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HYGIENIC EVALUATION OF THE MOST COMMON METHODS OF AGRICULTURAL CROPS TREATMENT WITH CHEMICAL PROTECTION PRODUCTS (literature review)

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Ключові слова: *пестициди, умови праці, професійний ризик, вид обприскування, екотоксикологічний ризик, дисперсність, біологічна ефективність*
Ключевые слова: *пестициды, условия труда, профессиональный риск, вид опрыскивания, экотоксикологический риск, дисперсность, биологическая эффективность*

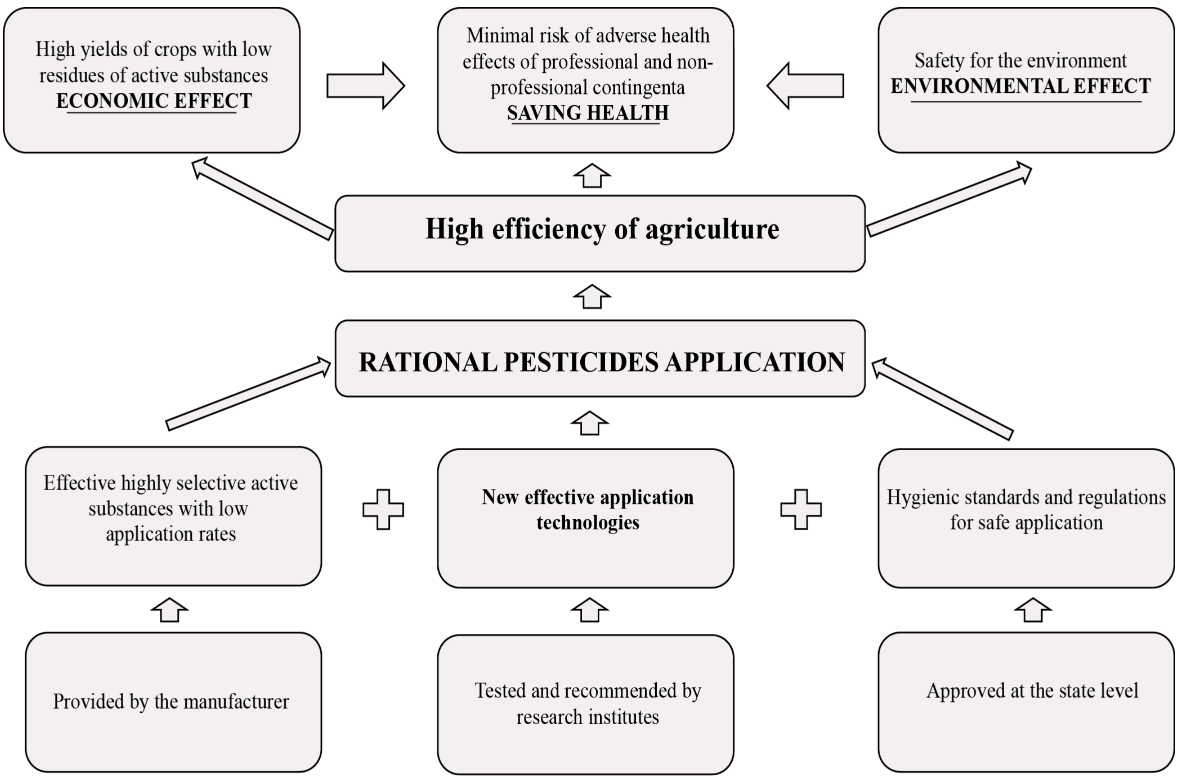
Abstract. Hygienic evaluation of the most common methods of agricultural crops treatment with chemical protection products (literature review). Borysenko A.A., Antonenko A.M., Shpak B.I., Omelchuk S.T., Bardov V.G. *Global strategies, including application of chemical plant protection products, are important in the cultivation of safe corps and preservation of human health. A promising area of preventive medicine, agronomy, agroecology and agroengineering is the optimization of methods of pesticide formulations application. The aim of the work was a hygienic assessment of the most common and latest methods of crops treatment with chemical pesticides. Results. The biological effectiveness of different types of pesticides is achieved by different application rates of the working solution. The most common method of pesticide application is spraying, which ensures the application of pesticides in the drop-liquid state and is characterized by low consumption of active substance per unit area, variable-controlled distribution on the treatment surface, provides good adhesion and retention on facilities, allows the use of combined formulations. One of the most effective ways to minimize the negative impact of chemical plant protection products and achieve economic success is a rational approach to the choice of pesticide application, as it takes into account the hazard class of pesticides, the presence of water protection zones, the sensitivity of target crops, etc. Conclusion. Rational application of pesticides includes minimizing the overall effect of pesticides on human health and the environment and achieving high-targeted biological efficiency. Adherence to the methodology of choosing the type of pesticide application and selection of the type of spray is a key point in optimizing the rational use of chemical plant protection products, which requires a detailed study from the standpoint of both efficiency and safety. Control over compliance with the recommendations should be included in sanitary-hygienic and sanitary-ecological monitoring.*

