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BIOLOGICAL ELEMENTS AGRICULTURAL TECHNOLOGIES OF GROWING CROPS IN RADIOACTIVELY CONTAMINATED AREAS

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Розглянуто сучасні енвайронментально-біологічні підходи до підбору польових сільськогосподарських культур для культивації на радіоактивно забруднених територіях. Встановлено, що насиченням сівозмін сільськогосподарськими культурами, які відрізняються потенційно невисокою здатністю до накопичення ^{137}Cs, можна значно розширити ареал використання радіоактивно забруднених земель для виробництва гарантовано безпечної продукції. Проаналізовано вплив арбускулярних мікоризних грибів на надходження радіоцезію до рослин. Виявлено здатність арбускулярної мікоризи суттєво модифікувати накопичення радіоцезію сільськогосподарськими культурами.

Ключові слова: *біологічні елементи агротехнологій, радіоцезій, сільськогосподарські культури, радіоактивно забруднені території, арбускулярні мікоризні гриби, мікоризна колонізація*

Nowadays the radiocaesium remains the most biologically significant pollutant that determines the degree of radiation risk for the population. The principal pathway of its intake to humans is the consumption of agricultural products produced in contaminated areas. This paradigm is confirmed by experience to overcome the consequences of the Chernobyl catastrophe in1986 and the accident at Fukushima NPP Fukushima in 2011 [1–3]. The agricultural activity under these conditions implies the implementation of complex anti-radiation agrochemical measures aimed at reducing population exposure by ensuring the production of radioecologically safe agricultural products [4–6].

Last years the significant attention is paid to the greening of agriculture, in particular environmental biotechnologies aimed at the combined use of certain plants species and soil microorganisms [7]. Among these microorganisms arbuscular mycorrhizal (AM) fungi are of particular importance, since about 90 % of plants form symbiotic relationships with these fungi and create mycorrhizal associations [8]. Along with the preservation and improvement of soil fertility, the use of AM fungi significantly reduces the chemical load on the environment and the population, which is especially important in areas contaminated after nuclear and radiological incidents.

The activity concentration of ^{137}Cs and ^{134}Cs in roots and shoots of studied plants was determined using gamma-spectrometer with semiconductor p-type coaxial high purity HP-Ge detector with a relative efficiency of 15% and resolution of 2.5 keV at 1.33 MeV.

The plants were cultivated on the artificially prepared substrata spiked with ^{134}Cs. The activity concentration of ^{134}Cs in the soil was 77000 Bq·kg^{-1}. To evaluate the accumulation of radionuclides in crops at different radiocaesium concentrations the accumulation factor (AF, the ratio [Bq·kg^{-1} of plant air-dry weight / kBq·m^{-2} in soil]) and transfer factor (TF, the ratio [Bq·kg^{-1} of plant air-dry weight/Bq·kg^{-1} in soil]) of radiocaesium from soil to plants were used.

The colonization levels of plants with AM fungi were determined using Nikon Eclipse 800 (Japan) light microscope with a photographic system Nikon FDX-35. The plant roots were stained with a solution of 0.01% aniline blue and 80% lactic acid. The quantitative analysis of mycorrhizal colonization of plants with intraradical structures of AM fungi was carried out according to Trouvelot method [9], using a six-level colonization scale.

The environmental and biological approaches to the selection of crops in agriculture in contaminated areas are based on their potential ability to accumulate radionuclides. According to the data presented on Fig. 1, the plant field crops can be divided into three groups according to their potential capacity to accumulate ^{137}Cs.

The minimal ^{137}Cs accumulation in the harvest was found in case of corn. The radionuclide accumulation factor in grains of this plant species was 0.07 (Bq·kg^{-1})/(kBq·m^{-2}). The maximum radiocaesium concentration within the group of grain cereals was in oat grains. The concentration of ^{137}Cs in oat grains was 5 times higher than that of corn.

The group of plants with potentially low ability to accumulate ^{137}Cs also includes potatoes. The radiocaesium accumulation factor in its tubers is intermediate between spring wheat and barley, but is 71% higher than for corn. The group of groat cultures was characterized with higher potential accumulation of radiocaesium. Thus, the ^{137}Cs concentration in millet was nearly the same as in winter rye, but three times lower than in buckwheat (Fig. 1). However, the maximum accumulation of ^{137}Cs is typical for group of grain legumes. In particular, in pea plants the radiocaesium concentration was 13 times higher as compared to corn.

