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# Investigation of the dependence of the intake and distribution of tritium on the vegetative organs of agricultural plants during hydroponic cultivation

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# Investigation of the dependence of the intake and distribution of tritium on the vegetative organs of agricultural plants during hydroponic cultivation

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**Abstract.** As part of the study, the essential importance of the aerial mechanism of tritium in-take into plants was revealed, and a quantitative assessment of the parameters characterizing this transfer mechanism was given. It is shown that for such crops as cucumber, tomato, corn, the proportion of water supplied to the plant by the aerial mechanism is on average about 30% of the total water absorbed by the plant. It has been revealed that the ability of plants to absorb water from the air increases during the growing season. A quantitative assessment of the parameter characterizing the downward (from the leaves to the roots) flow of water – the newly introduced coefficient $K_{aps}$ - has been carried out. The $K_{aps}$ coefficient actually shows the amount of water transferred by the plant by the downward flow in milliliters per kilogram of green mass per day. The average value of the $K_{aps}$ was for the crop: cucumber – 240, tomato – 320, corn – 300 ml / (kg * day).

The presence of two significant routes of tritium intake at different concentrations in its carrier media (soil solution at the root route of entry, air vapors at the aerial route) leads to an uneven distribution of tritium concentration across organs and parts of plants. For all plants and at all stages of vegetation, there is an excess of free water tritium con-centration in leaves over concentrations in stems: 1.4 times for cucumber culture, 3.6 for tomato, 2.4 for corn. The difference in concentrations of TFWT in leaves and roots is even more pronounced: 7.6 for cucumber culture, 6.7 for tomato, 3.6 for corn.

The presence of significant concentrations of tritium of free water in plants, and especially in the roots, that is, in its part, which usually remains in the soil, as well as the revealed transition from plants to soil solution under conditions of its aerial formation shows the importance of a special mechanism of soil contamination with tritium along the path "water vapor of air – the free water of plants - the soil." The presence of this mechanism can lead to soil contamination with tritium in the absence of tritium-contaminated groundwater and surface waters, which, as a rule, are considered as the main source of pollution by it.

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## 1. Introduction

Tritium is one of the main radionuclides in the emissions of nuclear power plants during their regular operation. Currently, the volume of annual tritium emissions in the world is estimated at $n*10^{17}$ Bq [1]. Given the pace of development of the atomic energy industry, the amount of tritium in the environment will increase. A fairly large number of works, including reviews, are devoted to the issues of tritium intake in plants: [1-17].

Quite a large number of works are devoted to the aerial intake of tritium into vegetation: [2-12]. The intake of tritium along this path is characterized by a coefficient R, de-fined as the ratio of the concentration of tritium in free water (hereinafter referred to as TFWT) in a plant to the concentration of tritium in water vapor in the air. In different sources, the R coefficients vary from 0.1 to > 1.0. For example, in [4], the R coefficient for woody plants of different species grown in clean conditions and planted for 300 minutes in an area with tritium content in aqueous air vapor varies from 0.1 to 0.5. The author of the work [5] presents both data from his own experiments and data from the Nuclear Regulatory Commission, the Environmental Protection Agency. According to these data, the values of the R coefficient range from 0.23 to 1.38. In [7], the values of the R coefficient vary from 0.22 to 0.86. Thus, the range of R b values presented is extremely wide and suggests the need for further research in this direction.

The presence of two significant routes (conventional root and aerial) for the uptake of tritiated water with different concentrations of tritium can lead to an uneven distribution of tritium across the vegetative organs of the plant. In support of this, there are a number of publications: [2], [6], [7], [10], [11], [13-16]. In the work [15], with the aerial intake of tritium into vegetation for 6 hours of exposure, the concentration of TFWT in leaves and stems differs by an order of magnitude. In [2], the aerial intake of tritium into vegetation is modeled. The author points out: "Uptake of HTO from the atmosphere by leaves required 66 min to achieve 50% equilibrium activity while stems required 1970 min." The author assumes that during 32 hours of exposure, the concentrations of TFWT in the stems and leaves of the plant become the same and reach 50% of the concentration of tritium in the water vapor of the air. This effect is not confirmed by data from other analyzed sources.