Реферат. Гігієнічна оцінка найбільш поширених способів обробки сільськогосподарських культур хімічними засобами захисту (огляд літератури). Борисенко А.А., Антоненко А.М., Шпак Б.І., Омельчук С.Т., Бардов В.Г. *Світові стратегії, включаючи використання хімічних засобів захисту рослин, мають важливе значення у сферах вирощування безпечної рослинної продукції та здоров'я людини. Перспективним напрямком роботи профілактичної медицини, агрономії, агроекології та агроінженерії є оптимізація методів їх використання. Метою роботи була гігієнічна оцінка найбільш поширених та найновіших методів обробки сільськогосподарських культур хімічними засобами захисту. Біологічна ефективність різних видів пестицидів досягається різними нормами витрат робочого розчину. Найбільш поширеним способом застосування пестицидів є обприскування, що забезпечує внесення пестицидів у краплинно-рідкому стані та характеризується малою витратою діючої речовини на одиницю площі,* *варіабельно-контрольованим її розподілом на оброблювальній поверхні, забезпечує добре прилипання та утримання на об`єктах, дозволяє застосування комбінованих препаратів. Одним з найбільш дієвих способів мінімізації негативного впливу хімічних засобів захисту рослин та досягнення економічної успішності є раціональний підхід до вибору способу застосування пестицидів, оскільки враховується клас небезпеки пестицидів, наявність водоохоронних зон, чутливість цільових об'єктів та ін. Раціональне використання пестицидів включає в себе мінімізацію сумарного ефекту впливу пестицидів на здоров'я людини і навколишнє середовище та досягнення високої цільової біологічної ефективності. Дотримання методології вибору виду внесення пестицидів та підбору типу розпилювача є ключовим моментом в оптимізації раціонального використання хімічних засобів захисту рослин, що потребує детального вивчення як з позиції ефективності, так і безпечності. Контроль за дотриманням рекомендацій необхідно включити до санітарно-гігієнічного та санітарно-екологічного моніторингу.*

Global strategies, including the application of chemical plant protection products, are important in the cultivation of safe crops and preserving human health. Reasonable use of pesticides, on the one hand, can mean minimizing and prudent use of them in agriculture, but it can also be interpreted as the complete elimination of their application. Unfortunately, current trends in the development of the agro-industrial sector indicate the impossibility of complete abandonment of chemical plant protection products (ChPPP) [3, 20, 21, 23, 27]. Due to its versatility, relative technological simplicity and high efficiency, chemical method of plant protection is used worldwide and currently has no alternative. Therefore, a promising area of preventive medicine, agronomy, agroecology and agroengineering is not only the improvement or development of new pesticides, but also the optimization of methods of their application [4, 6, 11, 14, 15, 18, 27, 30].

That is why the aim of our work was a hygienic assessment of the most common and latest methods of crops treatment with chemical plant protection products.

The interaction between the needs of agriculture, environmental protection and human health is a complex and rational use of pesticides, which involves the development of integrated methods of pest control, is a way to optimize it (Fig.) [3, 14, 21, 23, 29].



General scheme of rational use of pesticides

Improving of ChPPP, applied technologies and their integration with chemical, physical and biological knowledge will truly optimize pesticides application without compromising the quality and efficiency of agriculture or the protection of consumers and the environment.

Choosing the right method of pesticide application is an integral part of achieving success in the protection of plant products and the economic justification for the use of a particular ChPPP, providing a minimal risk of adverse effects of the chemical compound on human health. The main factors that are taken into account when choosing a method of application are the formulation, the type of pest and plant, as well as safety for the environment and human health [6, 14, 15, 23].

