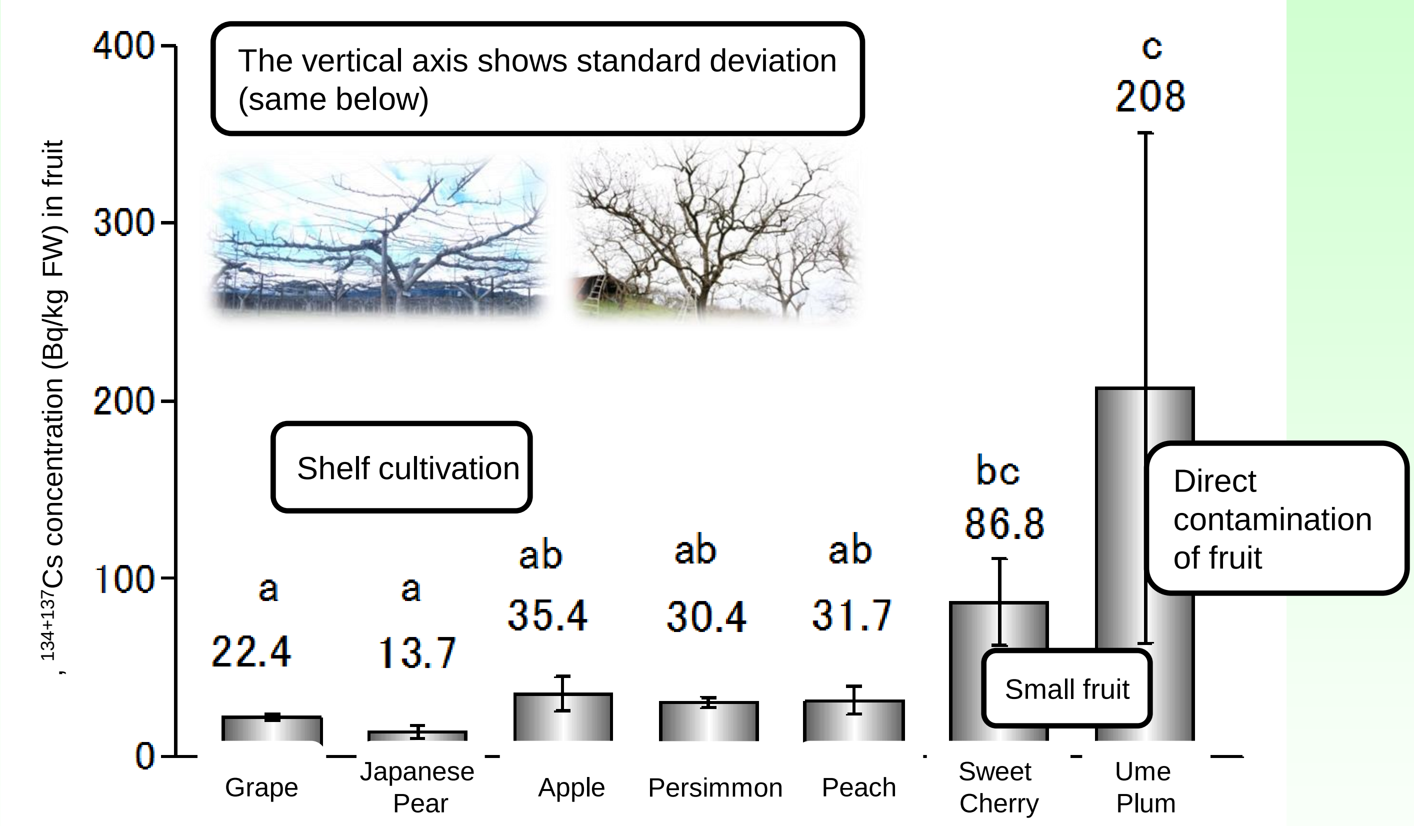
According measurement results by airplane monitoring of Fukushima prefecture by Ministry of Education, Culture, Sports, Science and Technology (Sept. 12, 2011)

Day of budding by the major deciduous fruit trees in 2011

Fruit tree species	*Cultivar*	*Date of sprouting*
Peach	*Akatsuki*	March 28
Japanese Pear	*Kosui*	April 8
Apple	*Fuji*	March 31
Sweet Cherry	*Satonishiki*	March 31

The orchards were contaminated by radiation in rain and snow which fell between March 15-22
Ume (plum) was contaminated after blooming, other deciduous fruit trees were before budding
The main parts of contamination above ground were; first crop of figs of the previous year, young fruit of ume plum, bark on dormant deciduous fruit trees, and leaves on Yuzu and loquat, which are evergreen fruit trees.

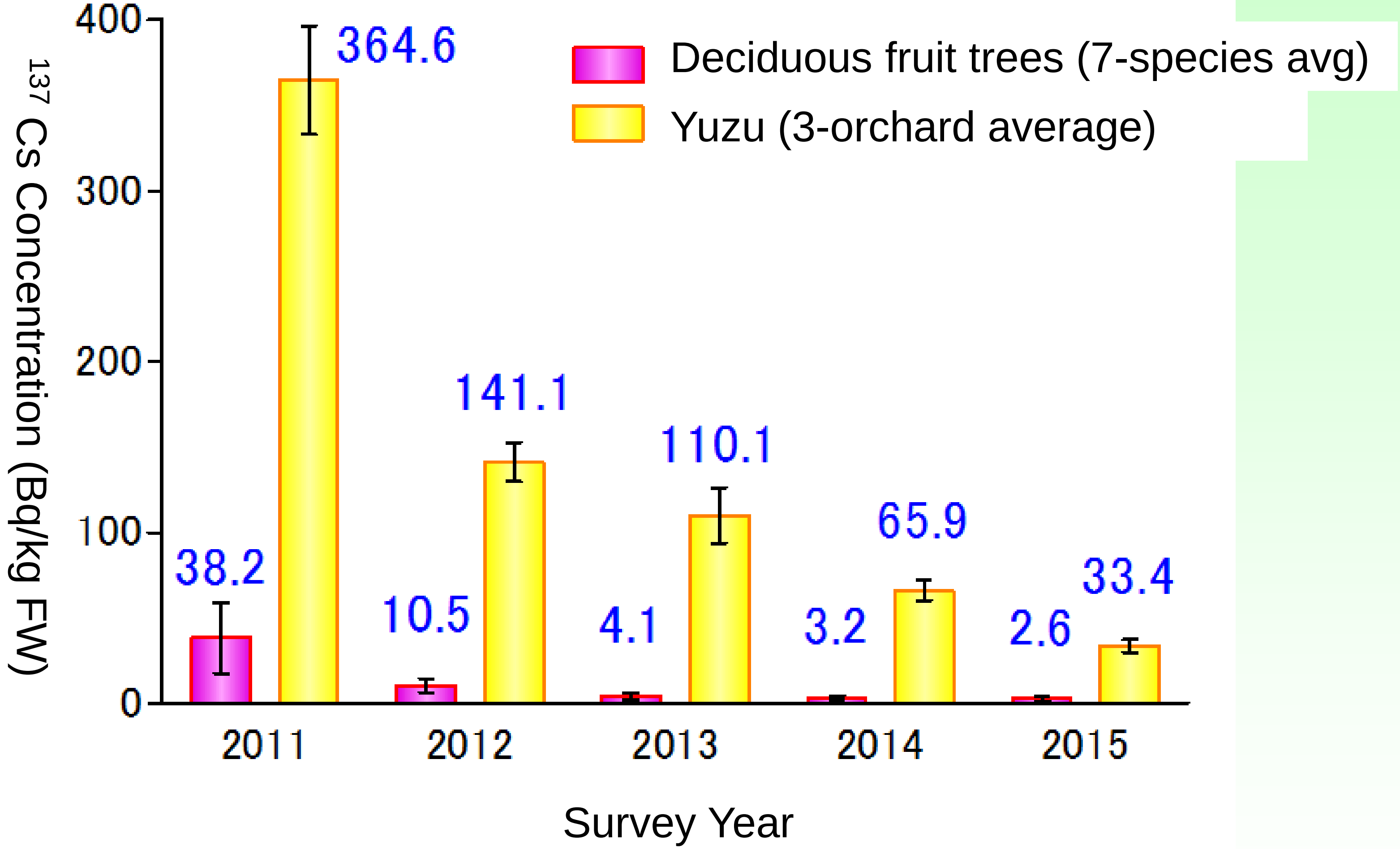
Radioactive Cs concentration of mature fruit in the fruit research laboratory in 2011