Separately, it is necessary to point out on the weak knowledge of the possible pathway of tritium "air - plant – soil". This path is possible due to the presence of a water flow with organic substances formed in the leaves through the phloem system and their release in the form of exudates [18-20], however, it was not possible to find any quantitative estimates of the significance of this mechanism in the available literature.

The purpose of this work was to study the dependence of the intake and distribution of tritium on the various vegetative organs of some agricultural plants during their hydroponic cultivation under conditions of aerial intake of tritium at various stages of vegetation, as well as to assess the level of tritium transfer by the "air - plant - soil" mechanism.

## 2. Materials and methods

*2.1* The experiments were conducted at the Kurchatov Institute Research Center - RI-RAE in 2023. The following experimental species were selected: cucumbers (Cucumis sativus) of the “Gavrish” variety, tomatoes (Solánum lycopérsicum) of the “Verlioka” variety, corn (Zéa máys) of the “Sugar Delicacy” variety. The seeds of the plants were germinated in tritium-free conditions. The plants were grown in vegetative vessels by the meth-od of hydroponic cultivation in "tritium-free" conditions, that is, in atmospheric air, nutrient solution, the concentration of tritium was at the background level. At a certain vegetative stage, the plants were transferred to a special

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vegetative house with a "tritiated" atmosphere, where they stayed for 3-5 days. After that, the plants were cut, divided into separate parts (usually leaves, stem, root) and analyzed.

*2.2 The methodology of the vegetation experiment*

*2.2.1 Cultivation of plants by the hydroponic method*

The plants were grown using the AquaPot hydroponic plant. The installation consists of a vegetative vessel (a 20-liter container with a device for controlling the water level in it) filled with a nutrient solution, a lid with a hole for a vessel filled with an inert substrate, a compressor for supplying air to a nutrient solution with an aeration stone.

3 plants were grown in each vessel, which were planted there as seedlings at the stage of the appearance of the first real leaf. In total, 10 vessels were prepared for each plant species. The composition of the nutrient solution is shown in Table 1. A certain level of nutrient solution was maintained in the vegetative vessels, ensuring sufficient hydration of the substrate throughout the experiment. Cultivation was carried out in natural conditions under a canopy. Cultivation under these conditions continued until sufficient green mass was obtained for subsequent analysis. This period was 25 days for cucumber and tomato crops and 40 days for corn.

**Table 1.** Composition of the nutrient solution

| Compound | Concentration, mg/L | Compound | Concentration, mg/L |
|---|---|---|---|
| $NH_4NO_3$ | 94 | $KNO_3$ | 881 |
| $CaHPO_4$ x $2H_2O$ | 430 | $CaCl_2$ | 419 |
| $MgCl_2$*$6H_2O$ | 439 | - | - |

*2.2.2 Conducting a vegetation experiment under conditions of an aerial intake of tritium into vegetation during hydroponic cultivation*

At a certain stage, 1-2 vegetative vessels with grown plants of each species were transferred to a vegetative house with a "tritiated" atmosphere. The vegetation house was a maximally sealed greenhouse measuring 3*5 m, up to 2 m high. The "tritiated" atmosphere, that is, an atmosphere with a high content of tritiated water vapor was created by ultrasonic spraying of water with a tritium concentration of 5250 Bq/L. Commercial air humidifiers of the LU-1558 brand were used for spraying water (water consumption is ap-proximately 200 ml/hour), which worked round–the-clock during the entire experiment. Humidifiers were located at opposite walls of the vegetation house for the most uniform distribution of tritium in the atmosphere of the vegetation house. To maintain a certain humidity, NeoClima ND-40AZ dehumidifiers were installed near the opposite walls of the house, working around the clock.

Since the temperature in the vegetation house could exceed the values of the temperature acceptable for the vital activity of plants, a Ballu air conditioner was installed in it. To prevent hypothermia, it was not turned on at ambient temperatures below 15 degrees and in cloudy weather.

The tritium content was monitored twice a day by sampling water condensed by dehumidifiers. The temperature and humidity control of the greenhouse atmosphere was carried out by an Eli-Tech device attached to the wall of the vegetation house. The results of temperature and humidity control are shown in Figure 1.