The most common method of pesticide application is spraying, which ensures the application of pesticides in the drop-liquid state and is characterized by low consumption of active substance per unit area, variable-controlled distribution on the treatment surface, provides good adhesion and retention on facilities, allows the use of combined formulations [21, 22, 29]. Spraying with pesticides is carried out with the help of special ground machines – sprayers or aircrafts, which are installed on airplanes, helicopters and other aircrafts. In small areas of private agricultural plots, in gardens, in country areas for spraying hydraulic panels and knapsack sprayers of various modifications are used [1, 17, 19].

According to the amount of working fluid applied per unit area, spraying is divided into three main types: multi-volume, full-volume, small-volume and ultra-small-volume (Table) [6].

Types of spraying by the amount of working solution

Type of spraying	Drop dispercity, µm	Application rates of the working solution, l/ha
Multi-volume	>300	More than 300
Full-volume	150-300	200-300
Small-volume	50-150	75-200
Ultra-small-volume	<50	up to 25*

Note. * – Ultra-small-volume application of pesticides does not involve the preparation of a working solution; the formulation is applied in its pure form.

Multi-volume application is not very popular among farmers, as it is characterized by low productivity of units due to frequent stops of the sprayer for filling with working solution. As a result, the utilization rate of working time changes in production conditions is sometimes less than 0.5. It also results in long-term exposure of workers involved in pesticide application procedure, which can significantly increase the risk of adverse health effects. Another disadvantage of this type is the contamination of soils with chemicals, the excess of which flows from the plant when applied in the above way. This in turn can lead to contamination of underground water supply sources and greater negative impact on non-professional contingents of the population [1, 6, 16, 19].

The appearance of this type of application, due to a number of ChPPP with a phytotoxic effect in high concentrations of the working solution, have only a contact effect and to obtain maximum efficiency it requires good wetting of plants [6]. Since this type of spraying involves the introduction of fairly large volumes of working solution (more than 300 l/ha), the most widely used are nozzles that form large droplets [11, 27, 30]. The working solution wear zone, due to the formation of large droplets, is minimal. The gravity force prevails over the air resistance force, which causes movement of the droplets of the working solution with acceleration. This is a positive side of this type of treatment in terms of hygienic regulations, as the wear zone does not require the establishment of large sanitary protection zones and there is less risk of transfer to neighboring fields [13, 17, 25, 28].

Full-volume treatment is currently the most widely used, because the consumption of working solution of 200-300 l/ha achieves a fairly high quality of the process, and therefore high technical and economic efficiency compared to multi-volume spraying [6, 9]. From a hygienic point of view, this type of formulations application has a number of advantages over multi-volume, as it reduces the time spent by workers on the treated area, and therefore reduces the amount of occupational risk. Due to the formation of medium-sized droplets, a smaller volume of working solution makes it possible to achieve a similar effect, but reduces the load on the soil, ecotoxicological risk and the risk of groundwater contamination [16, 19, 30]. The wear zone of the working solution is medium, medium-sized drops are formed. The gravity force prevails over the air resistance force, the deposition of droplets of the working solution occurs without acceleration, which poses a low risk to the environment and the population living around [2, 13, 23, 24, 25].

A promising direction in the development of spraying technology is low-volume and ultra-low-volume application of formulations, which allows to reduce consumption rates and the size of the drops of the working solution while increasing their number [5, 6, 9, 15, 28]. The advantages of low-volume and ultra-low-volume spraying over multi-volume spraying are increased mobility, biological and economic efficiency. The productivity of devices increases and costs for carrying out spraying decrease. Improvement and development of new types of sprayers and pesticide formulations lead to the widespread use of low-volume spraying method [5, 6, 21]. It should be noted that this type of treatment has advantages in terms of exposure time of workers involved in pesticide work, relatively low risks of contamination of groundwater, soil and ecotoxicological risk [8, 23, 24].