In view of aforesaid, the use of selection and saturation of crop rotations differed with potentially low capacity to accumulate radiocaesium could extend significantly the areal of contaminated lands exploitation for the cultivation of agricultural production that meets the current hygienic standards.

To study the influence of arbuscular mycorrhizal (AM) fungi on the radiocaesium accumulation by agricultural crops in laboratory conditions alfalfa (*Medicago truncatula*) and sunflower (*Helianthus annuus*) plant species were selected. The AM fungus *Glomus intraradices* (strain BIO; company BIORIZE, Didjon, France) was used for plant inoculation. This species is widespread in a variety of soil types and shows high colonization ability in symbiosis with many plant species [10].

The obtained results demonstrate the ability of arbuscular mycorrhiza to modify significantly the accumulation of radiocaesium by plants. In particular, the inoculation with AM fungus *G. intraradices* resulted in 52% decrease of ^{134}Cs transfer factor in above-ground parts of alfalfa as compared to non-mycorrhizal control. At the same time, the mycorrhizal *M. truncatula* plants accumulated 19% less of ^{134}Cs than mycorrhizal ones (Table 1). Thus, the presence of arbuscular mycorrhizal symbiosis led to 80% increase of the ratio between ^{134}Cs activity concentration in underground and above-ground parts of alfalfa, and consequently to reduction of the radionuclide transfer from plant root system to aboveground organs.

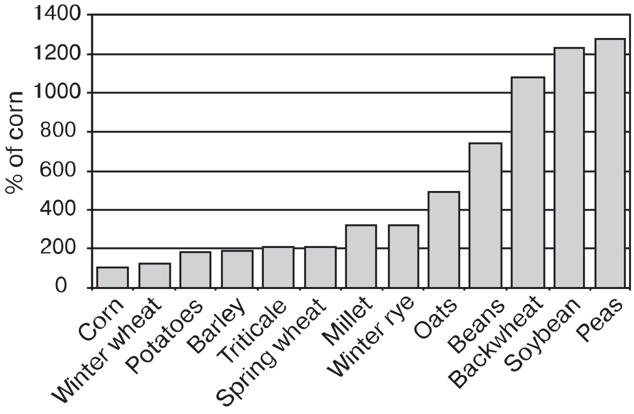

Fig. 1. The relative accumulation of ^{137}Cs by field crops, % of corn

The opposite effect of arbuscular mycorrhiza impact was observed in sunflower, where almost tenfold rise of 134Cs activity concentration was noticed in AM inoculated plants as compared to the control ones (from 0.50 to 4.92 in the root system and 0.34 to 3.19 in the aboveground organs). The mycorrhizal plants of this species demonstrated the hyperaccumulation

Table 1

^{134}Cs activity concentration ($Bq \cdot kg^{-1}$), ^{134}Cs total activity in roots and shoots of single plant (Bq per plant tissue), ^{134}Cs transfer factors (TFs) and root-to-shoot ratios of ^{134}Cs activity concentration in Medicago truncatula and Helianthus annuus mycorrhizal (M) or not (NM) with Glomus intraradices

	Activity concentration, $Bq \cdot kg^{-1}$		Total activity, Bq per plant tissue		Transfer factor (TF)		Root/Shoot ratio
	Roots	Shoots	Roots	Shoots	Roots	Shoots	
	Medicago truncatula						
NM	106400±19986a	132100±15505b	2.3±0.2a	12.3±0.6b	1.38±0.21a	1.72±0.20b	0.81±0.28a
M	126441±11463b	86888±20022a	3.1±0.1b	9.3±0.6a	1.64±0.15b	1.13±0.26a	1.45±0.41b
	Helianthus annuus						
NM	38412±3933a	26202±1147a	0.4±0.1a	6.4 ±1.8a	0,50±0.05a	0,34±0.04a	1.47±0.21a
M	378932±10233b	245353±4502b	6.5±1.2b	104.1±4.6b	4,92±0.08b	3,19±0.06b	1.54±0.10a

*Values within a column followed by the different letters differ significantly at $p<0.05$.