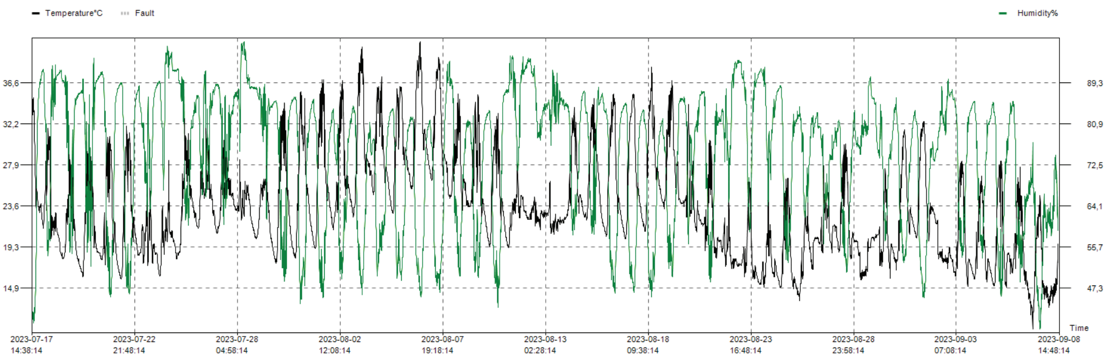


**Figure 1.** The results of temperature and humidity control in the greenhouse

The average humidity during the observation period is 74.3%, the temperature is 23.4°C.

Plants in hydroponic vessels were kept in a "tritiated" atmosphere for 3-5 days. At the end of the experiment, the plants were collected by cutting at the root and divided into organs and their parts. The labeled samples were stored in sealed plastic bags in the re-frigerator before processing. Also, to determine tritium, a sample of a nutrient solution was taken from a hydroponic vegetative vessel, and its mass was recorded.

### 2.3 *Sampling, preparation of samples and analytical samples and their measurement*

The collected plants were divided into parts and pre-shredded with scissors. The root was washed with water, after which it was dried with filter paper. The crushed samples of plant parts were placed in sealed plastic bags, labeled and stored in the refrigerator.

Extraction of free plant water was carried out by distillation in a salt bath directly from the crushed sample. For this purpose, an aqueous solution of CaCl2 was prepared at a concentration of 2 kg/l on tap water in a metal container with a capacity of 2 liters. The container was placed for heating on an electric stove made by Energy. The salt solution boiled at a temperature of 120 to 150 degrees, as the water boiled away, the solution was diluted with clean water.

Samples of plant parts weighing 50-70 grams were placed in a flat-bottomed conical or round flask, which was placed in a boiling solution. The resulting water vapor was condensed using a standard Liebig refrigerator. The free water was collected in labeled test tubes and used to create analytical samples. Samples of the nutrient solution for analysis were also distilled using the traditional method using a flask heater and a Liebig refrigerator.

The analysis of the concentration of plant TFWT was carried out by liquid scintillation spectrometry. Analytical samples were prepared in vials by mixing 5 ml of a sample of water distilled from the vegetable mass with 15 ml of a liquid scintillation cocktail (herein-after referred to as LSC) "LIRA–1" (the required volumes of liquid were introduced with a pipette dispenser). In parallel with the analytical samples, blank samples and standard analytical samples were prepared. Blank analytical samples were obtained by mixing dis-tilled water with LSC and standard samples were obtained by mixing water with a known concentration of tritium (2700 Bq/l) with LSC. The water/LSC ratio for analytical samples, blanks and reference samples was 5/15. The finished analytical samples were labeled and thoroughly shaken, settled in a dark place for 10-20 hours.

The analysis of the tritium content in the analytical samples was carried out on a Tri-Carb 4810 TR spectrometer. The spectrum set time was 3 hours, the tritium activity in the sample was determined relative to the measured tritium activity in the standard sample.

## 3. Results

*3.1 The results of determining the concentration of tritium in the water vapor of the air in the vegetation house*

The results of the determination of tritium in the water vapor of the air in the vegetation house during the day and at night are shown in Figure 2.