But at the same time, with reducing the size of the droplets, the rate of their settling decreases and the rate of evaporation increases, which increases the risks of irritating, sensitizing, inhalation, percutaneous effects on workers involved in the treatment. The wear zone of the working solution is large, due to the predominance of drops of small size. The gravity force is balanced with the air resistance force; the deposition of droplets of the working solution is due to the pressure created by the sprayer. As a result, neighboring crops may be damaged and surface water bodies contaminated. This poses a threat to humans and animals, contaminates other field crops, and changes the application values of the formulations [11, 13, 25, 28, 30]. When carrying out treatments with low-volume application, additional preventive measures are required: additional individual means of skin and respiratory protection (or state-of-the-art standard ones), increase of sanitary protection zones around the cultivated field, control of crops in neighboring fields, etc. [2, 7].

According to [9, 23, 24], the biological effectiveness of different types of pesticides is achieved by different application rates of the working solution. For example, reducing the application rate of the working solution of the fungicide to 200 l/ha when treated against plant diseases, significantly reduces its biological effectiveness. Therefore, from the standpoint of biological efficiency, the recommended values of fungicide application rates are on average 200-400 l/ha. It is better to work with herbicides on vegetable crops at a rate of up to 50 l/ha, and on cereals – up to 100 l/ha. The application rate of insecticides is in the range of 100-150 l/ha. In this regard, for the effective and safe ChPPP application it is necessary to have at least three sizes of sprayers.

CONCLUSIONS

1. The rational pesticides application includes minimizing their cumulative effect on human health and the environment and achieving high-targeted biological efficiencies.
2. One of the most effective ways to minimize the negative impact of chemical plant protection products and achieve economic success is a rational approach to the choice of pesticide application, as it takes into account the hazard class of pesticides, the presence of water protection zones, sensitivity of target crops, etc.
3. Adherence to the methodology of choosing the type of pesticide application and selection of the spray type is a key point in optimizing the rational use of chemical plant protection products, which requires detailed study from the standpoint of both efficiency and safety. Control over compliance with the recommendations should be included in sanitary-hygienic and sanitary-ecological monitoring.

Conflict of interests. The authors declare no conflict of interest.

REFERENCES

1. Bublyk LI, Vasechko GI, Vasyliev VP. [Handbook of plant protection]. Editor MP Lisovyi. Kyiv: Urozhai; 1999. p. 744. Ukrainian.
2. Vavrinevych O. [Hygienic estimation of potential combined risk of mixed fungicide harmful effects on workers]. Ukrainian journal of occupational health, [Internet]. 2015;1(42):58-66. Ukrainian.
doi: https://doi.org/10.33573/ujoh2015.01.058
3. Antonenko AM, Vavrinevych OP, Korshun MM, Omelchuk ST, Stavnichenko PV. [Hygienic substantiation of the model of human hazard prediction when using agricultural products contaminated with pesticides (on the example of pyrazolecarboxamide class fungicides)]. Informaciinyi lyst pro novovvedennia v sferi okhorony zdorovia. 2018;29:4. Ukrainian.
4. Omelchuk ST, Stecenko OV, Gyrenko TV, Borysenko AA, Aleksiichuk VD. [Hygienic assessment of working conditions when using pesticides on soybeans]. Ukrayinskyi zhurnal z problem medycyny praci. 2019;15(3):240-6. Ukrainian.
doi: https://doi.org/10.33573/ujoh2019.03.240
5. Lysov AK, Kornilov TV, Naumova NI, et al. [New ultra low volume spraying equipment in cabbage pest control, environmental and economic benefits].

Tekhnologii i tekhnicheskie sredstva mekhanizirovannogo proizvodstva produktsii rastenievodstva i zhivotnovodstva. 2019;1(98):115-24. Russian.

6. Markevich AYe, Nemirovets YuN. [Fundamentals of effective use of pesticides: a handbook of questions and answers on mechanization and quality control of pesticides in agriculture]. Gorki: educational institution "Mogilev state educational center for training, advanced training, retraining, consulting and agrarian reform"; 2004. p. 60. Russian.

7. [Methodical guidelines on study, estimation and reduction of risk of pesticides inhalation and dermal effects on the workers or by standerds during and after its application for plants and other objects chemical protection: 324/13.05.2009.]; 2009. p. 29. Ukrainian.

8. [On approvals by the Ministry of Health of plans for the implementation of certain acts of EU law: Order: No. 1141-p. from 26.11.2014]. [Internet]. Ukrainian. Available from:
http://zakon.rada.gov.ua/laws/show/1141-2014-p

9. Revyakin YeL, Krakhovetskiy NN [Machines for chemical protection of plants in innovative technologies: scientific. analyte. review]. Moskva: FGNU «Rosinformagrotekh»; 2010. p. 124. Russian.

