Response

official opponent

candidate of technical sciences

Associate Professor **Ihor Volodymyrovych Shelekhov**

for a dissertation **Wang Xinfa (Ван Сіньфа)**

«Environmental coupled multi-factor precise regulation and optimization for the artificial light plant factory based on a growth model»,

(«Екологічне обгрунтування оптимальних параметрів роботи штучного освітлення теплиці на основі моделі росту рослин»),

applied for the degree of Doctor of Philosophy,

from the field of knowledge **13** - «**Mechanical engineering**»,

on specialty **133** - «**Industrial Machinery Engineering** ».

1. Relevance of the dissertation topic.

Plastic greenhouses and glass greenhouses have played a huge role in off-season vegetable production and ensuring "vegetable baskets" and food security. However, due to the low stability and reduced safety of multi-layer greenhouse structures, it is difficult to build higher greenhouses to fully improve land resource utilization. In addition, due to its poor sealing performance and unstable insulation effect, it is difficult to accurately regulate the plant production environment. Moreover, its construction is greatly influenced by the natural climate and geographical location. Therefore, it is not possible to meet the requirements of large-scale, localized, and sustainable factory production of plants throughout the year. The emergence of

artificial light plant factories enables the construction of industrialized plant production systems in any climate and location to meet the demand for clean and fresh edible plants.

Although artificial light plant factories have attracted great interest from governments, enterprises, and researchers in many countries around the world, due to their high construction investment and operating costs, they have become an unattainable “luxury” item. Therefore, reducing production costs has become a core issue affecting the development of artificial light plant factories. With an appropriate increase in construction investment, if production costs can be significantly reduced and product quality can be improved, it is also the only way to promote vegetable "luxury goods" for low-income people to enjoy.

Wang Xinfa's paper conducted extensive research on the precise regulation and optimization of the artificial light plant factory environment, aiming to improve the comprehensive resource utilization rate, reduce the consumption of electricity, water resources, and nutrient solution, and lower market prices through precise regulation technology of the factory production environment of plants. This research has an international leading level, which can not only create large-scale economic benefits and social value in China, but also has significant significance for Ukraine and even other countries around the world.

2. Connection with scientific programs, topics, plans.

The scientific research work of this dissertation is conducted at the Department of Agricultural Engineering of Faculty of Engineering and Technology and the Department of Breeding and Seed Production of Faculty of Agricultural Technologies

and Nature Management, in Sumy National Agrarian University, Ukraine, within the framework of No: 0121U110454 "Scientific support of technologies for growing technical crops (sunflower for grain)" and No: 0121U110453 "Scientific support of technologies for growing technical crops (corn for grain)" and multiple Key Research and Development and Promotion Special Project Plans of Henan Province related to environmental regulation in artificial light plant factories.

The subject of this dissertation is closely related to these programs and plans.

3. Scientific novelty of the obtained results.

1) For the first time, the concepts of intelligent building greenhouses and intelligent building greenhouses plant factories were proposed, with clear definitions. Extensive social demand research and literature analysis were conducted to systematically and scientifically demonstrate their strategic significance. The development strategy of "3-Positions and 1-Entity" was studied, providing an innovative model and systematic solution for the sustainable and clean plant production system in urban development.

2) For the first time, it is proposed to use the physiological mechanisms and biological theories of plant light regulation as the theoretical basis for artificial light plant factory light environment regulation, improve the technical means of light environment regulation, and regulate the production process of plants through the role of light in photosynthesis, growth and development, morphological construction, material metabolism, gene expression, and nutritional quality, in order to adapt to market changes.

3) For the first time, a flat IoT solution using multiple sensors and controllable

work units has been provided for artificial light plant factories. A system architecture for constructing scientific big data for plant factories has been proposed, and the process and methods of comprehensively utilizing IoT, big data, and deep learning technologies to construct plant growth models have been systematically studied. The plant factory big data platform and crop growth model service system constructed using this method can provide data and model services for plant factory industrial enterprises through cloud services.

4) For the first time, the architecture and framework of a multi-factor environmental regulation platform for artificial light plant factories based on growth models were proposed, and control system software was designed, developed, and tested. The system software can automatically obtain plant growth model files from the cloud, and intelligently and accurately regulate the environment of plant growth based on the plant growth model, to obtain high-quality and high-yield plant products with minimal cost.

5) An improved YOLOv3 deep learning model and algorithm have been proposed for target detection of hydroponic tomato fruits in artificial light plant factories, providing theoretical foundation and technical support for yield estimation, robotic picking, and precise regulation of growing environments. This method can classify and detect the growing tomato fruits, obtain the quantity of green fruits, color changing fruits, and red fruits, as a basis for precise regulation of light environment and nutrient solution concentration, thereby effectively reducing water, electricity, nutrient solution waste and sewage discharge, improving resource comprehensive utilization rate and yield.