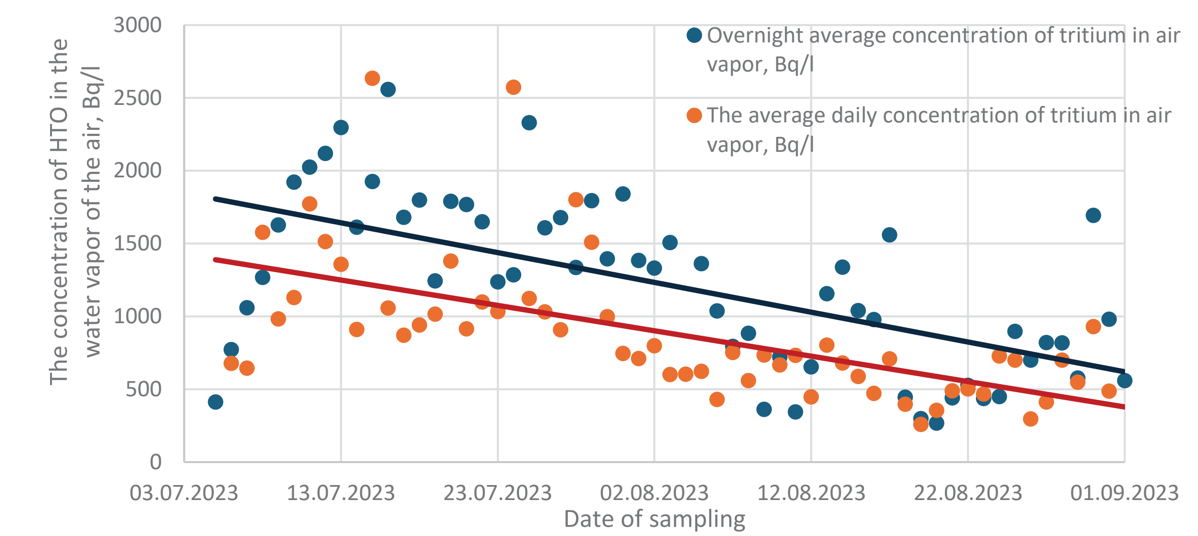


**Figure 2.** The results of determining the concentration of tritium in the water vapor of the air in the vegetation house

The results show that the concentration of tritium in the water vapor of the air fell during the experiment. In addition, the concentration of tritium in air vapors during the day differs from the concentration of tritium in water vapor at night. In this regard, when as-sessing the ratio of the content of TFWT in a plant to the content of tritium in water vapor, the arithmetic mean value of the concentration of tritium in the air for the entire period of the experiment was not used, but the average concentration of tritium in the air during the period of direct residence of the studied plants in the vegetation house. The calculation results are shown in Table 2.

**Table 2.** The average concentration of tritium in air vapor during the period of plant aging in a vegetative house with a tritiated atmosphere

| Period, dates | $C_T$, Bk/l | Period, dates | $C_T$, Bk/l |
|---|---|---|---|
| 12.07-17.07 | 1710 ± 300 | 25.08-29.08 | 650 ± 150 |
| 27.07-01.08 | 1340 ± 250 | 31.08-04.09 | 670 ± 150 |
| 02.08-04.08 | 970 ± 200 | 4.09-6.09 | 650 ± 150 |
| 12.08-15.08 | 840 ± 200 | | |

3.2 *Results of the determination of TFWT in vegetative organs of plants and their parts grown by the hydroponic method with an aerial mechanism of tritium intake*

Table 3 shows the fresh masses of collected vegetative organs of plants and their parts obtained in experiments to study the transition of tritium into cucumber, tomato and corn crops by an aerial mechanism. The results of the determination of free water tritium (TFWT) in the collected samples are presented in Tables 4-6. They also show the periods of plants in a vegetation house with a "tritiated" atmosphere.

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**Table 3.** Masses of collected vegetative organs of plants (gr.) aged in a vegetative house with a "tritiated" atmosphere

