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INFLUENCE OF ELECTROMAGNETIC RADIATION ON PLANT GROWTH

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Abstract. The increasing level of electromagnetic radiation is a dangerous factor that poses risks of damage to living organisms. Currently, research focuses on the influence of industrial sources of electromagnetic radiation; however, the sources of such radiation in the living environment are given insufficient attention. The combined effects of these sources of radiation on living organisms can be investigated using phytoindication. The purpose of the current study was to analyze the impact of electromagnetic radiation on the growth of cereals. Assessment of the trends of change in the length of shoots of test objects at the average absolute growth, the average rate of change and the average growth rate showed inhibition of plant growth indicators, but the most depressing effect was caused by radiation from a computer systems unit and a TV (shorter shoots compared to the control samples ranged between 13.3% in *Hordeum vulgare L.* to 46.2% in *Sorghum vulgare Pers.*). The study defined the sensitivity of test objects to electromagnetic radiation of appliances (in descending order): *Sorghum vulgare Pers. – Triticum aestivum L. – Hordeum vulgare L.* (maximum inhibition of growth performance compared to control samples stood at 46.2%, 27.9%, 15.3% respectively).

Keywords: electromagnetic radiation appliances, phytoindication, test object, growth, tendency, index.

Introduction

In nature, background exposure to electromagnetic fields (EMF) can be observed. The natural source of EMF is a geomagnetic field of the Earth. Currently, electromagnetic radiation (EMR) from human made sources is increasing, resulting in the increase in the electromagnetic pressure in natural environment and thus affecting human beings (Fedorovich 2004).

The living organisms have adjusted to special natural degree of electromagnetic field intensity during the evolution process and a significant difference from it in the higher or lower side (behind the borderline of the optimal vital activity of the living beings) is a stress factor. The human made EMFs that have other features than the geomagnetic field cause desynchronization in the cell-to-cell and organ-to-organ cooperation in a biological system that is tuned with natural electromagnetic background (Selga, T., Selga, M. 1996; Goiceanu *et al.* 2001; Ursache, Mindrul 2009).

Now the electromagnetic radiation is classified as a dangerous ecological factor because WHO has defined electromagnetic fields as a biologically active factor that greatly influences the formation and development of the living beings. In 1995 WHO has termed this phenomenon' global electromagnetic environmental pollution' and included the problem of the electromagnetic pollution of the environment to the priority problems list of the human beings because the pollution degree increases 10–15 times every 10 years. The electromagnetic background degree of the Earth currently exceeds the natural degree 200 000 times. Human made sources of electromagnetic fields are industrial processes, transferring and dividing systems of the electricity, electromagnets, electrostatic charging fields in the industry and households. This causes concerns for people working in the zone of the industrial frequency EMF or living near the bulk transferring lines. The influence of weak EMF on the human organism is manifest in the changes in the range and phase of the biological indicators rhythms. It is known that desynchronization is a general feature of health problems at the beginning stage. The influence of the electromagnetic radiation is increasing constantly because of the extended use of devices that have electromagnetic radiation. Some of such sources are actively used household devices. The wide use of such devices increases the ecological risk

degree for population health (Zamanian, Hardiman 2005; Baldi *et al.* 2011; Heinrich *et al.* 2011; Bortkiewicz *et al.* 2012; Frei *et al.* 2012; Christ *et al.* 2012).

Phytoindication methods are used for the evaluation of the electromagnetic radiation influence on the growth and development of the living beings (Lagroye *et al.* 2011). The most common are investigations on the organism level of the living matter organization focusing on the analysis of biochemical and physiological reactions, anatomical, morphological, biorhythmic and behavioral differences (Ibrahim *et al.* 2013).

Plants that are sensitive to the changes of the environmental conditions are often used as phytoindicators in such research.

In the current research, cereals – soft wheat *Triticum aestivum L.,* common barley *Hordeum vulgare L.*and sorghum *Sorghum vulgare Pers*. – were chosen as *the objects of the research.* These plants react sensitively to the external conditions. Under favourable conditions they exhibit quick and approximately 100 percent growth. Under unfavourable conditions changes in the growth dynamic and development of the vegetative organs can be observed. Also they are broadly used as crop species that are in the zone of influence by the human made electromagnetic radiation sources. Therefore, it is important to know their degree of sensitivity to electromagnetic radiation (Mamienko, Chemerys 2016).