Species of deciduous fruit trees

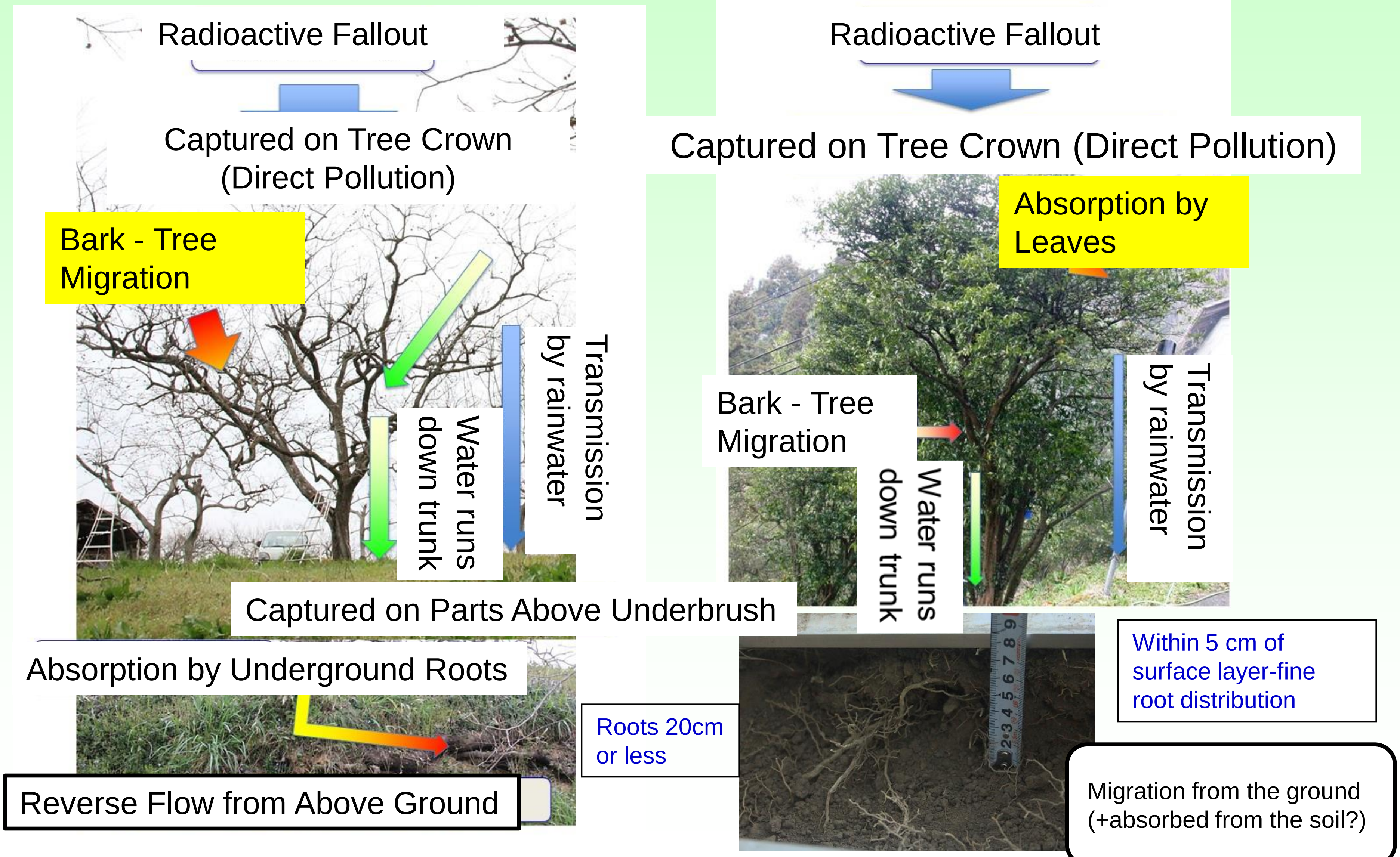
Seven species were surveyed (Ume plum, sweet cherry, peach, grape, apple, and persimmon). The number of tested cultivars were 5 for peaches, 3 for sweet cherry, and 2 others

Change in ^{137}Cs concentration in the fruit over the years in deciduous fruit trees and Yuzu Citrus



Concentration rapidly decreased in deciduous fruit trees up to the third year. A leveling off tendency is seen from the fourth year. In Yuzu, rapid decrease continued even into the fifth year.

Migration routes of radioactive Cs released by the Fukushima nuclear accident in orchards



Contamination status of the tree surface

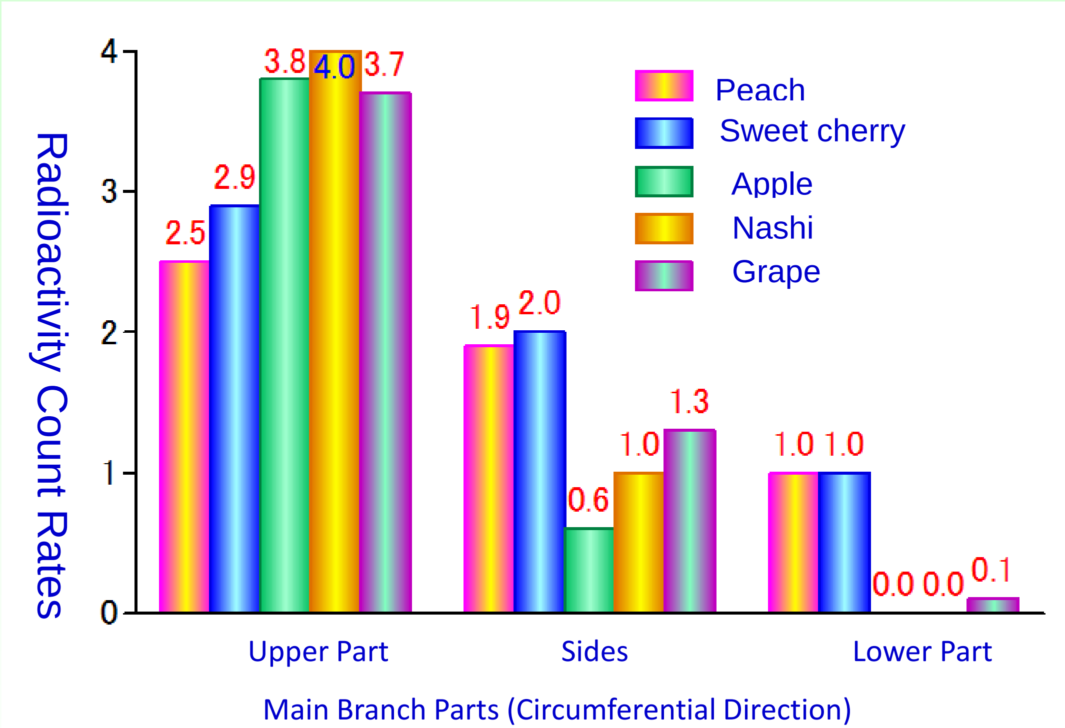
Survey Year 2011

Upper (sky facing side)

Side

Bottom part

Five species of deciduous fruit trees (peach, sweet cherry, apple, nashi, grape) were surveyed. Pollution status of the upper, side, and bottom, 30cm in the surrounding direction from the main branch were measured by GM survey meter.

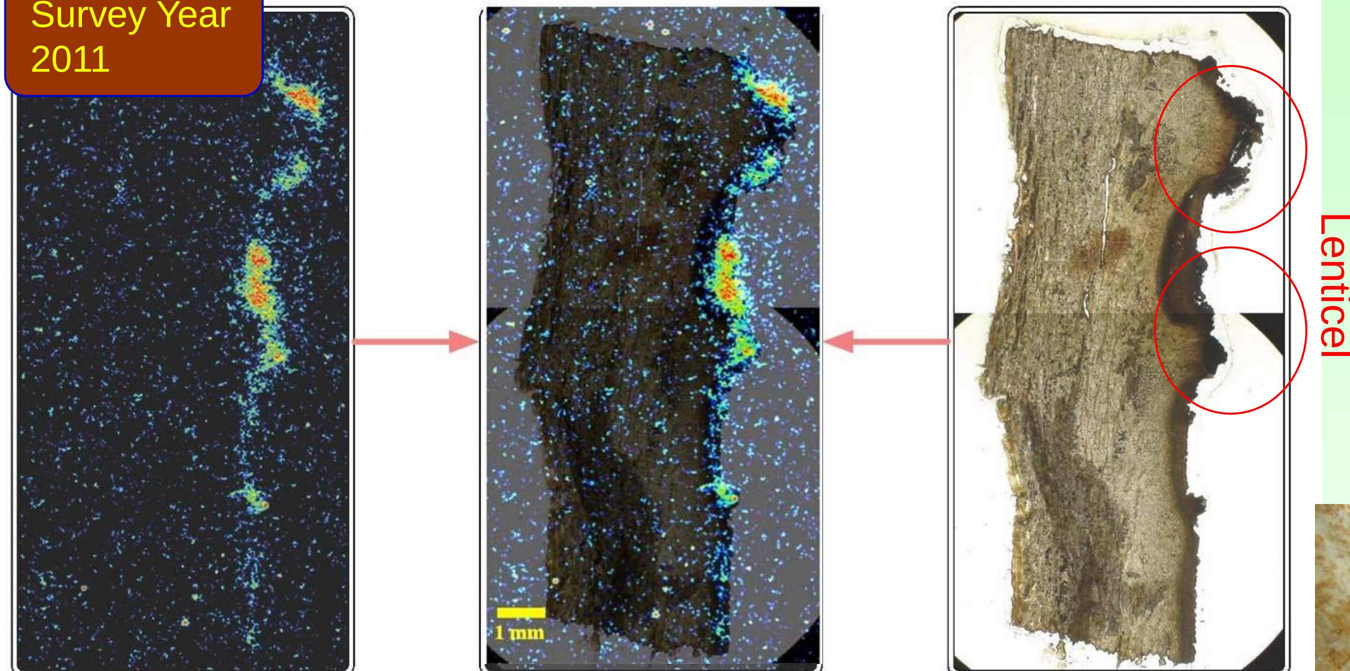


Amount of radiation on the surface of the main branch (measured in May 10, 2011)

The amount of radiation was higher in the order of upper > side > bottom, and a clearly higher amount of contamination was measured on the sky facing side on the main branch surface, than the ground side.