| Experiment dates | Cucumber | | | | Tomato | | | | Corn | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaf | Stem | Fruit | Root | Leaf | Petiole | Stem | Root | Leaf | Stem | Root |
| 12.08-17.08 | 38 | 32,5 | - | 21 | 31 | - | 18 | 8,8 | - | - | - |
| 27.07-01.08 | 100 | 50 | 65 | 44,5 | 73 | - | 47 | 32 | 41,5 | 29,5 | 16,5 |
| 02.08-04.08 | 100 | 45 | 96 | 38 | 59 | - | 39,5 | 23 | 32,5 | 33 | 15,5 |
| 12.08-15.08 | 105 | 41 | - | 26 | 107 | 73 | 110 | 53,5 | 26 | 33 | 10,5 |
| 25.08-29.08 | 46 | | 255 | - | 124 | 83 | 128 | 42,5 | 36 | 41 | 12 |
| 31.08-04.09 | 62 | | 235 | - | 105 | - | 84 | 21 | 48 | 44 | 19 |
| | 155 | 83 | 220 | 71 | 290 | - | 173 | 75 | 47,5 | 50 | 17,5 |
| | 190 | 73 | 275 | 94 | 65 | 56 | 80 | 29 | 31 | 32 | 4,1 |
| 4.09-6.09 | 195 | 87 | 118 | 101 | 49 | 68 | 37 | 13,5 | 40 | 37 | 7,0 |
| | - | - | - | - | 78 | 58 | 103 | 29 | 44,5 | 40 | 15,5 |

**Table 4.** Concentrations of TFWT in cucumber culture with tritium intake by the "air – plant" mechanism, Bk/l of water

| Experiment dates | Cucumber | | | | |
|---|---|---|---|---|---|
| | Leaf | Stem | Fruit | Petiole | Root |
| 12.07-17.07 | 770±70 | 720±140 | - | - | 57±20 |
| 27.07-01.08 | 230±40 | 200±40 | 680±140 | - | - |
| 02.08-04.08 | 200±50 | 260±50 | 300±60 | - | 70±20 |
| 12.08-15.08 | 200±20 | 160±16 | 180±20 | - | 70±20 |
| 25.08-29.08 | 190±20 | | 60±15 | - | - |
| 31.08-04.09 | 250±25 | 180±20 | 200±20 | - | 50±15 |
| 4.09-6.09 | 280±35 | 95±15 | 130±20 | 135±25 | 20±10 |
| **Arithmetic mean** | **316** | **244** | **258** | | **48** |

**Table 5.** Concentrations of TFWT in tomato cucumber culture with tritium intake by the "air – plant" mechanism, Bk/l of water

| Experiment dates | Tomato | | | |
|---|---|---|---|---|
| | Leaf | Petiole | Stem | Root |
| 12.07-17.07 | 380±40 | - | 210±20 | 60±15 |
| 27.07-01.08 | 220±40 | - | 90±20 | 20±15 |
| 02.08-04.08 | 140±30 | - | 70±20 | 30±20 |
| 12.08-15.08 | 200±40 | 40±20 | 25±15 | 15±15 |
| 25.08-29.08 | 260±30 | 100±20 | 90±20 | 85±30 |
| 31.08-04.09 | 225±20 | - | 100±20 | 75±30 |
| 4.09-6.09 | 260±15 | 60±15 | 45±15 | 42±15 |
| **Arithmetic mean** | **243** | **67** | **82** | **49** |

**Table 6.** Concentrations of TFWT in corn culture with tritium intake by the "air – plant" mechanism, Bk/l of water

| Experiment dates | Corn | | |
|---|---|---|---|
| | Leaf | Stem | Root |
| 27.07-01.08 | - | - | 65±15 |
| 02.08-04.08 | 260±50 | 120±25 | 80±40 |
| 12.08-15.08 | 185±30 | 80±20 | 60±20 |
| 25.08-29.08 | 370±70 | | 120±30 |
| 31.08-04.09 | 220±30 | 120±30 | 80±15 |
| 4.09-6.09 | 205±20 | 75±15 | 30±15 |
| **Arithmetic mean** | **248** | **103** | **78** |

First of all, it should be noted that in all cases significant concentrations of TFWT were obtained, amounting to approximately 30% (27% for tomato – 34% for corn) from the concentration of tritium in the water vapor of the air. This fact indicates the great importance of the aerial mechanism of tritium intake into plants.

Attention is drawn to the significant heterogeneity in the distribution of tritium across the vegetative organs. For all the studied plants, the concentration of tritium in the roots is significantly less than its concentration in the aboveground organs. Concentrations of TFWT in other organs also differ significantly at all stages of plant vegetative development. Since sufficiently high concentrations of TFWT were also detected in the root, that is, in the organ, which in most cases remains in the ground even for agricultural plants, the possibility of accumulation of tritium in the soil by the mechanism of tritium migration - "air - plants – soil" should be more carefully considered.