The aim of the research is to reveal and analyse the influence of the household devices (computer, TV, refrigerator, microwave oven) on the cereal growth. The comparison was conducted with control samples that experienced minimal influence of the electromagnetic radiation.

The research objectives:

1. To reveal and analyse the influence of the electromagnetic radiation from widely used household devices on the growth indicators of the researched plants.

2. To compare the sensitivity degree of the researched plants to the EMR activity of the household devices.

3. To draw conclusions about the degree of ecological risk of using investigated household devices according to the general changes in trends of the growth indicators.

The research theme is relevant in the light of increased electromagnetic pressure on the environment. The EMR influence increases and will increase due to the growing use of devices that have electromagnetic radiation.

The analysis of the bibliographical sources showed that currently there is a growing awareness of the influence of the electromagnetic radiation from industrial radiation sources on the living beings (Russello *et al.* 1996; Balassa *et al.* 2009; Sommer *et al.* 2009). However, it is not known how exactly household devices influence biological systems. So far, the most researched is the radiation of cell phones or microwave radiation (Kwon *et al.* 2008; Mandala *et al.* 2014).

Materials and methods

Three types of the cereal were chosen for investigation: soft wheat (*Triticum aestivum L.*); common barley (*Hordeum vulgare L.*); and sorghum (*Sorghum vulgare Pers*). Every plant was sowed in the amount of 100 seeds in pots and was watered regularly. The pots with investigated samples were situated in the distance of 0.1 m from devices with electromagnetic radiation: a computer base unit, TV, refrigerator, microwave oven. Control samples of the investigated plants were exposed to minimal influence by EMR. The experiment time span was a fortnight. The growth dynamics of the shoots was observed and analysed. All the data were compared with that of the controls (Rudenko *et al.* 2008).

The results were elaborated statistically and tabulated using Microsoft Excel (Tarasova 2008).

Results and discussion

The highest influence of electromagnetic field to the living spaces in the frequency range of 50 Gz was exerted by electrotechnical equipment of the building, i.e. cable connections, dispensing boards and electric transformers. All household devices operated using electricity are sources of electromagnetic fields. The most powerful ones are microwave ovens, aero grills, refrigerators with ‘no frost’ system, kitchen hoods, electrical stoves, PCs, TVs.

The dynamic assessment of the growth indicators of the soft wheat

The length analysis of the soft wheat shoots grown near such household devices as refrigerator, microwave oven, TV and computer showed inhibited growth rate compared to control samples.

Veracity of the difference between medium indicators among the investigation variants and control samples is sustained by the Student’s criterion (see Table 1).

Throughout the experiment the length of the shoots of the control samples significantly outweighed the length of the shoots of investigated samples. Equal growth rate

was observed in both sample groups; however, there was a difference in growth among the investigated plants.

Table 1. Student's criterion value

t_{st} by $t_{0.05} = 2.12$			
Refrigerator	Microwave	TV set	Computer
36.64	7.01	6.65	10.58

During the experiment the length of the shoots in the control group increased on average 1.3 times more than of the plants growing near the household devices (see Fig. 1).

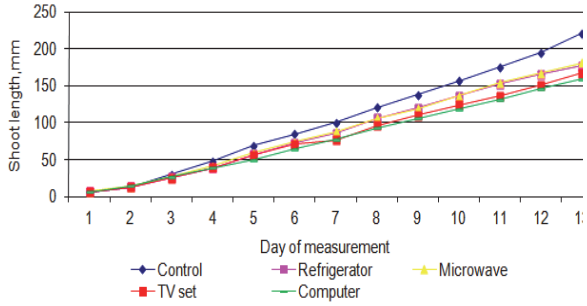

Fig. 1. The dynamics of growth of wheat sprouts

The most inhibited growth was observed in plants that were growing near the computer base unit: the length of the shoots of such plants was 61.45 mm lower than in the control samples. Also, growth inhibition was observed in the investigated samples that were growing near the TV – the difference from the control samples was 53.67 mm. Much less inhibition was caused by the refrigerator – the difference was 43.61 mm. The lowest negative influence on the soft wheat growth was that of microwave oven radiation – the difference from the control samples was 39.34 mm.

The dynamic assessment of the growth indicators of the common barley

It must be noted that the common barley seeds that were sowed near the microwave oven and computer have not grown up as much as other species of the investigated plants. The shoots length analysis of the common barley growing near refrigerator and TV showed inhibition of growth rate compared to control samples.