Distribution of radioactive material on the bark of peach trees (verification of distribution by the imaging plate method)

Survey Year 2011



IP image (≒Radiation)   Superimposed image   Optical micrograph

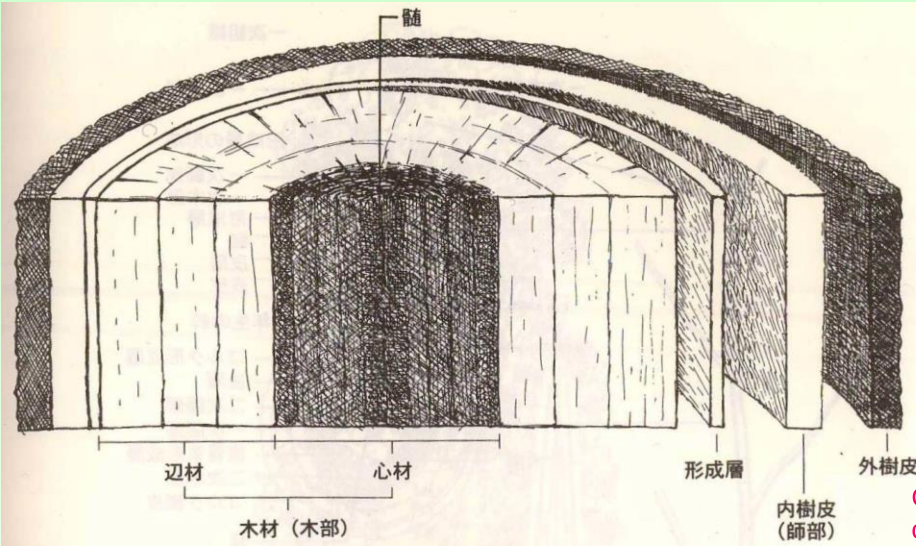
Composition of IP image of the bark (main branch part) and optical micrograph image

PEACH ORCHARD IN THE DISTRICT
CULTIVAR: AKATSUKI 18TH YEAR
(JUNE 16, 2011)

IP analysis was carried out at University of Tokyo

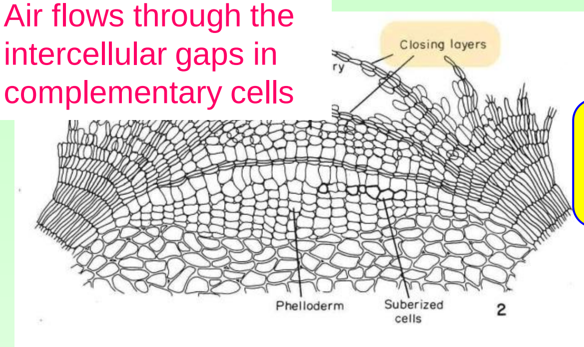
Radiation Cs accumulated around the lenticel. Lenticel is a structure of the trunk of deciduous trees which occupies 2-3 % of the bark surface

Trunk structure of deciduous trees



Cross-section of the trunk

Air flows through the intercellular gaps in complementary cells

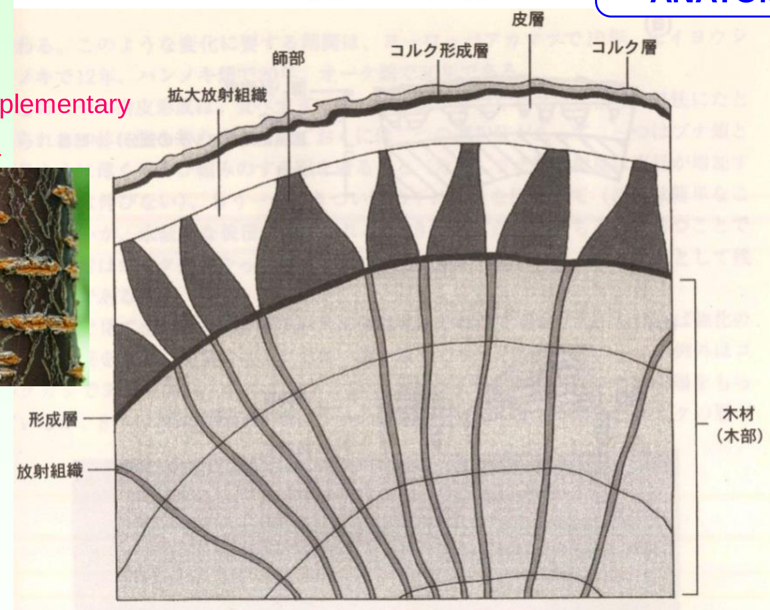


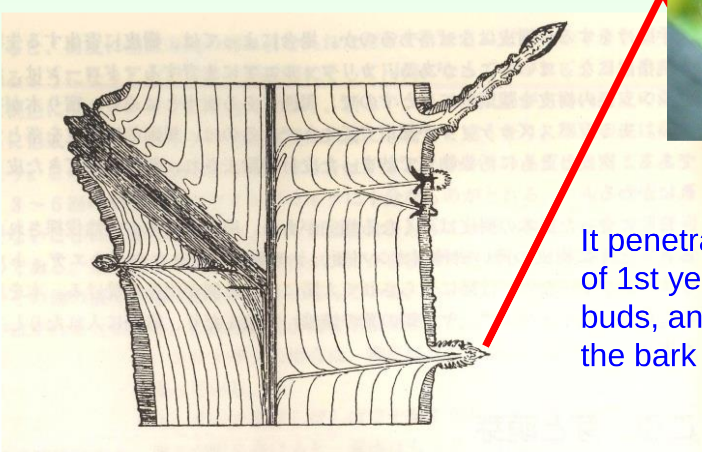
Prunus avium の成熟木皮目の図解

Dominant transitional organ of radioactive Cs

Source: PLANT ANATOMY

Complementary cell





樹幹の縦断面
樹幹の中央部でできた萌芽をもち、毎年樹皮の表面に出るように成長している。時に分岐する

It penetrates the xylem of 1st year dormant buds, and is dormant in the bark surface

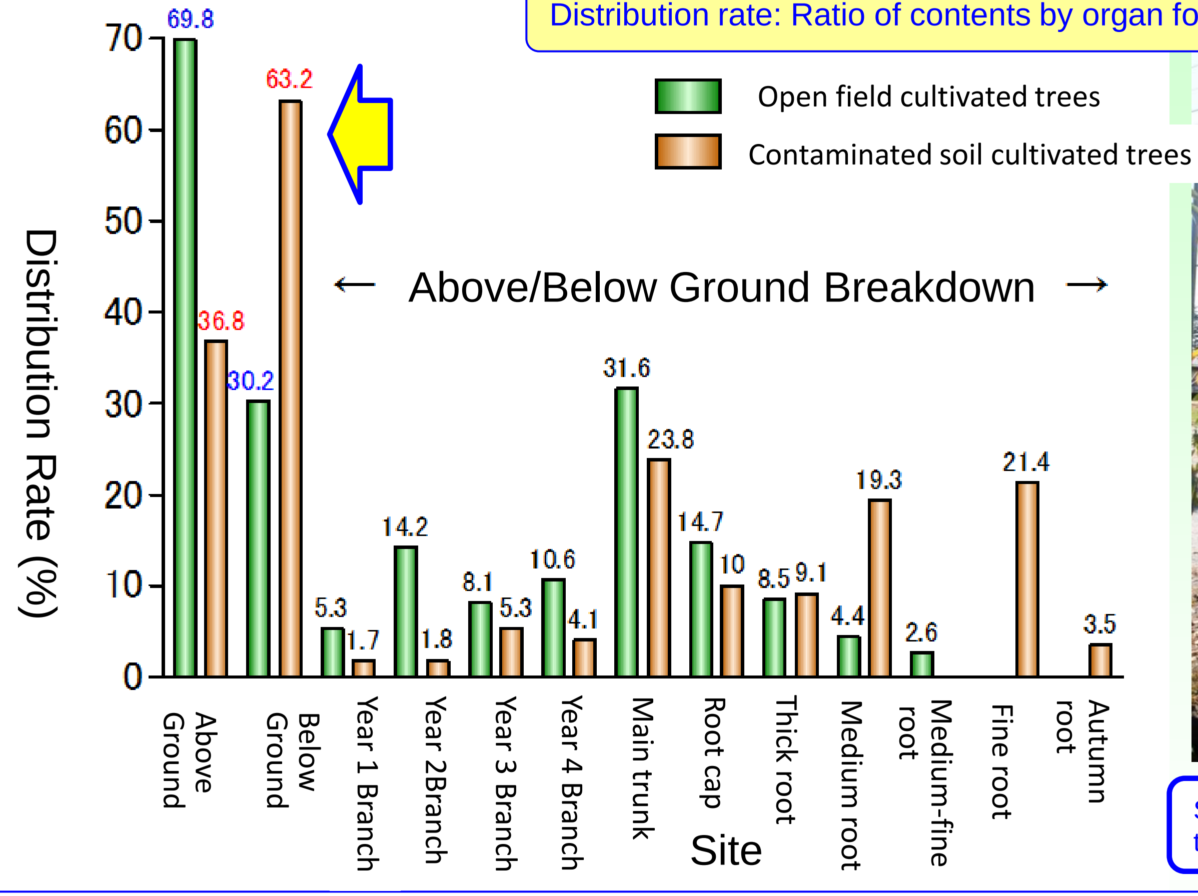
Pith ray

Living cells which functions as a ventilation and storage organ, as well as the route of nutrient liquids