### 3.3 *The results of determining the concentration of tritium in a nutrient solution after aging plants in vegetative hydroponic vessels in a "tritiated" atmosphere*

Table 7 shows the results of determining the concentration of tritium in a nutrient solution on the 3rd day of exposure of hydroponic plants in a vegetative house with a "tritiated" atmosphere, as well as the final mass of nutrient solutions in grams (mass of NS).

**Table 7.** Tritium concentration ($C_T$, Bq/l) in nutrient solution and its mass after exposure of hydroponic plants in a vegetative house with a "tritised" atmosphere

| Dates of the experiment | Cucumber | | Tomato | | Corn | |
|---|---|---|---|---|---|---|
| | $C_T$, Bq/l | Weight of NS, gr. | $C_T$, Bq/l | Weight of NS, gr. | $C_T$, Bq/l | Weight of NS, gr. |
| 12.07-17.07 | 104±20 | 1660 | 140±25 | 2204 | | |
| 27.07-01.08 | 72±15 | 738 | 80±18 | 982 | 116±25 | 1748 |
| 02.08-04.08 | 58±15 | 1372 | 42±15 | 784 | 42±15 | 302 |
| 12.08-15.08 | 35±15 | 1120 | 33±15 | 1386 | 30±15 | 1326 |
| 25.08-29.08 | 22±12 | 1444 | 32±14 | 440 | 26±14 | 1796 |
| 4.09-6.09 | <10 | 2109 | <10 | 2072 | 32±12 | 705 |

Thus, numerical values of the tritium concentration in the nutrient solution were obtained, which exceed the detection limit by several times and, accordingly, are reliably determined. Significant concentrations of tritium indicate the presence of another mechanism of the "air–plants –soil" tritium migration pathway through the release of exudates by the root system.

## 4. Discussion of the results

### *4.1 Assessment of the level of intake of tritium into plants by the aerial route and its dependence on the growing time*

Since the highest concentrations of TFWT are noted in the leaves, in the framework of this work, the ratio of the concentration of TFWT in the leaves to the concentration of tritium in water vapor in the air will be used as the already mentioned coefficient R. The results of the arithmetic mean of the coefficients R, which actually reflect the proportion of water entering the plant by the aerial route, for all plants of all species turned out to be ~ 0.3 (Table 8). Such a high value of the R coefficient confirms the fact that a significant part of the water entering the plant is supplied by the aerial route.

Since the plants were aged in a tritiated atmosphere at different stages of their vegetation, an attempt was made to assess the dependence of the intensity of tritium absorption by plants at different stages of their development. The results are shown in Figure 3. De-spite the abnormal values at two or three points, we can say that there is a directly proportional dependence of the degree of intake on the time of vegetation. On average, the intensity of tritium uptake by plants is greater in the late stages of development than in the early stages, and this difference reaches 4 times.

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**Table 8.** The results of calculating the coefficients M, K, and R for the studied plants

| The period when plants are in a tritiated atmosphere | Cucumber | | | Tomato | | | Corn | | |
|---|---|---|---|---|---|---|---|---|---|
| | **M = $C_l$ / $C_s$** | **К = $C_l$ / $C_r$** | **R** | **M = $C_l$ / $C_s$** | **К = $C_l$ / $C_r$** | **R** | **M = $C_l$ / $C_s$** | **К = $C_l$ / $C_r$** | **R** |
| 12.07-17.07 | 1,1±0,3 | 13,5±4,0 | 0,45±0,12 | 1,8±0,6 | 6,3±2,2 | 0,22±0,06 | | | |
| 27.07-01.08 | 1,2±0,4 | | 0,17±0,06 | 2,4±1,2 | 11,0±6,6 | 0,16±0,06 | | | |
| 02.08-04.08 | 0,8±0,5 | 2,9±1,1 | 0,21±0,09 | 2,0±1,2 | 4,7±2,2 | 0,14±0,06 | 2,2±0,4 | 3,3±1,8 | 0,27±0,11 |
| 12.08-15.08 | 1,3±0,2 | 2,9±1,1 | 0,24±0,08 | 8,0±5,0 | 13,3±8,5 | 0,24±0,11 | 2,3±0,5 | 3,1±1,4 | 0,22±0,09 |
| 25.08-29.08 | | | | 2,9±0,9 | 3,1±1,3 | 0,40±0,14 | 3,1±1,6 | 2,4±1,1 | 0,57±0,24 |
| 31.08-04.09 | 1,4±0,2 | 5,0±2,1 | 0,37±0,12 | 2,3±0,9 | 3,0±0,9 | 0,34±0,14 | 1,8±0,6 | 2,8±1,3 | 0,33±0,16 |
| 04.09-06.09 | 2,9±1,3 | 14,0±6,0 | 0,43±0,22 | 5,8±2,2 | 5,8±2,2 | 0,40±0,18 | 2,7±1,3 | 6,7±2,8 | 0,31±0,14 |
| **Average** | **1,4** | **7,6** | **0,31** | **3,6** | **6,7** | **0,27** | **2,4** | **3,6** | **0,34** |