The shoots length analysis revealed that from the second till the fifth day of the experiment the length of the shoots of the control group was approximately the same as in the investigated samples. Yet on the sixth day the length of the shoots of the control group was 1.3 times higher than of the plants growing near the refrigerator and 1.2 times higher compared to plants grown near the TV.

Veracity of the difference between medium indicators among the investigation variants and control samples is sustained by the Student's criterion (Table 2).

Table 2. Student's criterion value

t_{st} by $t_{0.05} = 2.12$	
Refrigerator	TV set
5.69	7.38

After two weeks, the length of the shoots of the control group plants exceeded the respective indicators of the investigated plants 1.2 times (see Fig. 2).

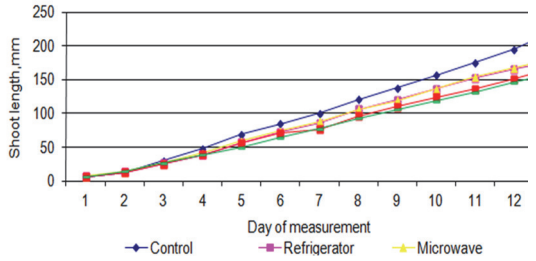

Fig. 2. The dynamics of growth of barley shoots

So the refrigerator and TV radiation caused similar growth inhibition of the investigated common barley plants – the difference in the length of the shoots compared to control samples was respectively 29.99 and 29.44 mm.

The dynamic assessment of the growth indicators of sorghum

The analysis of the length of the shoots of sorghum grown near refrigerator, microwave oven, TV and computer has shown inhibition of the growth rate in all investigated samples.

On the fourth day all control samples had sprouts. The shoots were observed in 90% of the samples of the test objects grown near the TV and computer. On the third day of the experiment the length of the shoots in the control group was 1.2 times higher than in the plants grown near household devices (Fig. 3).

Veracity of the difference between medium indicators among the investigation variants and control samples is sustained by the Student's criterion (see Table 3).

Table 3. Student's criterion value

t_{st} by $t_{0.05} = 2.12$			
Refrigerator	Microwave	TV set	Computer
9.24	10.30	16.92	16.01

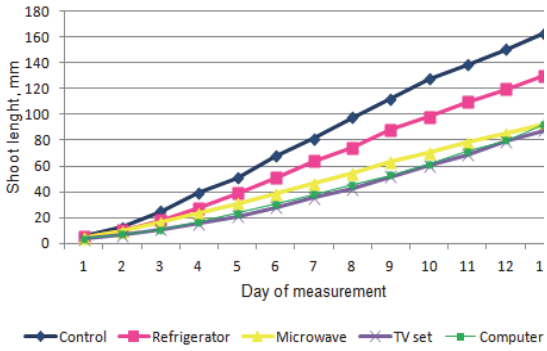

Fig. 3. The dynamics of growth of sorghum

So TV radiation has exerted the highest rate of inhibition on the growth of sorghum – the medium shoot length of the investigated samples was 75.32 mm lower compared to control plants. The radiation of the microwave oven and computer also had an inhibiting effect on the growth of sorghum. The difference between the length of the shoots compared to control samples was 70.33 mm and 70.52 mm accordingly. The lowest inhibition was in the samples grown near the refrigerator – the difference in the length of the shoots was 32.67 mm.

Table 4 shows the parameters of the investigated plants by the sensitivity to electromagnetic radiation from household devices and by the difference between shoots' length compared with control plants.

Table 4. The sensitivity scale of the investigated plants to the electromagnetic radiation from household devices

Plants	Difference in shoots' length compared to control samples, mm			
	Computer	TV set	Microwave	Refrigerator
Sorghum vulgare Pers.	70.52	75.32	70.33	32.67
Triticum aestivum L.	61.45	53.67	39.44	43.61
Hordeum vulgare L.	–	29.99	–	29.44

Note: – the seeds failed to grow.

Based on the analysis of sensitivity to the electromagnetic radiation from household devices, sorghum were the most sensitive; the most inhibitive effect on sorghum growth was caused by TV radiation, the microwave oven and computer had almost equal effect, the lowest inhibition was caused by the refrigerator radiation. The soft wheat plants were the second in terms of sensitivity: the most inhibiting effect on plant growth was caused by the computer base unit, TV radiation had less influence, then refrigerator radiation, and the least inhibiting was the microwave oven radiation. Barley growth results were distinctive because the seeds at the computer and microwave oven failed to grow. This leads to assumption that these devices might have a significantly negative impact on the growth of plants. Yet the grown up barley samples showed the lowest rate of inhibition compared to other kinds of plants researched.