Source: Dendrology

Comparison of the distribution ratio of ^{137}Cs in percutaneous absorption and in root absorption of "Hachiya" persimmon trees

Distribution rate: Ratio of contents by organ for the whole tree



Sites above ground used to measure the tree

The distribution rate of the section above ground and the section underground in percutaneous absorption is 70:30 and 37:63 in root absorption

One outdoor cultivated "Hachiya" persimmon tree and one from contaminated soil were dissected and analyzed

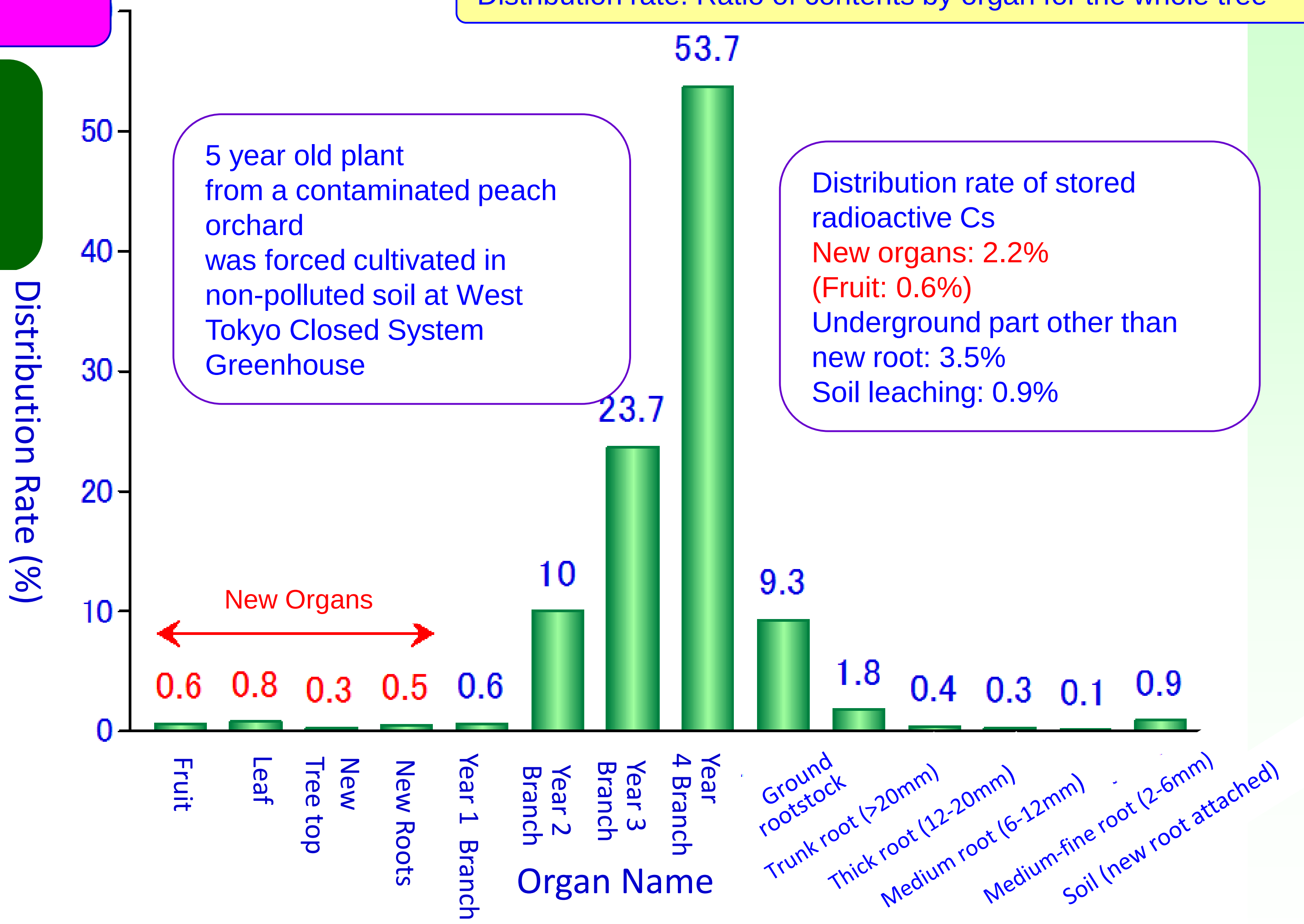
Dissection analysis date: Outdoor cultivated tree: January 31, 2012, on pot cultured tree: October 3, 2014

Distribution rate of stored radioactive Cs on the year following contamination

Survey Year 2012

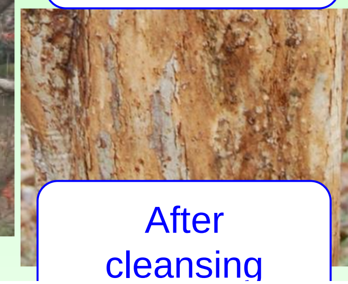
Joint research with the University of Tokyo

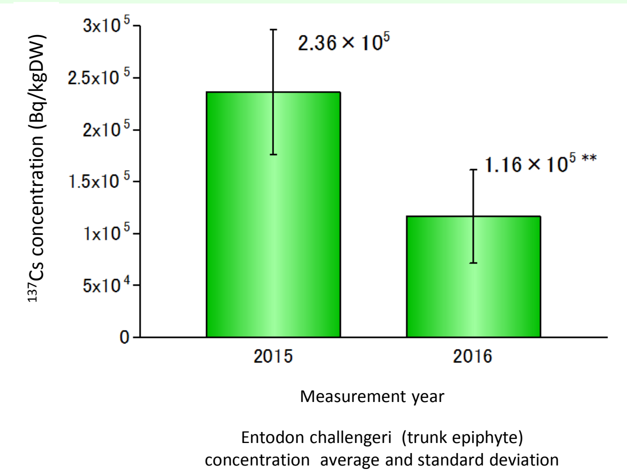
Distribution rate: Ratio of contents by organ for the whole tree



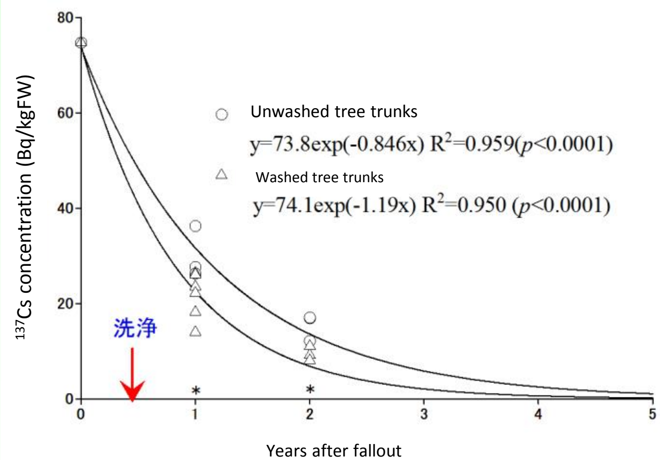
Distribution rate by site of radioactive Cs (5 year old “Akatsuki”)

Bark cleansing effect in a persimmon orchard

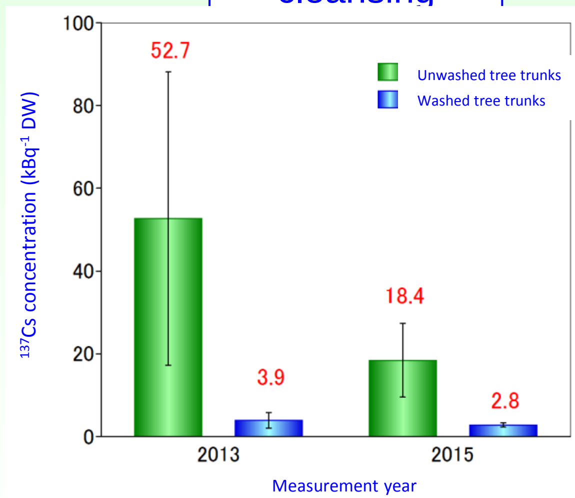




^{137}Cs in moss attached to the main trunk
Annual change in concentration



Comparison of ^{137}Cs
in the fruit where the bark was cleaned



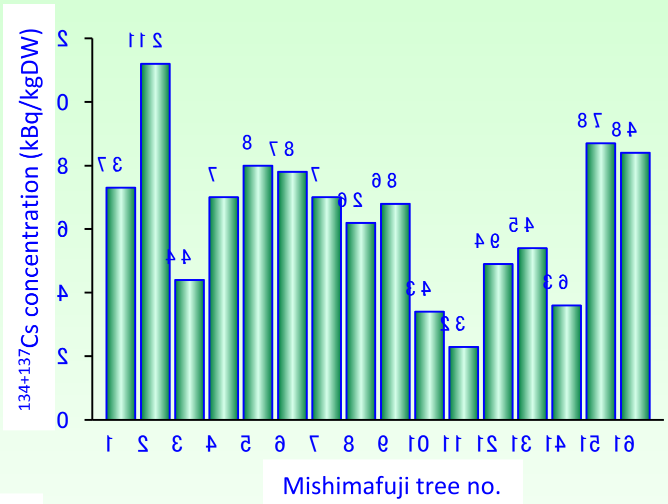
^{137}Cs in the bark of the main trunk
Annual change in concentration

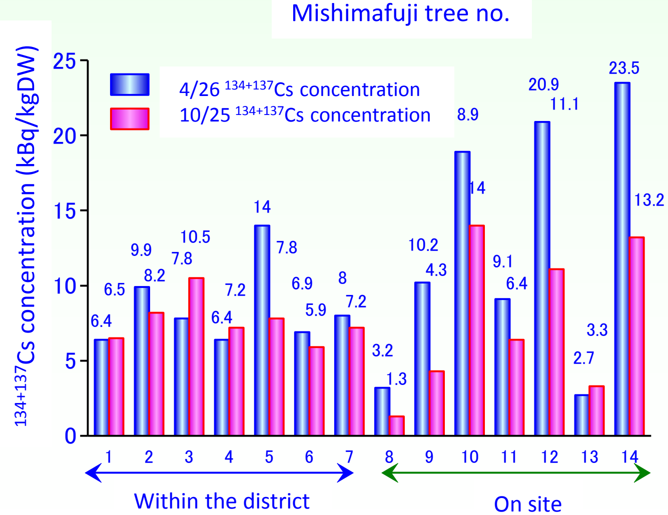
A reduction effect of ^{137}Cs of 29.1% after bark cleansing was calculated according to the model formula.

