TRITIUM ABSORPTION BY SOYBEAN FOLIAGE

BACKGROUND

The soybean is one of the many staple plants growing outdoors in northeast Asian countries. It is generally sown in May and harvested in October. The products are leaf, stem, shell, and seed. The seeds are used for the human diet, and the remainder is sometimes used for feeding animals.

The purpose of the experiments is to simulate the tritium exposure for soybean while it is growing. The tritium concentrations of the seed were measured, and the concentrations of the other parts were also measured for a better understanding of the tritium distribution from the leaves to the seeds.

EXPERIMENTS

Sowing and growing

The commercially available soybean was sown on May 22, 2001 in a plastic pot 41cm wide, 33cm long, and 23cm high. A total of six pots (SB1 to SB6) were arranged outdoors. For SB1 and SB4, there were 12 plants in a pot in order to sample the soybean parts along with time. 4 plants were grown in a pot for the rest of the experiments. 2 plants were taken as a sample in the beginning and at harvest, while 1 or 2 plants were taken for SB1 and SB4 during the plants growth.

The soil in the pot needed to be wet enough for the plants growth, so there was supplemental watering twice or three times a week. There were drain holes at the bottom of the pot for the bulk of water which did not stay in the pot. All plants looked to be grown uniformly.

The moisture content of the soil depended on the season. It was 18-19%(wet base) when we measured it on July 13, 8-14% on October 5, and 8-9% on October 19. The properties of the soil in the pot were as in Table 1.

Table 1. The physical and chemical properties of the soil

p.H		5.1
Organic Matter(%)		1.56
Total Nitrogen(ppm)		904.7
Cation exchange capacity(me/100g)		
Exchangeable cation(me/100g)	Ca	1.38
	Mg	0.36
	K	0.67
Sand(%)		73
Silt(%)		23
Clay(%)		4
Soil type		Sandy loam

The sowing was made on May 22, and the flowers of the plants started to show on July 7. The pods seemed to grow from July 10 or later. The harvest was done on Oct. 5.

Table 2 shows the fresh and dried biomass of the soybean when the tritium exposure experiments were conducted. Table 3 shows the fresh and dried biomass at harvest(Oct.5).

Table 2. Biomass of soybean(g-fresh/m2) when conducting the exposure experiment.

Exp.	Date of exp.	Biomass(g-fresh/m2)				
		stem	leaves	shell	seed	total
SB1	7/2	323.7	637.7			961.4
SB2	7/13	416.6	803.0			1219.5
SB3	7/30	789.4	1557.1	379.7		2726.2
SB4	8/9	545.8	914.6	392.8	162.6	2015.7
SB5	8/24	918.7	1555.9	939.5	754.2	4168.4
SB*	8/30	700.2	1193.6	750.0	688.7	3332.6
SB6	9/17	759.2	1354.0	836.8	635.9	3586.0

SB*: this experiment was conducted for other purposes.

Table 2-continued. Biomass of soybean(g-dry/m2) when conducting the exposure experiment

Exp.	Date of exp.	Biomass(g-dry/m2)				
		stem	leaves	shell	seed	total
SB1	7/2	57.6	115.6			173.2
SB2	7/13	86.5	172.8			259.3
SB3	7/30	222.5	424.7	70.5		717.7
SB4	8/9	174.3	303.5	109.5	44.5	631.8
SB5	8/24	324.0	503.3	267.4	225.1	1319.9
SB*	8/30	243.8	378.3	206.2	213.3	1041.5
SB6	9/17	281.2	471.1	224.4	189.1	1165.7

SB*: this experiment was conducted for other purposes.

Table 3. Biomass of soybean(g-fresh/m2) at harvest

Exp.	Biomass(g-fresh/m2)				
	stem	leaves	shell	seed	total
SB1	1259.6	1503.0	920.0	703.0	4385.7
SB2	1529.5	2211.1	1388.2	1191.4	6320.2
SB3	1530.2	2201.0	1141.9	609.5	5482.6
SB4	1194.5	1687.1	876.0	193.9	3951.5
SB5	1356.1	1985.5	1075.2	513.8	4930.7
SB*	1144.9	1826.3	852.2	438.7	4262.1
SB6	1205.5	2079.2	669.8	579.9	4534.4

SB*: this experiment was conducted for other purposes.

Table 3-continued. Biomass of soybean(g-dry/m2) at harvest

Exp.	Biomass(g-dry/m2)				
	stem	leaves	shell	seed	total
SB1	370.0	552.4	448.5	358.0	1728.9
SB2	503.5	1278.6	747.5	695.3	3225.0
SB3	453.7	846.1	357.0	220.8	1877.6
SB4	329.2	617.1	261.2	79.4	1286.9
SB5	398.2	745.6	335.6	188.9	1668.3
SB*	360.2	685.4	446.7	247.9	1740.3
SB6	535.3	1068.3	319.3	318.6	2241.4

SB*: this experiment was conducted for other purposes.