Statistic assessment of the growth changes among the investigated plants

The assessment of the changes in shoot growth

The trends of changes of the shoot length of the test objects were assessed based on the indicator analysis of the intensity and speed of changes in the dynamic ranges, namely average absolute growth, average rate of changes tempo and average rate of growth.

The average absolute growth is defined as a direct average of chain growth according to formula 1:

$$\Delta\bar{O} = \frac{\sum \Delta y}{n-1}. \quad (1)$$

The average speed of changes in the length of the vegetative organs is characterized by the change medium coefficient (formula 2):

$$\bar{K} = \sqrt[n-1]{\frac{y_n}{y_1}}. \quad (2)$$

The average rate of changes was calculated based on the average change speed (formula 3):

$$\bar{T} = \bar{K} \cdot 100\ \%. \quad (3)$$

For evaluation of the average rate of growth formula 4 was used:

$$\Delta\bar{T} = \bar{T} - 100\%. \quad (4)$$

The general indicators of the growth dynamics showed in Table 5.

Table 5. The general indicators of the growth dynamics of *Triticum aestivum L.*

Performance dynamic series	Control	Refrigerator	Microwave	TV set	Computer
$\Delta\bar{O}$	19.49	15.53	17.06	15.18	13.92
$\bar{K}$	1.383	1.355	1.351	1.353	1.34
$\bar{T}$	138.3	135.5	135.1	135.3	134.3
$\Delta\bar{T}$, %	38.3	35.5	35.1	35.3	34.3

The average absolute growth Δ Ō shows the highest average growth speed is a characteristic to control samples, and the lowest – to samples grown near the computer base unit (see Table 5). Also the low average growth speed is indicative of the wheat grown near the TV, and the least inhibition on the growth speed is caused by microwave oven radiation. The average rate of change of the growth indicators shows the proportion of change (in %) in the investigated feature. The control samples have the highest average rate of change, samples grown near the computer base unit – the lowest.

Accordingly, the average growth rate is the highest among the control plants (38.3%) and the lowest among the plants grown near the computer (34.3%). The average growth rate among the plants grown near other household devices stood at approximately similar degree (35.1–35.5%).

Similar calculations were carried out for the common barley. The dynamic range indicators of the common barley growth are shown in Table 6.

Table 6. The general indicators of the growth dynamics of *Hordeum vulgare L.*

Performance dynamics series	Control	Refrigerator	TV set
$\Delta\bar{O}$	17.32	14.67	14.61
$\bar{K}$	1.382	1.358	1.353
$\bar{T}$	138.2	135.8	135.3
$\Delta\bar{T}$, %	38.2	35.8	35.3

In wheat samples, the highest average growth speed was observed in control samples, the lowest – in samples grown near the TV, but the average growth speed of samples grown near refrigerator is almost similar.

The average growth rate is also higher in the control samples and it is almost equal to the growth rate of the wheat control samples (38.2% vs. 38.3% in the wheat samples). In the barley samples, the average shoots growth rate of the investigated samples was by 3% lower than that of the control plants.

The highest average growth speed in sorghum samples, compared to other kinds of plants researched, was observed in the control samples, and the lowest – in the samples grown near the TV (see Table 7).

The sorghum plants grown near the microwave oven and computer had almost similar average growth rate (accordingly 8.01 and 8.17). The average growth rate is also the highest in the control samples (36.2%), and the lowest in the samples grown near the microwave oven (31.8%) – almost 5% lower than in the control samples. The average growth rate in the plants grown near other household devices is almost similar (34.6% near the computer and 34.8% near the refrigerator), and a little lower among the plants grown near the TV – 34.2%.

Table 7. The general indicators of the growth dynamics of *Sorghum vulgare Pers.*

Performance dynamic series	Control	Refrigerator	Microwave	TV set	Computer
$\Delta\bar{O}$	14.31	11.39	8.01	7.65	8.17
$\bar{K}$	1.362	1.348	1.318	1.342	1.346
$\bar{T}$	136.2	134.8	131.8	134.2	134.6
$\Delta\bar{T}$, %	36.2	34.8	31.8	34.2	34.6

So the investigation results of the influence of the electromagnetic radiation from household devices on the growth of plants showed inhibition in growth of all investigated plants compared to the control samples.