Horizontal distribution of radionuclides in 5cm of surface soil

Survey Year 2011

Measurement of radionuclides within the top 5cm of soil





Compared to the Fruit Tree Experiment Station field:

Space between trees

were five times larger on a 3a field.

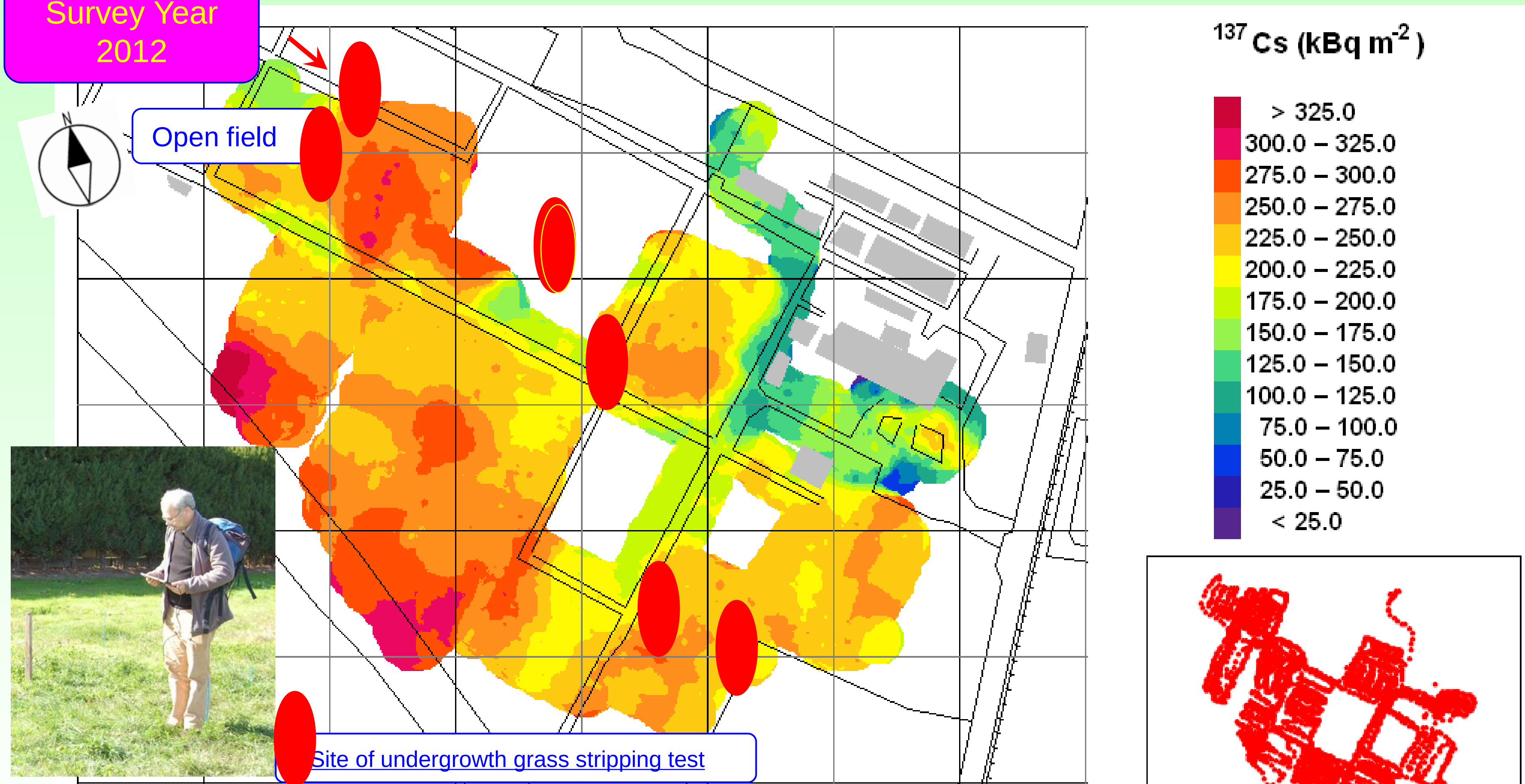
Space between fields

was twice as large between seven fields with a total size of 5ha.

Determining the level of contamination in a fruit orchard using only radioactive substance concentration measurements is a method with limitations.

Distribution map of ^{137}Cs in the soil of the fruit research field

Survey Year
2012



n = 3830
mean = 235
stddev = 51
Percentiles

10	161
50	242
90	293

SUERC
Scottish Universities Environmental Research Centre

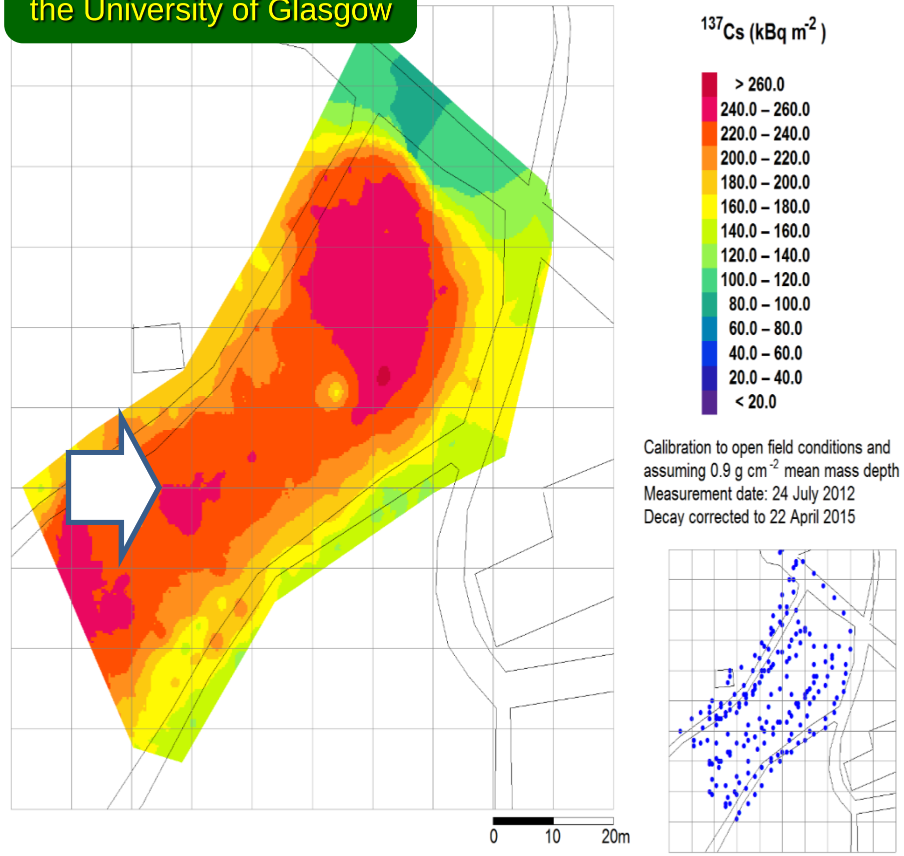
Measured by:
the University of Glasgow

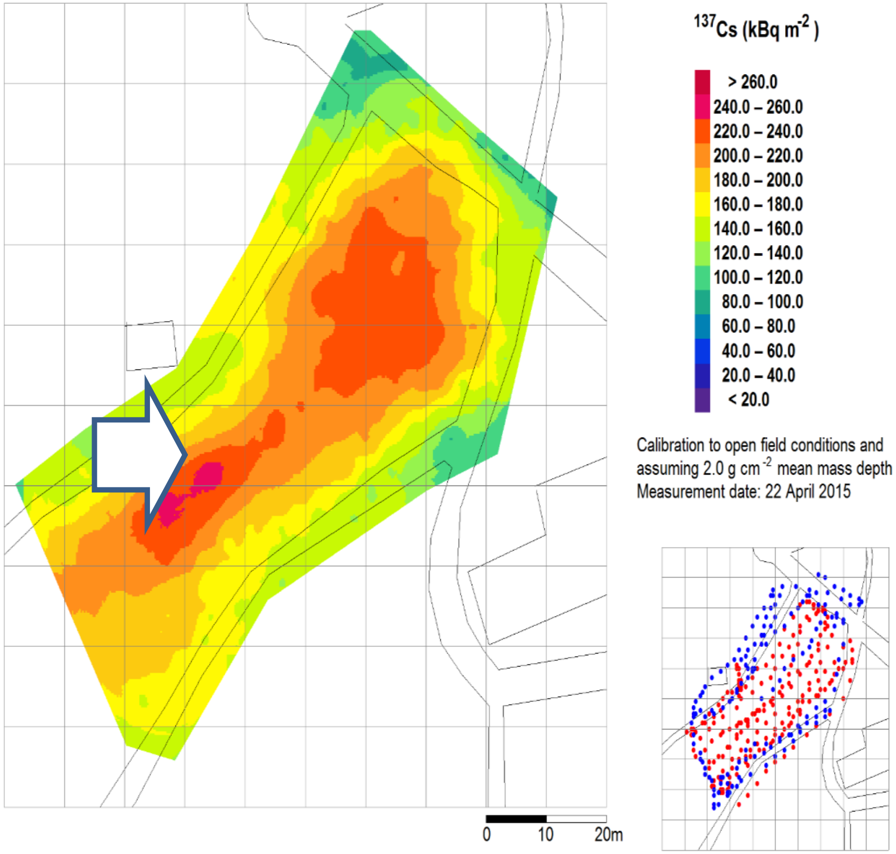
Calibrated to open field planar geometry
mean mass depth: 0.9 g cm^{-2}
Measurement dates:
8th March, 21st May, 12th July, 3rd Nov 2012