The leaf area index(LAI) was not measured during the experiments, however we found a simple description for the LAI in a publication[1)]. In general for the soybean, LAI increases proportionally from about May 25 to Aug. 10 reaching 6 to 7. Remaining constant for a while until about Aug. 30, LAI decreases to 2 to 4 by about Oct.5.

Tritium exposure

The pots with soybeans were introduced into a glove box 95cm long, 95cm wide, and 130cm high for the tritium exposure. The glove box was made of acryl and the experiments were conducted under natural solar conditions.

The surface of the soil was covered with vinyl paper to prevent a direct contact of the tritium with the soil so that the soybean absorbed the tritium through only foliage. While the tritiated water was evaporated in the glove box, the inside of the glove box was getting foggy due to the condensation of the water inside the wall of the glove box. The surface of the soybean leaves might be covered with the condensed water film. This is a more realistic situation if the tritium exposure happened in the morning.

After the exposure, the soybean was moved outdoors. Then the vinyl paper covering the soil surface of the pot was removed as soon as the plant sampling was finished. The pots were placed

in an open field among other soybean plants.
The tritium exposure was carried out six times at different growth times: July 2, July 13, July 30, August 9, August 24, and September 17.
The glove box included the heating coil for the HTO evaporation, fans for an even circulation of the HTO in the glove box. The tritium exposure was conducted between about 9:00 am and 10:00 am for an hour. The air of 1.5L including HTO in the glove box was drawn every five minutes. Then the air was passed through the scintillation vial which contained 20ml of distilled water in order to remove the HTO moisture to the distilled water.
After exposure for an hour, an external fan was operated to clean up the tritium in the glove box for about 5 minutes. Then the glove box was opened to move the pots out for the sampling of the parts of the soybean. It took about 5-7 min. The total elapsed time between just finishing the tritium exposure to sampling was 10 to 12 min, or 0.2 hr.

TRITIUM MEASUREMENTS

Sampling and measurement

In six experiments, the first and the fourth experiments were analyzed for the tritium change of the soybean parts with time by sampling several times while the soybean was growing outdoors. The other experiments had sampling times of twice only, which are the exposure and harvest. The soybean was harvested on October 5, 2003.
The samples were separated by parts and stored in a freezer. The tissue free water tritium(TFWT) was extracted and collected by freeze drying. Residual TFWT and exchangeable organically bound tritium(OBT) in the freeze dried samples were removed by an appropriate exchange process. Then the samples were dried using P_2O_5, and combusted by an Oxidizer(Oxidizer 306, Canberra Packard). The generated water was collected in a 20ml scintillation vial.
Tritium was measured using a liquid scintillation detector(Quantulus 1220, Wallac). The measurement was conducted

three times for 20 - 30 min. each. The uncertainty of the measurement was about 10%.

Air in the glove box

Tritium concentration in the glove box is summarized in Table 4. The rest of the detailed data is attached in the excel file(sbTbox.xls). The HTO concentration in the 6th column in Table 4 means the HTO in air moisture.

Table 4. Tritium exposure for the soybean(SB1:July 2)

Run ID	Time (hr:min)	Temp.(C)	Rel. humidity(%)	Solar radiation(klux)	HTO(Bq/ml H2O) in air moisture
SB1	9:25	33.5	59.4	36.3	-
	9:30	34.2	75.1	44.3	start
	9:35	34.7	80.4	42.6	7049.4
	9:40	36.0	83.7	46.4	67371.4
	9:45	37.0	85.2	44.1	72540.9
	9:50	38.1	85.1	48.9	100810.4
	9:55	39.2	84.9	61.7	94546.7
	10:00	40.4	83.7	42.9	103855.3
	10:05	41.0	82.6	48.1	92975.5
	10:10	41.5	81.5	61.5	90677.4
	10:15	42.2	81.0	66.7	84050.9
	10:20	43.1	80.2	61.7	83696.6
	10:25	43.6	78.8	66.9	73117.1
	10:30	44.0	77.1	72.3	72617.8
	10:35	42.2	43.5	35.2	66306.7

The HTO concentration in the glove box increased for 20-30 min by an evaporation of the HTO. After completion of the HTO evaporation, it decreased gradually.

Background

HTO concentrations in the air in the background, ranged as follows depending on the season.