In Table 8 household devices are grouped according to the power of influence as well as characteristics affected, such as shoots' length, the average growth speed and average growth rate.

Table 8. The scale of influence of electromagnetic radiation from household devices on the growth indicators of tested plants

Test-objects	Household devices according to the influence on		
	Shoot length	The average growth speed	The average growth rate
Triticum aestivum L.	Computer	Computer	Computer
	TV set	TV set	Microwave
	Refrigerator	Refrigerator	TV set
	Microwave	Microwave	Refrigerator
Hordeum vulgareL.	Computer	Computer	Computer
	Microwave	Microwave	Microwave
	Refrigerator	TV set	TV set
	TV set	Refrigerator	Refrigerator
Sorghum vulgarePers.	TV set	TV set	Microwave
	Computer	Computer	TV set
	Microwave	Microwave	Computer
	Refrigerator	Refrigerator	Refrigerator

As it is shown in Table 8, the most inhibitive action on the shoot length of the investigated plants is caused by the radiation of the computer base unit and TV, only in barley samples the microwave oven is on the second place

in terms of negative influence. The average growth speed was most negatively affected by computer radiation, in sorghum samples – by TV. The average growth rate was most negatively influenced by a computer, and also by a microwave oven (in sorghum samples).

Analysis of individual indexes of the investigated indicators

Indexes are relative statistic indicators that characterize the change of the investigated event compared to a special standard.

Individual indexes show the correlation of a specific indicator and are calculated using the formula 5:

$$i_w = \frac{w_1}{w_0}. \quad (5)$$

The indexes are estimated using the basis method and are shown in Table 9.

Table 9. The value of the individual indexes

Home appliances	Test objects		
	Triticum aestivum L.	*Hordeum vulgare L.*	*Sorghum vulgare Pers.*
Refrigerator	0.802	0.847	0.799
Microwave	0.821	–	0.568
TV set	0.757	0.850	0.538
Computer	0.721	–	0.567

All indexes have the value lower than 1, which approves the decrease in indicator values compared to the basis (control plants). It is evident that the highest decrease was in the shoot length under the influence of computer radiation among – 27.9% in wheat samples compared to control samples (100 – 72.1) and in sorghum samples (43.3%). Also the sorghum shoot length was influenced by the TV radiation – the shoot length decrease compared to control samples was 46.2%; the microwave oven caused a 43.2% decrease. The growth – the shoot length decrease was 20.1%. As for other plants, the refrigerator radiation caused less inhibition on their growth indicators – in wheat samples – 18.8%, barley – 15.3%. In wheat samples, the greatest inhibition was caused by computer and TV radiation – 24.3%, while refrigerator radiation caused less inhibition and microwave oven radiation resulted in a 17.9% decrease in growth.

Thus, it was demonstrated that the influence of the electromagnetic radiation from household devices on sorghum growth was the highest (from 20.1% by refrigerator to 46.2% from TV). The least of all inhibited were barley plants whose growth inhibition indicators were in the range of 15.0% to 15.3% compared to control samples. Among wheat samples plants grown near the computer had the most inhibited shoot length – 27.9%, plants grown near microwave oven were least inhibited (19.8%).

Conclusions

1. In the living environment, electro technical equipment of the building has the highest influence on the electromagnetic fields in the frequency range of 50 Gz. All household devices operating by using electricity are also EMF sources. The most powerful ones are microwave ovens, aero grills, the refrigerators with the "No Frost" system, kitchen hoods, electrical stoves, PCs, TVs.

Such fields differently influence the biological systems depending on the frequency and voltage of the field.

2. The investigation carried out showed that all investigated plants exhibited growth inhibition compared to the control samples: the shoots' length of the control samples significantly exceeded the shoots' length of the experimental samples.

3. The sensitivity comparison of the investigated plants to the electromagnetic radiation from the household devices showed that the most sensitive were sorghum samples: the TV radiation strongly inhibited sorghum growth (the average shoots' length of the investigated samples was 75.32 mm lower compared to control plants), the microwave oven and computer had practically equal influence on the growth indicators (the difference with control samples was accordingly 70.33 mm and 70.52 mm). The least inhibitive was the refrigerator radiation (the difference was 32.67 mm).