10. Selivanov NI, Chepelev NI, Matyushev VV [Theoretical aspects of improving the safety of technological processes of agricultural enterprises]. Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta. 2016;2:151-5. Russian.

11. Sidorenko V. [Current technological solutions for the effective use of pesticides]. [Internet]. Agronom; 2020. Russian. Available from:
https://www.agronom.com.ua/aktualni-tehnologichni-rishennya-dlya-efektyvnogo-zastosuvannya-pestytsydiv/

12. Agricultural Spray Nozzles and Accessories. Catalogue Lechler. EN; 2012. p. 65.

13. Andrew Storrie. Reducing herbicide spray drift. NSW Department of Primary Industries. [Internet]. Available from:
https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift

14. Fargnoli M, Lombardi M, Puri D, et al. A Risk Assessment Procedure for the Enhancement of Occupational Health and Safety (OHS) Management. International Journal of Environmental Research and Public Health. 2019;16(3):310.
doi: https://doi.org/10.3390/ijerph16030310

15. Directive 2009/127/EC of the European Parliament and of the Council of 21 October 2009 Amending Directive 2006/42/EC with Regard to Machinery for Pesticide Application. [Internet]. Available from: http://data.europa.eu/eli/dir/2009/127/oj

16. Novohatska OO, Stavnichenko PV, Kondratiuk MV, et al. Comparative hygienic evaluation of behavior of different pesticides groups in soil, prediction of risk of ground water contamination and its danger for human health in areas with irrigation farming. Rawal Medical Journal. 2018;43(1):129-36.

17. Li Y, Li Y, Pan X, et al. Comparison of a new air-assisted sprayer and two conventional sprayers in terms of deposition, loss to the soil and residue of azoxystrobin and tebuconazole applied to sunlit greenhouse tomato and field cucumber. Pest Manag Sci. 2018;74(2):448-55. doi: https://doi.org/10.1002/ps.4728

18. Antonenko AM, Shpak BI, Vavrinevych OP, Borysenko AA, Omelchuk ST. Forecasting of the hazard for human health of the consumption of vegetables grown with the application of abamectin-based insecticide formulations. Medical sciences: history, the present time, the future, EU experience: international scientific and practical conference. Poland: Wroclawek; 2019. Sep 27-28. p. 224-6.

19. Grella M, Gallart M, Marucco P, et al. Ground deposition and airborne spray drift assessment in vineyard and orchard: The influence of environmental variables and sprayer settings. Sustainability. 2017;9:728 doi: https://doi.org/10.3390/su9050728

20. Machado SC, Martins I. Risk assessment of occupational pesticide exposure: Use of endpoints and surrogates. Regul. Toxicol. Pharmacol. 2018;276-83. doi: https://doi.org/10.1016/j.yrtph.2018.08.008

21. Michael F. Wilson Optimising pesticide use. Application technologies. UK, 2003;1-6.
doi: https://doi.org/10.1002/0470871792

22. Nasr GG, Yule AJ, Bendig L Agricultural Sprays. Industrial Sprays and Atomization Design, Analysis and Applications. UK. 2002;185-208.
doi: https://doi.org/10.1007/978-1-4471-3816-7_5

23. Omelchuk ST, Vavrinevych OP, Antonenko AM, Bardov VG. Forecastins the risk of bifenthrin-based insecticides for human health when consuming agricultural products grown after their application. One Health and Nutrition Problems of Ukraine. 2019;1(50):28-33. doi: https://doi.org/10.33273/2663-9726-2019-50-1-28-33

24. Overview of Risk Assessment in the Pesticide Program. US EPA. [Internet]. Available from: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/overview-risk-assessment-pesticide-program

25. Paul E. Sumner. ReducingSpray Drift. The University of Georgia and Ft. Valley State College, the U.S. Department of Agriculture and Counties of the state Cooperating. Available from:
https://athenaeum.libs.uga.edu/bitstream/handle/10724/34969/reducing.pdf?sequence=1

26. Recommendations for spraying technology for field crops. Available from:
https://www.syngenta.kz/rekomendacii-po-tehnologii-opryskivaniya-polevyh-kultur