July 0.016 - 0.069 Bq/m3

August	0.013 - 0.049 Bq/m3
September	0.040 - 0.060 Bq/m3

Vegetation

The leaf, stem, shell and seed of the soybean were sampled just after the tritium exposure and harvest with six experiments. Particularly, for the first(SB1) and the fourth experiments(SB4), parts of the soybean plants were sampled several times while they were growing. For SB1, the elapsed times after the exposure and the sampling date and times were: 0.2hr(July 2), 1hr(July 2), 24hrs(July 3), 120hrs(July 7), 336hrs(July 16), 936hrs(August 10), 1608hrs(Sept. 7), and 2280hrs(Oct. 5). For SB4, they were 0.2hr(Aug. 9), 1hr(Aug. 9), 24hrs(Aug. 10), 120hrs(Aug. 14), 336hrs(Aug. 23), 768hrs(Sept. 10), and 1368hrs(Oct. 5).

METEOROLOGICAL MEASUREMENTS

The soybean was moved after tritium exposure, and grown outdoors. The location of the planting has an elevation of 20m above sea level. The tritium concentration decreased gradually with time. There is a meteorological tower near the planting area, and the meteorological information could be obtained from the tower. The related meteorological information is attached in files: sbTHS.xls for the temperature, humidity, solar radiation information and sbWR.xls for the wind and rainfall information. The information on the stability class was added to sbWR.xls.
The unit used in sbTbox.xls is klux, while in sbTHS.xls it is W/m2. The instruments for measuring the solar radiation are in Table 5.

Table 5. Instruments for measuring the solar radiation

For glove box	Illuminance Meter(ANA-F11) Tokyo Photoelectric Co.Ltd(Japan)
For meteorological tower	Silicon Cell Pyranometer(Model 3120) Qualimetrics, Inc. (USA)

According to the publication[2)], the conversion factor between radiant flux density(W/m2) and illuminance(klux), (W/m2)/klux depends on the wave length, ranging from 4.0 to 5.5.
However, the experiments were carried out in acryl-made glove box so that the actual light effect in the glove box might be less than what actually happened in an open field. Local cloud condition or a nearby forest may affect the results, for example. We have checked the relation between the radiant flux density(W/m2) and the illuminance(klux) and summarize it in Table 6.

Table 6. Measurement of the illuminance and radiant flux density

		Illuminance(klux)		Radiant flux density(W/m2)
Date and time		In the glove box	In the field, Nearby glove box	In the field
Dec.05	14:00	4.76	5.64	52.61
	15:30	3.41	3.69	70.02
Dec.08	11:30	43.8	51.7	426.90
	12:30	27.8	42.6	257.54
	13:30	4.8	5.0	110.78

SCENARIO CALCULATIONS

Using the information provided, please calculate

1.HTO concentration in the free water of the soybean in the SB1 experiment at the following plant parts, dates and times.

(i)in the plant body(stem and leaves)

10:40 July 2(0.2 hr)*

11:30 July 2(1 hr)

July 3 (24 hrs)

July 7 (120 hrs)

July 16 (336 hrs)

Aug. 10 (936 hrs)

Sep. 7 (1608 hrs)

Oct. 5 (2280 hrs)

*The numbers in parenthesis means the elapsed time after the exposure experiments

(ii)in the pods(shell and seeds)

Aug. 10 (936 hrs)

Sep. 7 (1608 hrs)

Oct. 5 (2280 hrs)

2.HTO concentration in the free water of the soybean in the SB4 experiment at the following plant parts, dates and times.

(i)in the plant body(stem and leaves)

10:40 Aug. 9(0.2 hr)*

11:30 Aug. 9(1 hr)

Aug. 10 (24 hrs)

Aug. 14 (120 hrs)

Aug. 23 (336 hrs)

Sept. 10 (768 hrs)

Oct. 5 (1368 hrs)

*The numbers in parenthesis means the elapsed time after the exposure experiments

(ii)in the pods(shell and seeds)

10:40 Aug. 9(0.2 hr)*

11:30 Aug. 9(1 hr)

Aug. 10 (24 hrs)

Aug. 14 (120 hrs)

Aug. 23 (336 hrs)
Sept. 10 (768 hrs)
Oct. 5 (1368 hrs)

3.The non-exchangeable OBT concentration in the soybean at harvest for the six experiments SB1 to SB6

(i) in the plant body(stem and leaves)
(ii) in the shell
(iii) in the seeds

4.Estimate the 95% confidence intervals for the predictions in questions 1-3.

REFERENCES

1)Cho,J.Y et al., FOOD CROP SCIENCE, 4th ed.,Hyangmoon, 1986(Korean)

2) Thimijan, R.W. and R.D. Heins.,''A review of conversion constants and procedures for photometric, radiometric, and quantum light units of measure'', *HortScience* 18(6):818-822. J. *Amer. Soc. Hort. Sci.* lll:ll4-l2l.(1983)