Measured in: March 8, May 12, November 3, 2012

Change in ^{137}Cs concentration in the surface layer in persimmon field over years

Measured by:
the University of Glasgow





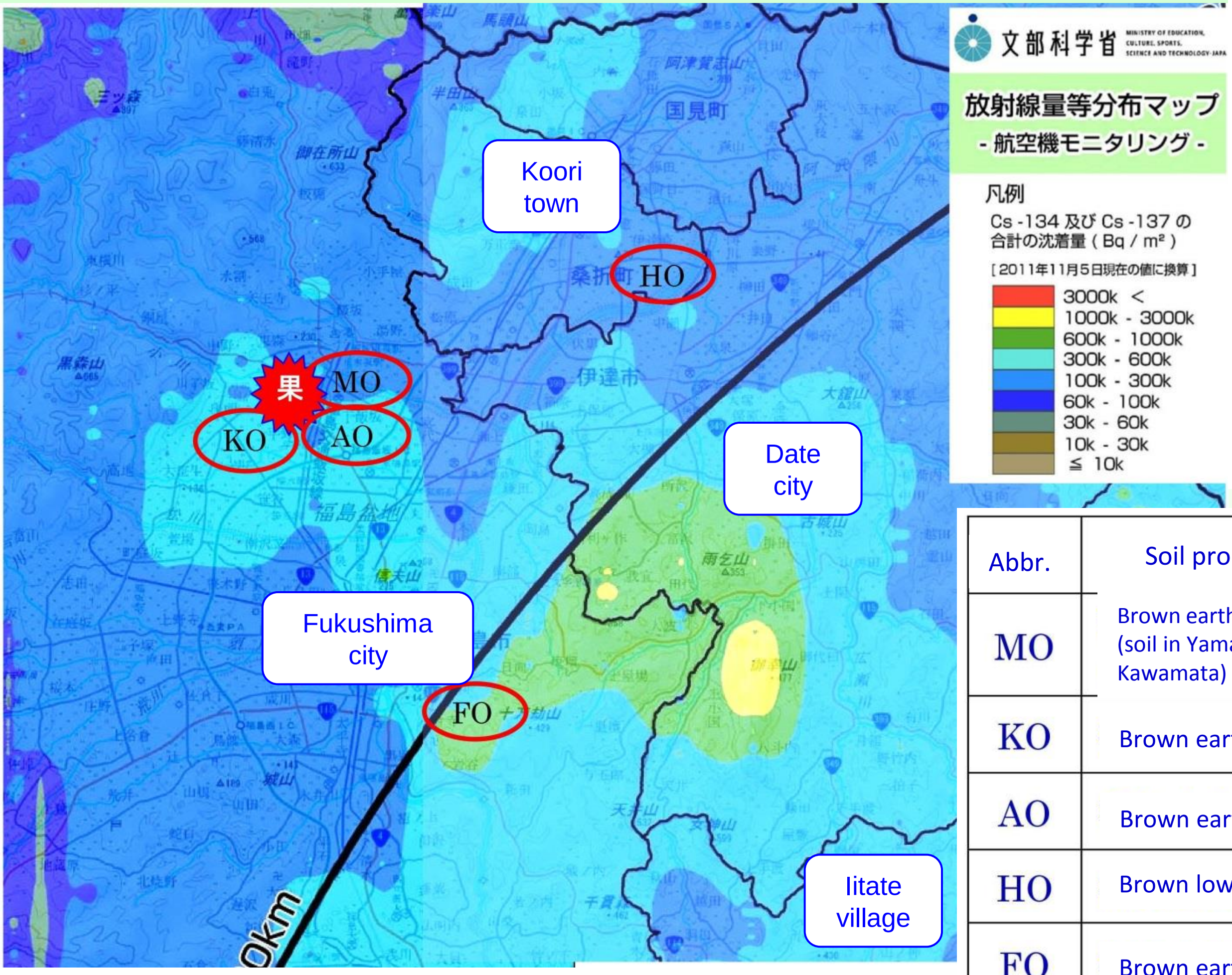
The value measured in July 24, 2012, was attenuation-compensated in April 22, 2015

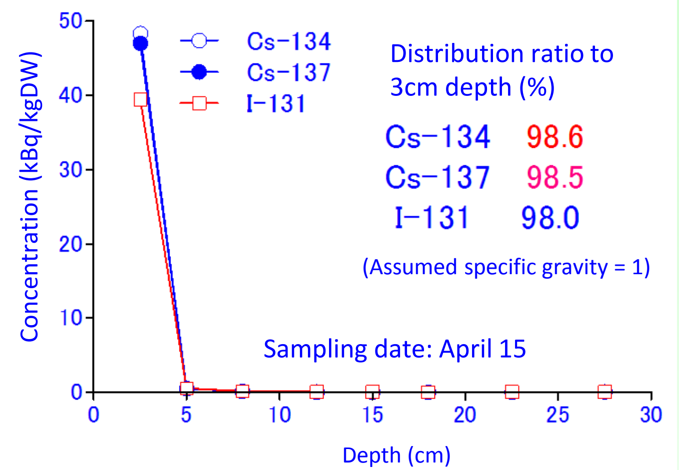
Measured in: April 22, 2015

A decrease greater than the theoretical value in the penumbra of the field was observed, and ^{137}Cs remained in the area covered by tree crowns.

Vertical distribution of ^{137}Cs in the soil of the field with different soil textures.

For the survey fields for radioactive Cs vertical distribution in soil, five fields with different soil textures were selected in April 2011.



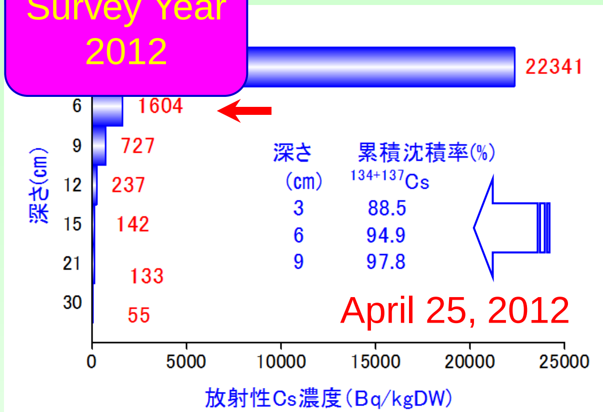


Vertical distribution on April 15
(Clay loam for Kogyoku in Fruit Research Station)

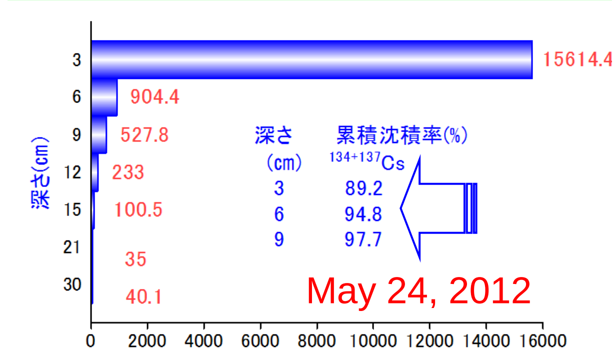
Abbr.	Soil properties	Soil characteristics	Tree species / cultivar
MO	Brown earth (soil in Yamakiya, Kawamata)	Sandy loam Loamy coarse sand	Apple / Mishima, Fuji
KO	Brown earth	Clay loam	Apple / Kogyoku
AO	Brown earth	Clay loam	Peach / Akatsuki
HO	Brown lowland soil	Sandy clay loam	Peach / Hatsuhime
FO	Brown earth	Heavy clay	Apple / Fuji

Vertical distribution of radioactive Cs concentration in the soil in field with different contamination levels