27. Reducing Spray Drift (AE1210, Reviewed June 2017). Available from:
https://www.ag.ndsu.edu/publications/crops/reducing-spray-drift

28. Robert E. Wolf. Strategiesto Reduce Spray Drift. Kansas State University. Available from: http://cotton.tamu.edu/Weeds/Spray%20Drift%20Strat.pdf

29. Llop J, Gil E, Gallart M, et al. Spray distribution evaluation of different settings of a hand-held-trolley sprayer used in greenhouse tomato crops. Pest Management Science. 2015;72:505-16.
doi: https://doi.org/10.1002/ps.4014

30. TeeJet Technologies. A Spraying Systems Company. Wheaton; 2007. p. 192.

СПИСОК ЛІТЕРАТУРИ

1. Бублик Л. І., Васечко Г. І., Васильєв В. П. Довідник із захисту рослин / за ред. М.П. Лісового. Київ: Урожай, 1999. 744 с.
2. Вавріневич О. П. Гігієнічна оцінка потенційного комбінованого ризику небезпечного впливу сумішевих фунгіцидів для працюючих. *Український журнал з проблем медицини праці.* 2015. Т. 42, № 1. С. .58-66. DOI: https://doi.org/10.33573/ujoh2015.01.058
3. Гігієнічне обґрунтування моделі прогнозування небезпеки для людини при вживанні сільськогосподарських продуктів, контамінованих пестицидами (на прикладі фунгіцидів класу піразолкарбоксамідів) / А. М. Антоненко та ін. *Інформ. лист про нововведення в сфері охорони здоров'я*. 2018. № 29. 4 с.
4. Гігієнічна оцінка умов праці при застосуванні пестицидів на сої / С. Т. Омельчук та ін. *Укр. журнал з проблем медицини праці.* 2019. Т. 15. № 3. С. 240-246. DOI: https://doi.org/10.33573/ujoh2019.03.240
5. Лысов А. К., Корнилов Т. В., Наумова Н. И., Гончаров Н. Р. Новое оборудование для ультрамалообъемного опрыскивания в борьбе с вредителями капусты, экологические и экономические преимущества. *Технологии и технические средства механизированного производства продукции растениеводства и животноводства*. 2019. Т. 98, № 1. С. 115-124.
6. Маркевич А. Е., Немировец Ю. Н. Основы эффективного применения пестицидов: справочник в вопросах и ответах по механизации и контролю качества применения пестицидов в сельском хозяйстве. Горки: учреждение образования "Могилевский государственный учебный центр подготовки, повышения квалификации, переподготовки кадров, консультирования и аграрной реформы", 2004. 60 с.
7. Методичні рекомендації з вивчення, оцінки і зменшення ризику інгаляційного і перкутанного впливу пестицидів на осіб, які працюють з ними або можуть зазнавати впливу під час і після хімічного захисту рослин та інших об'єктів. 324/13.05.2009. 29 с.
8. Про схвалення розроблених Міністерством охорони здоров'я планів імплементації деяких актів законодавства ЄС: наказ від 26.11.2014. № 1141-р. URL: http://zakon.rada.gov.ua/laws/show/1141-2014-p (дата звернення 05.09.2019).
9. Ревякин Е. Л., Краховецкий Н. Н. Машины для химической защиты растений в инновационных технологиях: науч. аналит. обзор. Москва: ФГНУ «Росинфор-магротех», 2010. 124 с.
10. Селиванов Н. И., Чепелев Н. И., Матюшев В. В. Теоретические аспекты повышения безопасности технологических процессов сельскохозяйственных предприятий. *Вест. Алтайского гос. аг-рарного университета*. 2016. № 2. С. 151-155.
11. Сидоренко В. Актуальні технологічні рішення для ефективного застосування пестицидів. *Агроном*. 2020. URL: https://www.agronom.com.ua/aktualni-tehnologichni-rishennya-dlya-efektyvnogo-zastosuvannya-pestytsydiv/ (дата звернення: 10.09.2020).
12. Agricultural Spray Nozzles and Accessories. *Catalogue Lechler*. EN, 2012. 65 p.
13. Andrew Storrie. Reducing herbicide spray drift. *NSW Department of Primary Industries*. URL: https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift (Date of access: 03 September 2020).
14. A Risk Assessment Procedure for the Enhancement of Occupational Health and Safety (OHS) Management / M. Fargnoli et al. *Inter. Journal of Environmental Research and Public Health*. 2019. Vol. 16, No. 3. P. 310. DOI: https://doi.org/10.3390/ijerph16030310
15. Directive 2009/127/EC of the European Parliament and of the Council of 21 October 2009 Amending Directive 2006/42/EC with Regard to Machinery for Pesticide Application. URL: http://data.europa.eu/eli/dir/2009/127/oj (Date of access: 28 September 2019).
16. Comparative hygienic evaluation of behavior of different pesticides groups in soil, prediction of risk of ground water contamination and its danger for human health in areas with irrigation farming / O. O. Novohatska et al. *Rawal Medical Journal*. 2018. Vol. 43, No. 1. P. 129-136.
17. Comparison of a new air-assisted sprayer and two conventional sprayers in terms of deposition, loss to the soil and residue of azoxystrobin and tebuconazole applied to sunlit greenhouse tomato and field cucumber / Y. Li et al. *Pest Manag Sci*. 2018. Vol. 74, No. 2. P. 448-455. DOI: https://doi.org/10.1002/ps.4728
18. Forecasting of the hazard for human health of the consumption of vegetables grown with the application of abamectin-based insecticide formulations. Medical sciences: history, the present time, the future, EU experience / A. M. Antonenko et al. *International scientific and practical conference.* Wroclawek, Poland. 27-28 September, 2019. P. 224-226.
19. Ground deposition and airborne spray drift assessment in vineyard and orchard: The influence of environmental variables and sprayer settings / M. Grella et al. *Sustainability*. 2017. No. 9. P. 728. DOI: https://doi.org/10.3390/su9050728
20. Machado S. C., Martins I. Risk assessment of occupational pesticide exposure: Use of endpoints and surrogates. *Regul. Toxicol. Pharmacol*. 2018. P. 276-283. DOI: https://doi.org/10.1016/j.yrtph.2018.08.008
21. Michael F. Wilson Optimising pesticide use. *Application technologies*. UK, 2003. P. 1-6. DOI: https://doi.org/10.1002/0470871792
22. Nasr G. G., Yule A. J., Bendig L. Agricultural Sprays. *Industrial Sprays and Atomization Design, Analysis and Applications*. UK, 2002. P. 185-208. DOI: https://doi.org/10.1007/978-1-4471-3816-7_5
23. Omelchuk S. T., Vavrinevych O.P., Antonenko A.M., Bardov V.G. Forecastins the risk of bifenthrin-based insecticides for human health when consuming agricultural products grown after their application. One