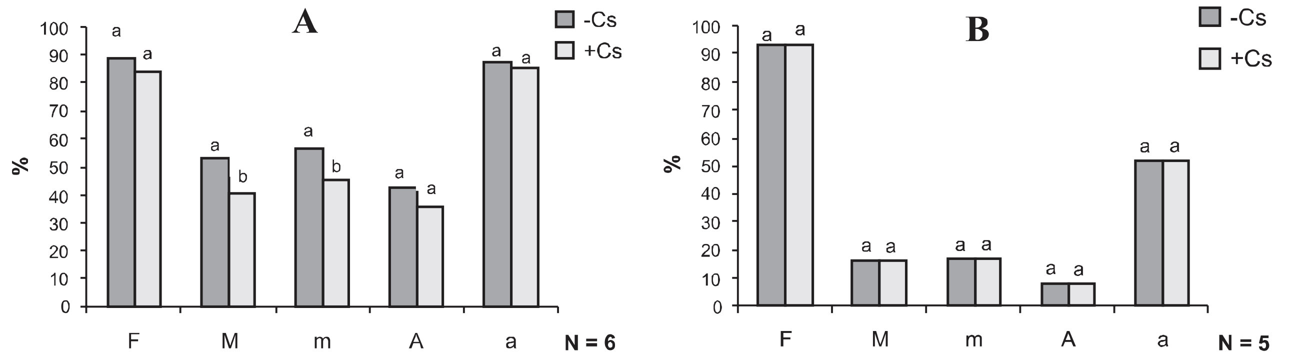

Fig. 2. Arbuscular mycorrhizal colonization parameters (%, medians) of Medicago truncatula (A) and Helianthus annuus (B) inoculated with Glomus intraradices:
F%, frequency of mycorrhiza; M%, mycorrhizal colonization intensity for all roots; m(%), mycorrhizal colonization intensity within individual mycorrhizal roots; A%, arbuscule richness for all roots; a%, arbuscule richness in root fragments where the arbuscules were present. Plants were cultivated on non-spiked substrata (−Cs) and substrata spiked with ^{134}Cs (+Cs); the different letters above bars mean statistically significant differences ($p < 0.05$)

ability for radiocaesium. During the three-month cultivation period they accumulated relatively large (0.22–0.27%) of the radionuclide from the substrata.

The mechanisms which AM fungi use to retain radiocaesium and other radionuclides into their structures and limit or increase their income to the plants have not been studied in details. Nowadays two basic processes are known: 1) release of chemical compounds by AM fungus that convert pollutants in the soil into non-exchangeable forms, sometimes with pollutant fixation on the outer surface of the mycelium and 2) compartmentalization — the translocation of absorbed pollutant to organ where it can be better tolerated or in a subcellular compartment where it can be stored away from the cytoplasm [11].

The mycorrhizal plants of alfalfa and sunflower cultivated on substrata spiked with ^{134}Cs and «control» soil were characterized with significant levels of AM colonization (84–98%). The colonization of plant root fragments was homogeneous, and intraradical structures of AM fungus *G. intraradices* formed Arum-type of mycorrhizae.

The high concentration of arbuscules in colonized roots of all plant species (52–89%) indicates the effective functioning and good qualitative condition of mycorrhizae. According to the data presented on Fig. 2, the parameters of AM colonization of alfalfa roots were significantly higher than those of sunflower.

It should be noted that the presence of radiocaesium in soil did not affect the parameters of AM colonization of sunflower. At the same time it resulted in a certain decrease (10–12%) of mycorrhizal colonization intensity parameters (M and m) in case of alfalfa.

CONCLUSIONS

The environmental and biological approaches in agriculture in contaminated areas include the more efficient use of the potential ability of crops to accumulate radionuclides and the application of certain species of soil microorganisms. It results in reduction of chemical load on agro-ecosystems and contributes to the preservation and fertility of radioactively contaminated soils.

AM fungi demonstrate the capacity to transform and immobilize radiocaesium in their structures and limit its uptake by certain plant species. The efficiency of mycorrhizae in the process of radiocaesium transfer is not determined by AM colonization degree and demonstrates the dependence of radionuclide transfer factors on the biological features of plants.