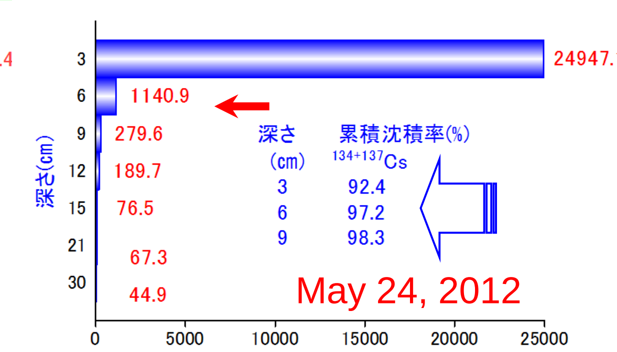
Survey Year 2012



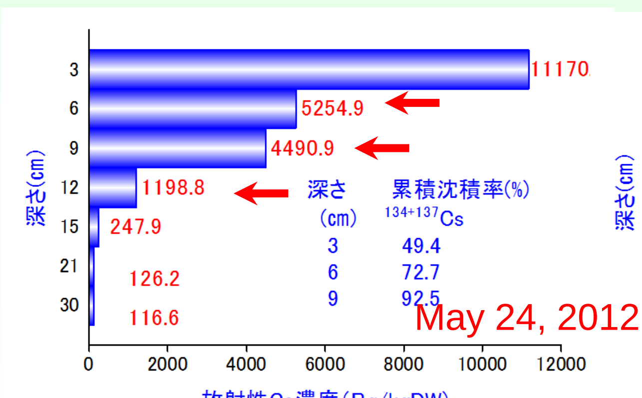
Watari (Fuji) repeated three times



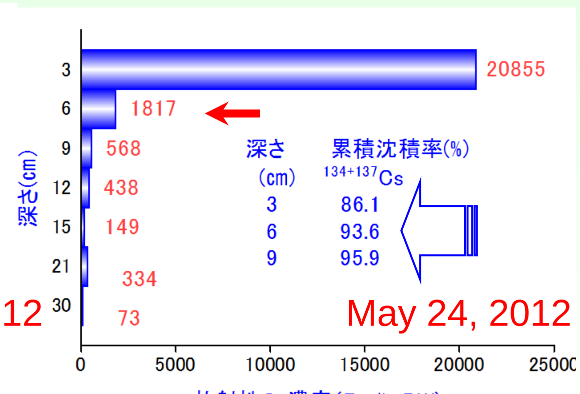
Koori (Hatsuhime)
repeated three times



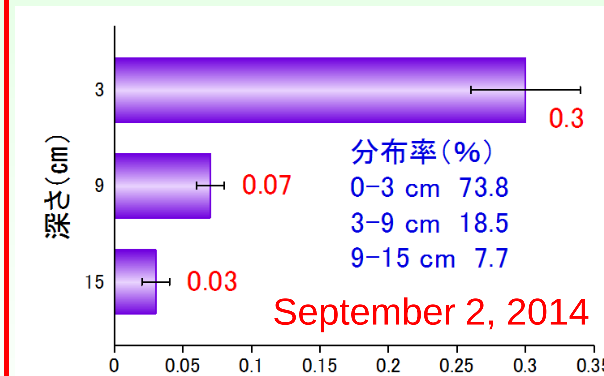
Fruit research laboratory (Kougyoku)
repeated three times



Shinobuyama (Yuzu)
repeated two times



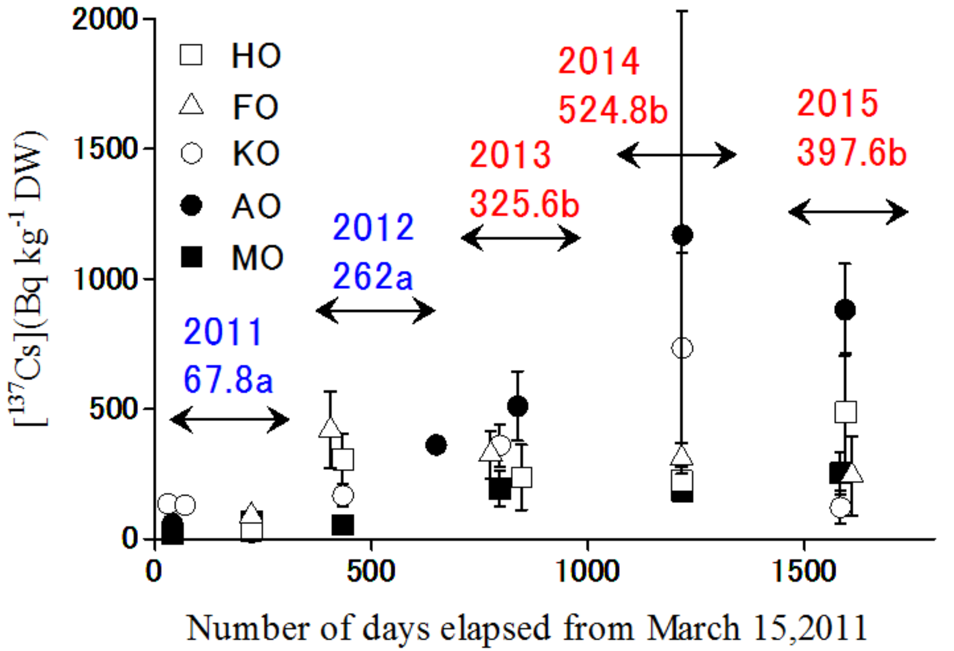
Hashirazawa (Hachiya)
repeated three times



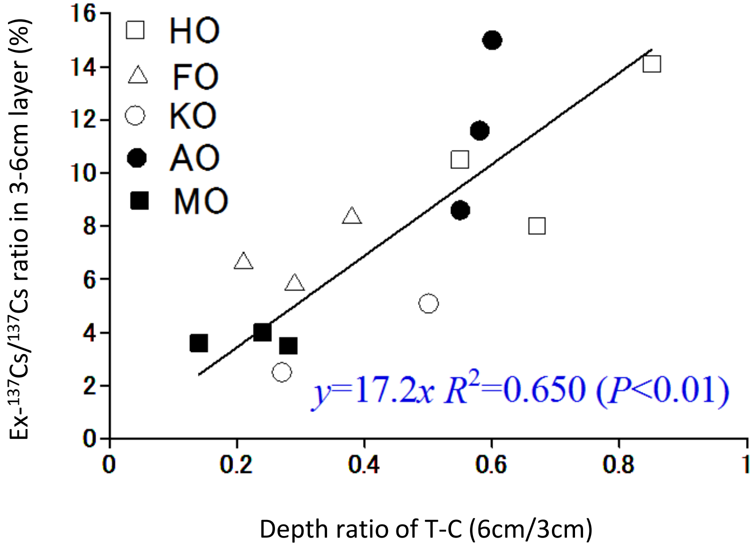
Vertical distribution of underground roots

Even in the following year of contamination, more than 85% of radioactive Cs was present in the 3cm surface layer, 73.8% was present 3cm to 15cm on the surface layer of the underground roots

Migration of ^{137}Cs in the soil to lower areas



Change in ^{137}Cs in 6-9cm layer over years



Correlation in the comparison of 3-6cm layer /0-3cm layer of total carbon and transferability of 3-6cm layer ^{137}Cs ratio (2013)

Calculated as the average migration length by the following formula,
and set as a variable showing vertical motion.