The second in terms of sensitivity to electromagnetic radiation are the plants of the soft wheat: the computer base unit was the most inhibitive on the plants' growth indicators (the difference in length with control samples was 61.45 mm), the influence of the TV radiation resulted in the 53.67 mm difference, refrigerator – 43.61 mm, microwave oven radiation – 39.34 mm (the least difference).

Barley growth results were distinctive. Near the computer and microwave oven, the seeds failed to grow, leading to a conclusion about a significantly negative effect of these household devices on the growth of barley seeds. Yet the samples that did grow up were the least affected compared to other kinds of plants (the difference in shoot length compared to control samples was respectively 29.99 mm and 29.44 mm).

4. In summary, the most inhibitive effect on the shoots' length of the investigated plants was caused by the

computer base unit and TV radiation, only in barley samples the microwave oven was the second in terms of negative influence.

The average growth speed was most negatively influenced by computer radiation, in sorghum plants – TV radiation. The average growth rate was most negatively influenced by the computer, in sorghum samples – microwave oven.

5. The analysis of individual growth indexes showed that the highest inhibition of growth indicators was observed in sorghum samples (from 20.1% by refrigerator to 46.2% by TV). The least of all inhibited were barley plants whose growth inhibition compared to control samples was in the range of 15.0% to 15.3%. In wheat samples, the highest inhibition of the shoots' length was observed in plants grown near the computer (27.9%), the least – in plants grown near the microwave oven (19.8%).

6. Further research is needed into the analysis of indicators researched. Also, the range of test-objects has to be expanded aiming at achieving a complex understanding of the influence of electromagnetic radiation from household devices on the morphologic features of plants.

References

Balassa, T.; Szemerszky, R.; Bardos, G. 2009. Effect of short-term 50 Hz electromagnetic field exposure on the behavior of rats, *Acta Physiologica Hungarica* 96(4): 437–48. https://doi.org/10.1556/APhysiol.96.2009.4.4

Baldi, I.; Coureau, G.; Jaffre, A.; Gruber, A.; Ducamp, S.; Provost, D.; Lebailly, P.; Vital, A.; Loiseau, H.; Salamon, R. 2011. Occupational and residential exposure to electromagnetic fields and risk of brain tumors in adults: a case-control study in Gironde, France, *International Journal of Cancer* 129(6): 1477–1484. https://doi.org/10.1002/ijc.25765

Bortkiewicz, A.; Gadzicka, E.; Szymczak, W.; Zmyslony, M. 2012. Heart rate variability (HRV) analysis in radio and TV broadcasting stations workers, *International Journal of Occupational Medicine and Environmental Health* 25(4): 446–55. https://doi.org/10.2478/s13382-012-0059-x

Christ, A.; Guldimann, R.; Bühlmann, B.; Zefferer, M.; Bakker, J. F.; van Rhoon, G. C.; Kuster, N. 2012. Exposure of the human body to professional and domestic induction cooktops compared to the basic restrictions, *Bioelectromagnetics* 33(8): 695–705. https://doi.org/10.1002/bem.21739

Fedorovich, G. V. 2004. *Ekologicheskij monitoring ehlektromagnitnyh polej*. Moskva: Nauka. 140 (in Russian).

Frei, P.; Mohler, E.; Braun-Fahrlander, C.; Frohlich, J.; Neubauer, G.; Roosly, M. 2012. Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus, *Environmental International* 38: 29–36. https://doi.org/10.1016/j.envint.2011.08.002

Goiceanu, C.; Artenie, V.; Avadanei, O.; Creanga, D. 2001. Some evidence of biological effects of ultra high frequency fields in Triticum, in *Proceedings of IXth Mediterranean Conference on Medical and Biological Engineering and Computing*, 781–784.

Heinrich, S.; Thomas, S.; Heumann, C.; von Kries, R.; Radon, K. 2011. The impact of exposure to radio frequency electromagnetic fields on chronic well-being in young people – a cross-sectional study based on personal dosimetry, *Environment International* 37: 26–30. https://doi.org/10.1016/j.envint.2010.06.008

Ibrahim, M.; Ozovehe, A.; Hamdallah, A. 2013. Risk assessment of magnetic field pollution in average home, *International Journal of Engineering Research and Applications*, March–April, 3(2): 1126–1130.