The potential use of AM fungi for cultivation of certain crops in radioactively contaminated soils require more comprehensive study in order to reduce the chemical load on the environment by minimizing the introduction of fertilizers and greening of agriculture.

REFERENCES

1. *Абагян А.А.* Информация об аварии на Чернобыльской АЭС и ее последствиях, подготовленная для МАГАТЭ / А.А. Абагян // Атомная энергия. — 1986. — Т. 61, вып. 5. — С. 301–320.
2. Національна доповідь України «25 років Чорнобильської катастрофи. Безпека майбутнього». — Київ: КІМ, 2011. — 395 с.

3. *Hirose K.* Fukushima Dai-ichi nuclear power plant accident: summary of regional radioactive deposition monitoring results / K. Hirose // J. Environ. Radioact. — 2012. — Vol. 111. — P. 13–17.
4. Ведення сільськогосподарського виробництва на територіях, забруднених внаслідок Чорнобильської катастрофи у віддалений період (методичні рекомендації) / редкол.: Б.С. Пристер та ін. — К.: Атіка-Н, 2007. — 195 с.
5. *Пристер Б.С.* Проблемы сельскохозяйственной радиоэкологии и радиобиологии при загрязнении окружающей среды молодыми смесями продуктов ядерного деления. — Чернобыль, К.: Книга, 2008. — 320 с.
6. *Дутов О.І.* Сучасні підходи до раціонального використання радіоактивно забруднених земель (на прикладі аварії на Чорнобильській АЕС) / О.І. Дутов // Агрохімія і Ґрунтознавство. Міжвідомчий тематичний науковий збірник. Випуск 77. — Харків: ННЦ «ІГА ім. О.Н. Соколовського», 2012. — С. 38–43
7. *Entry J.* Accumulation of ^{137}Cs and ^{90}Sr from contaminated soil by three grass species inoculated with mycorrhizal fungi / J.A. Entry, L.S. Astrud, M. Reeves // Environ. Pollut. — 1999. — Vol. 104. — P. 449–457.
8. *Smith S.* Mycorrhizal Symbiosis / S.E. Smith, D.J. Read // Academic Press. — 1997. — 312 p.
9. *Trouvelot A.* Mesure du taux de mycorhization VA d'un système radiculaire. Recherche de méthodes d'estimation ayant une signification fonctionnelle / A. Trouvelot, J.L. Kough, V. Gianinazzi-Pearson // Physiological and Genetical Aspects of Mycorrhizae. — INRA Press. Paris. — P. 217–221.
10. *Кріпка Г.В.* Отримання та випробування інокулятів арбускулярних мікоризних грибів з метою модифікації поглинання радіонуклідів рослинами / Г.В. Кріпка, Б.В. Сорочинський // Зб. наукових праць Інституту ядерних досліджень. — 2003. — № 2 (10). — С. 80–84.
11. *Meharg A.* The mechanistic basis of interactions between mycorrhizal associations and toxic metal cations / A. Meharg // Mycol. Res. — 2003. — Vol. 107. — P. 1253–1265.

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АНАЛІЗ БАЛАНСУ ПОЖИВНИХ РЕЧОВИН У ҐРУНТАХ ЗЕМЕЛЬ СІЛЬСЬКОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ ЗОН ПОЛІССЯ ТА ЛІСОСТЕПУ

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Проаналізовано результати досліджень родючості ґрунтів та балансу поживних речовин у ґрунтах земель сільськогосподарського призначення зон Полісся та Лісостепу. Встановлено, що для підвищення родючості ґрунтів необхідно збільшити обсяги застосування мінеральних та органічних добрив, розширити площі багаторічних та сидеральних посівів, здійснювати приорювання пожнивних решток, а також впровадження еколого-економічно обґрунтованих ґрунтозахисних сівозмін.

Ключові слова: *баланс поживних речовин, ґрунти, мінеральні добрива, органічні добрива, родючість.*

У зв'язку з економічними реформами, що відбулися в Україні, та переходом до ринкових відносин у сільському господарстві виникли проблеми зі збереження та підвищення родючості ґрунтів. Землеробство повернулося до екстенсивних методів формування врожаю