<x>=∑hi·Ci·Δhi·(∑Ci·Δhi) $^{-1}$

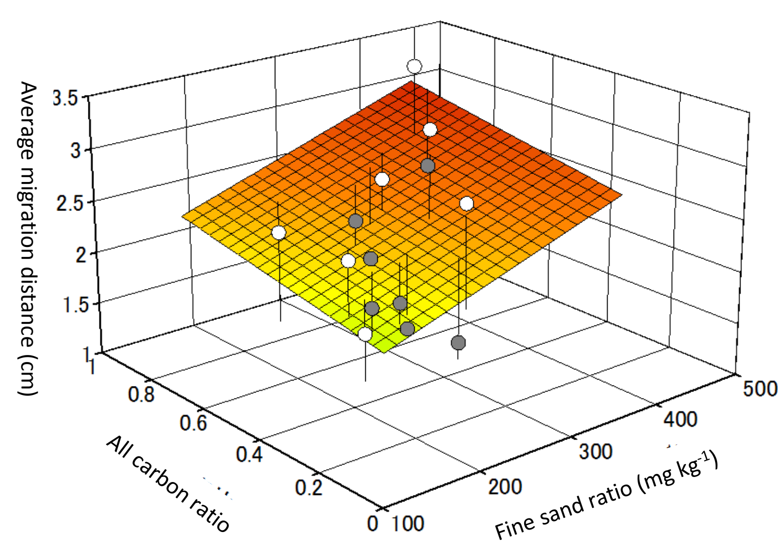
<x>: Average migration length

Ci: Concentration of layer i

hi: Depth of the middle point of each layer

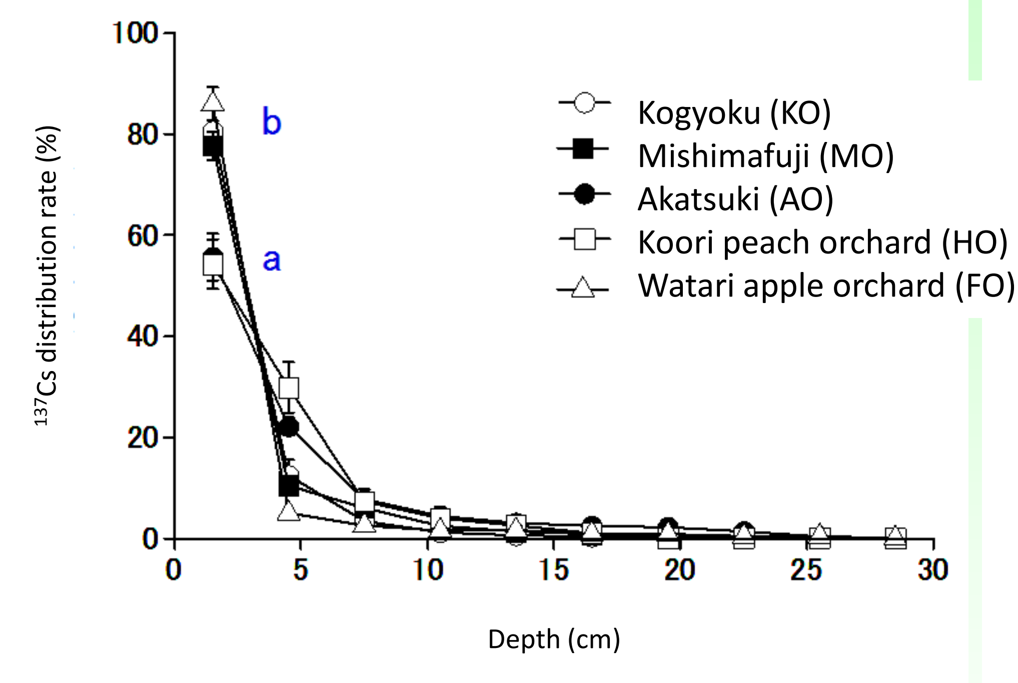
Δhi: Thickness of the layer

(Shiozawa et al. 2011)



Comparison of the average migration length and 3-6cm layer /0-3cm layer of total carbon and the correlation with the fine sand rate in 0-3cm layer (2013)

Change in distribution by depth of ^{137}Cs in the soil (2015) over years and average migration distance



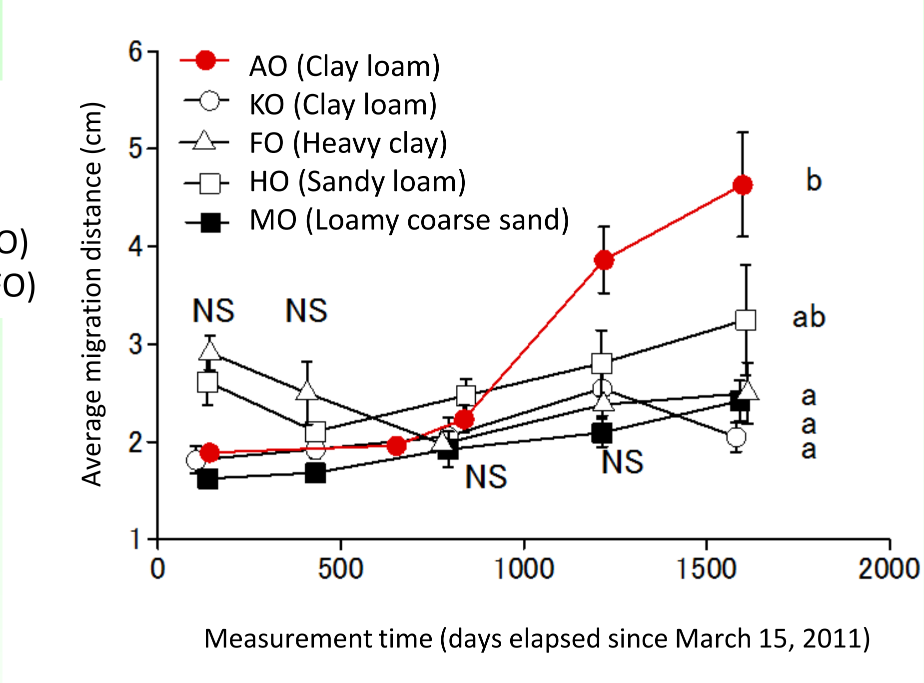
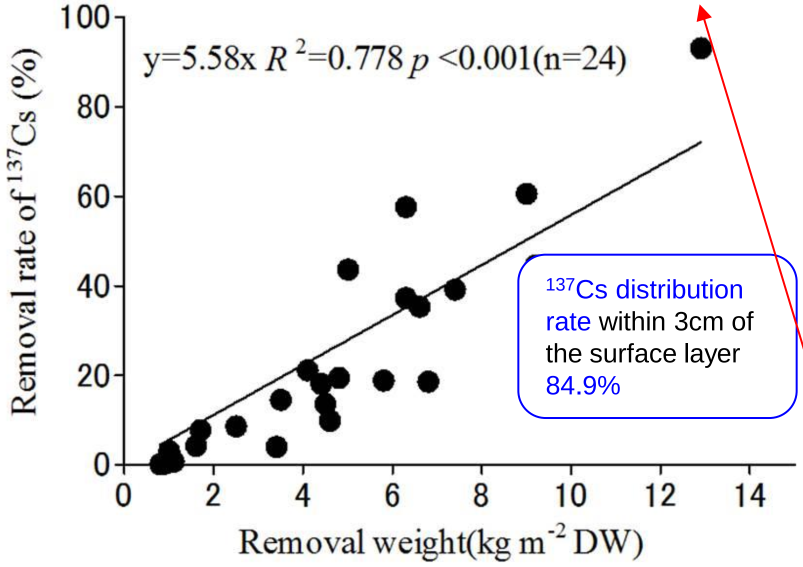


Fig. 1. Distribution rate by depth (2015)

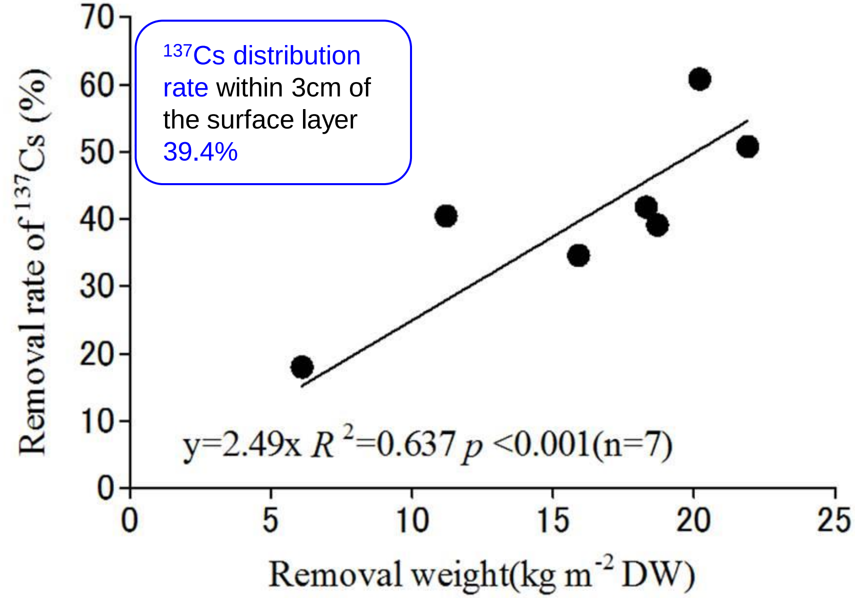
Fig. 2. Change in the average migration distance

In both the distribution rate on 3cm surface layer and average migration length,
a significant difference between fields was observed in 2015, 5 years after contamination. Also in sandy soil,
a MO field in Yamakiya, which has a base rock of granite,
there was less downward migration, but in a HO field with brown lowland soil, downward migration was high.
(Average migration length of the field in 2011 and 2012 was larger due to collection of “multi-compost”)

Removal of ^{137}Cs in the soil of the field



Removal effect of ^{137}Cs by stripping undergrowth grass (Under the tree crown: 2012-2014)



Removal effect of ^{137}Cs by stripping undergrowth grass (2014; Non-planted land)

Removal rate: 93.1%

- The removal effect of ^{137}Cs is reduced as the downward migration of ^{137}Cs proceeds.
- Cultivation of Kentucky blue grass which forms a root mat and white clover which develops creeping stems has a high removal effect for ^{137}Cs in the soil by stripping the undergrowth grass

Summary

1. Among fruit trees in the year of contamination, there was a difference in radioactive Cs concentration of approx. 10 fold between deciduous fruit trees which were contaminated before leafing, and evergreen fruit trees which had contaminated leaves.
2. In the deciduous fruit trees contaminated while dormant, radioactive Cs migrated to the tree via sections above ground. By the third year, radioactive Cs concentration in the fruit was reduced to one tenth of the initial year.
3. By the fifth year, reduction to one tenth of the initial year was observed in evergreen Yuzu trees which had contaminated leaves,.
4. A difference in concentration in the horizontal distribution of radioactive Cs in the soil of approx 2-5 times was observed.
5. In the vertical distribution of radioactive Cs in the soil, a more significant downward migration was observed in the third year of pollution, compared to the initial year. By the fifth year, the difference between fields became more noticeable.
6. Radioactive Cs in the soil tended move to downward more easily in soil with much fine sand and organic substances.
7. Removal of radioactive Cs in soil by stripping undergrowth grass was confirmed to have a higher effect in soil with less downward migration.
8. Removal effect of radioactive Cs in soil by stripping the undergrowth grass was higher with perennial graminaceous pasture grass and leguminous pasture grass.
9. Cultivating perennial graminaceous pasture grass and leguminous pasture grass is an effective soil management method for prevention and as a decontamination countermeasure for radiation pollution of the soil.

Thank you for listening.

Future
From
Fukushima.

ふくしまから
はじめよう。