Kwon, M. S.; Koivisto, M.; Laine, M.; Hamalainen, H. 2008. Perception of the electromagnetic field emitted by a mobile phone, *Bioelectromagnetics* 29(2): 154–159. https://doi.org/10.1002/bem.20375

Lagroye, I.; Percherancier, Y.; Juutilainen, J.; De Gannes, F. P.; Veyret, B. 2011. ELF magnetic fields: animal studies, mechanisms of action, *Progress in Biophysics and Molecular Biology* 107: 369–173. https://doi.org/10.1016/j.pbiomolbio.2011.09.003

Mamienko, V.; Chemerys, I. 2016. Evaluation of the influence of microwave radiation of Microwave ovens on water as a substratum for plant growth, in *Proceedings of the 19th Conference for Junior Researchers „Science – Future of Lithuania*, 111–116.

Mandala, M.; Colletti, V.; Sacchetto, L.; Manganotti, P.; Ramat, S.; Marcocci, A.; Colletti, L. 2014. Effect of bluetooth headset and mobile phone electromagnetic fields on the human auditory nerve, *Laryngoscope* 124(1): 255–259. https://doi.org/10.1002/lary.24103

Rudenko, S. S.; Kostishin, S. S.; Morozova, T. V. 2008. *Zagal'naekologiya.Praktichnijkurs: navchal'nijposibnik: u 2 chast.* CH.1. Chernivci: Knigi. 342 (in Ukrainian).

Russello, V.; Tamburello, C.; Scialabba, A. 1996. Microwave effects on germination and growth of Brassica drepanensis seed, in *Proceedings of 3rd International Congress of the European BioElectromagnetics Association,* 89.

Selga, T.; Selga, M. 1996. Response of Pinus Sylvestris L. needles to electromagnetic fields. Cytological and ultraestructural aspects, *The Science of the Total Environmen*^{t} 180: 65–73. https://doi.org/10.1016/0048-9697(95)04921-5

Sommer, A. M.; Grote, K.; Reinhardt, T.; Streckert, J.; Hansen, V.; Lerchl, A. 2009. Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: a multi-generation study, *Radiation Research* 171(1): 89–95. https://doi.org/10.1667/RR1460.1

Tarasova, V. V. 2008. *Ekologichna statistika: pidruchnik.* Kiïv: Centr uchbovoï literaturi, 392 (in Ukrainian).

Ursache, I.; Mindrul, G. 2009. The effects of high frequency electromagnetic waves on the vegetal organisms, *Journal Physics* 54(1–2): 133–145.

Zamanian, A.; Hardiman, C. 2005. Electromagnetic radiation and human health: a review of sources and effects, July, *High Frequency Electronics*: 16–26.

ELEKTROMAGNETINĖS SPINDULIUOTĖS ĮTAKOS AUGALŲ AUGIMUI TYRIMAS

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Santrauka

Didėjantis elektromagnetinės spinduliuotės lygis yra pavojingas veiksnys, kuris kelia žalą gyviesiems organizmams. Pastaruoju metu visi tyrimai buvo orientuoti į pramoninių šaltinių elektromagnetinės spinduliuotės įtaką, tačiau panašiems tyrimams gyvojoje aplinkoje buvo skirta pernelyg mažai dėmesio. Bendrasis pramoninių šaltinių spinduliuotės gyviesiems organizmams poveikis galėtų būti tiriamas naudojant fitoindikacijos metodus. Šio tyrimo tikslas buvo išanalizuoti elektromagnetinės spinduliuotės poveikio grūdams augti tendencijas. Bandomųjų objektų ūglių ilgio pokyčių, esant vidutiniam absoliutiniam augimui, tendencijos ir vidutinis augimo greitis parodė mažėjančius augalų augimo rodiklius, tačiau negatyviausia įtaka buvo nustatyta dėl kompiuterinės sistemos radiacijos ir televizijos poveikio (trumpesni ūgliai, palyginti su kontroliniais mėginiais, svyravo nuo 13,3 % *Hordeumvulgare L*. iki 46,2 % *Sorghumvulgare Pers*). Tyrime taip pat buvo įvertintas bandomųjų objektų jautrumas prietaisų elektromagnetinei spinduliuotei (mažėjančia tvarka): *Sorghum vulgare Pers. – Triticum aestivum L. – Hordeum vulgare L.* (maksimalus augimo veiksmingumo, palyginti su kontroliniais mėginiais, slopinimas buvo mažesnis nei 46,2%, 27,9%, 15,3%).

Reikšminiai žodžiai: elektromagnetinės spinduliuotės prietaisai, fitoindikacija, bandymo objektas, augimas, tendencija, indeksas.