Health and Nutrition Problems of Ukraine. 2019. Vol. 50, No. 1. P. 28-33.
DOI: https://doi.org/10.33273/2663-9726-2019-50-1-28-33

24. Overview of Risk Assessment in the Pesticide Program. US EPA. [Internet]. URL: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/overview-risk-assessment-pesticide-program (cited 05.09.2019).

25. Paul E. Sumner. Reducing Spray Drift. The University of Georgia and Ft. Valley State College, the U.S. Department of Agriculture and Counties of the state Cooperating. URL: https://athenaeum.libs.uga.edu/-bitstream/handle/10724/34969/reducing.pdf?sequence=1 (Date of access: 28 September 2019).

26. Recommendations for spraying technology for field crops. URL: https://www.syngenta.kz/rekomendacii-po-tehnologii-opryskivaniya-polevyh-kultur (Date of access: 10.09.2020).

27. Reducing Spray Drift (AE1210, Reviewed June 2017). URL: https://www.ag.ndsu.edu/publications/crops/reducing-spray-drift (дата звернення: 10.09.2020).

28. Robert E. Wolf. Strategiesto Reduce Spray Drift. Kansas State University. URL: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/overview-risk-assessment-pesticide-program (cited 02.09.2020).

29. Spray distribution evaluation of different settings of a hand-held-trolley sprayer used in greenhouse tomato crops / J. Llop et al. *Pest Management Science*. 2015. Vol. 72. P. 505-516. DOI: https://doi.org/10.1002/ps.4014

30. TeeJet Technologies. A Spraying Systems Company. Wheaton, 2007. 192 p.

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