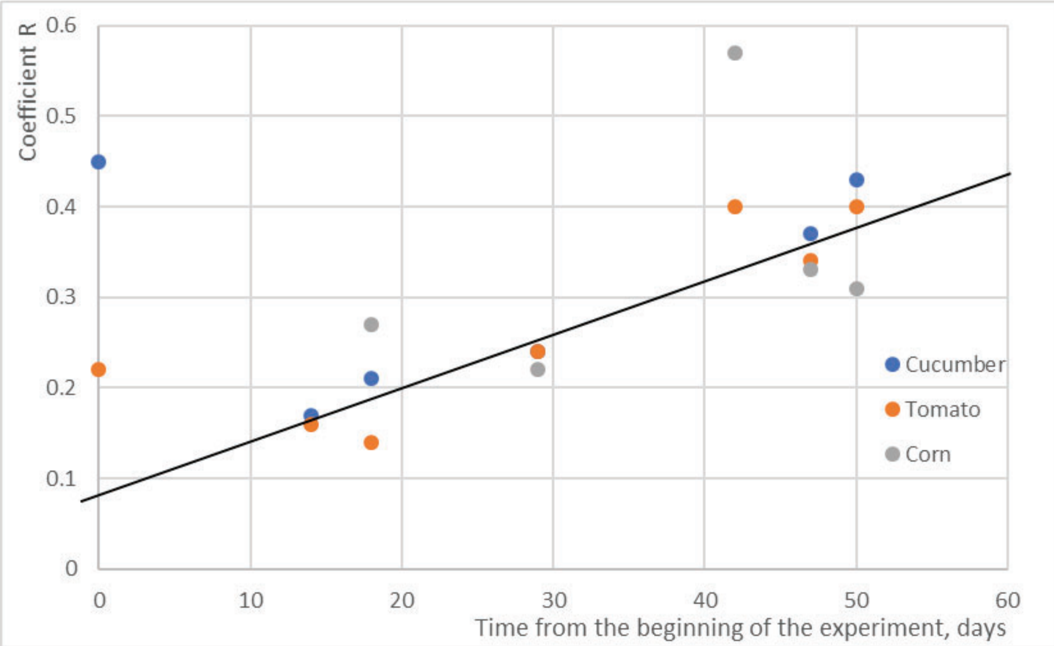


**Figure 3.** Dependence of the intensity of tritium absorption by plants (coefficient R) on the stage of their vegetation

4.2 *Distribution by vegetative organs and their parts during the aerial route of tritium intake into plants during hydroponic cultivation*

To assess the uneven distribution of tritium across vegetative organs, two coefficients are used in this work:

– the coefficient M, which is the ratio of the concentration of TFWT in the leaves to the concentration of TFWT in the stems;

– coefficient K, which is the ratio of the concentration of TFWT in the leaves to the concentration of TFWT in the roots.

A comparison of the values of the M coefficients for one species, as well as their average values for different plant species, allows us to draw some unambiguous conclusions. First-ly, for all plants and at all stages of vegetation, there is an excess of the concentration of TFWT in the leaves over the concentrations in the stems. The average values of the coefficient M are: 1.4 cucumber crops, 3.6 for tomato, 2.4 for corn. The difference in concentrations of TFWT in leaves and roots is even more pronounced. The average values of the K coefficient were: 7.6 for cucumber culture, 6.7 for tomato, 3.6 for corn.

The above information makes it possible to optimize the work on assessing the radioecological condition of agricultural lands on which crop production is produced and which is located in the zone of influence of radiation-hazardous objects capable of tritium emission. The optimal research strategy would be to use not the entire plant or its valuable economic part as the main object of research, but only the leaves. Since, precisely, the maxi-mum concentration of TFWT is observed in the leaves, their use will allow us to obtain the maximum numerical data on the content of TFWT in plants. The content of TFWT in other parts of plants, with knowledge of the relevant coefficients, can be calculated.

### 4.3 *Assessment of the intake of tritium into the soil/soil solution by the "air–plant-soil" mechanism*

The determination of tritium in nutrient solutions after exposure of hydroponic vessels with plants in a "tritiated" atmosphere revealed its presence in significant, reliably detectable amounts. In fact, this means that there is an "air–plant–soil" tritium migration path. This migration route is rarely considered, although its presence can easily be assumed due to the existence of the phloem, the vascular tissue of the plant, which transports substances produced in the leaves to all other parts of the plant, including the root system, as well as exudates. Using tritium as an indicator, based on the results obtained, it is possible to estimate the amount of water actually transferred by plants from the air to the nutrient solution (soil). The calculation results are shown in Table 9. Table 9 also contains the necessary intermediate data: At is the total activity of tritium in the final nutrient solution, M is the total mass of the aboveground part of the plants (stem, leaves, petioles). The transfer coefficient - $K_{aps}$ actually means the amount of water transferred by plants from the air to the soil/ nutrient solution per 1 gram of green mass per day, and has a dimension of - ml / (kg* day).

The results show that the average $K_{aps}$ values for different crops are in the range of 240 - 320 ml / (kg*day). Perhaps this coefficient also depends on the stage of vegetation – in the early stages it is higher, in the later stages it is much lower. This trend is most pronounced for tomato culture.

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**Table 9.** The results of the calculation of the tritium transfer coefficient by plants via the "air–plant–soil" mechanism ($K_{aps}$)

| **Date of experiment** | **Cucumber** | | | **Tomato** | | | **Corn** | | |
|---|---|---|---|---|---|---|---|---|---|
| | $A_T$, Bq | The weight of the aboveground part | $K_{aps}$, ml / (kg*day) | $A_T$, Bq | The weight of the aboveground part | $K_{aps}$, ml / (kg*day) | $A_T$, Bq | The weight of the aboveground part | $K_{aps}$, ml / (kg*day) |
| 12.07-17.07 | 172,6 | 70,8 | 475 | 309 | 48,4 | 1243 | | | |
| 27.07-01.08 | 53,1 | 150,4 | 88 | 79 | 120,7 | 162 | 202,8 | 71 | 710 |
| 02.08-04.08 | 79,6 | 145,5 | 188 | 33 | 98,5 | 115 | 12,7 | 65,8 | 66 |
| 12.08-15.08 | 39,2 | 146,4 | 106 | 46 | 289,5 | 63 | 39,8 | 59,2 | 267 |
| 25.08-29.08 | 31,8 | 46,5 | 350 | 14 | 335 | 22 | 46,7 | 77,2 | 310 |
| 4.09-6.09 | 21,1 | 175,6 | <62 | <21 | 198,0 | <54 | 22,6 | 74,7 | 155 |
| **Average** | | | **241** | | | **321** | | | **302** |

## 5. Conclusion

As part of the study, the essential importance of the aerial mechanism of tritium in-take into plants was revealed, and a quantitative assessment of the parameters characterizing this transfer mechanism was given. It is shown that for such crops as cucumber, tomato, corn, the proportion of water intaking to the plant by the aerial mechanism is on average about 30% of the total water absorbed by the plant. It has been revealed that the ability of plants to absorb water from the air increases during the growing season.

A significant unevenness in the distribution of the concentration of TFWT by organs and parts of plants has been identified and confirmed. Accordingly, when studying vegetation, assessing the contamination of agricultural products produced in an area with a increased content of tritium in air vapor, it is necessary to pay attention to the type of part of the plant being collected.

The presence of significant concentrations of tritium of TFWT in plants and especially in its root part, which usually remains in the soil, as well as the revealed transition from plants to soil solution under conditions of its aerial intake shows the importance of a special mechanism of soil contamination with tritium along the path "air (water vapor of air) – free water of plants – soil". The presence of this mechanism can lead to soil contamination with tritium in the absence of tritium-contaminated groundwater and surface waters, which, as a rule, are considered as the main source of pollution by it.

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