6) For the first time, a CMRDF algorithm for plant seedling instance segmentation was proposed, which integrates RGB-D multi-channel image data to improve the accuracy of seedling instance segmentation. It is used to analyze plant phenotypic data in artificial light plant factories, to construct crop growth models, and to provide theoretical and technical support for plant intelligent growth monitoring, disease and pest detection, production management, yield estimation, robotic operations, and environmental regulation.

7) For the first time, experimental studies on illumination screening and uniformity simulation of hydroponic lettuce, experimental study on the effect of light quality on the quality of hydroponic Cichorium endivia L., and screening study on the formulation of nutrient solution for hydroponic green leaf lettuce are conducted in an artificial light plant factory, providing technical references for precise regulation of environmental multi-factor coupling.

4. Theoretical significance of the dissertation.

The theoretical significance of the dissertation lies in the following:

1) The proposed concepts of the building greenhouse, the intelligent building greenhouses, and the intelligent building greenhouses plant factories extend the concept of plant growth greenhouses, which have profound scientific value and theoretical significance for the development of facility agriculture. This laid the theoretical and scientific foundation for the development of productive farming systems in urban areas.

2) The proposed theoretical method and system framework for constructing big data of the plant factory and plant growth models provide scientific methods and

theoretical foundations for constructing precise environmental regulation models and optimization technologies for artificial light plant factories.

3) The proposed multi-factor self-learning coupling precise regulation model for artificial light plant factory environment has certain theoretical guidance significance for the program design and development of plant factory comprehensive management system.

4) The research on tomato fruit target detection algorithm and CMRDF plant seedling instance segmentation algorithm in artificial light plant factories has theoretical guidance significance for plant growth modeling and environmental comprehensive regulation modeling.

5) The computer simulation of the light formula and uniformity of LED plant lighting lamps, the influence of light quality on the growth of hydroponic plants, and the experimental research on the selection of nutrient solution formulas for hydroponic plants have theoretical guidance significance for the intelligent regulation of the light environment and nutrient solution environment in artificial light plant factories.

5. Practical significance of the results of the dissertation.

The results of the paper provide a development direction and solution for the urban construction of a plant clean vegetable production system, and provide a complete set of technical solutions and system frameworks for plant growth model modeling and precise regulation of environmental factors. An intelligent monitoring system, a data collection and management platform, and a plant factory management system have been designed and developed. Experimental research on environmental

regulation of artificial plant factories has been conducted, and application research and practical verification have been carried out in cooperation with professional enterprises. This study has enormous economic benefits and social value.

6. Number of scientific publications.

In order to highlight important results of the study, the presence of at 30 scientific publications over the past four years, which include 12 articles in periodical included in the scientometric databases Scopus or Web of Science Core Collection, 4 articles in scientific journals included in the list of scientific professional publications of Ukraine, 6 articles in the other international scientific journals, and 8 papers in collections of the international academic conference; at 11 other research achievements, which include 4 Chinese patents and 7 Chinese computer software copyrights.

7. Complete presentation of the dissertation material in scientific publications.

To highlight the main content and materials in the paper, most of the research results in Sections 1, 3, and 4 have been publicly published in multiple Ukrainian or other national scientific journals, with 12 articles fully presented in journals included in the scientific metrology database Scopus or Web of Science Core Collection. For details, please refer to the "LIST OF PUBLICATION OF THE APPLIANT ON THE TOPIC OF THE DISSERTION".

8. The degree of validity of scientific provisions.

In the dissertation, the applicant, Wang Xinfa, used a sufficient number of information sources from open databases, regulatory and legal literature, statistical

and analytical materials. The results of the research and the author's recommendations have undergone practical testing, which is confirmed by relevant documents. The scientific provisions, conclusions and recommendations obtained from the research results are sufficiently substantiated and reliable.

The dissertation is characterized by a clear adherence to the structural and logical scheme of the research, the correspondence of the scientific results and the provisions issued for the protection of scientific novelty to the set goal and the specific task of the research.

The above is evidence of a sufficient level of validity and reliability of the results of scientific research, conclusions and proposals. Therefore, the applicant has met the validity of the scientific provisions of the Ukrainian Cabinet Minister's Resolution No. 283 dated 03.04.2019 No. 502 dated 19.05.2023.

9. The structure and content of the dissertation, its completeness and compliance with the established requirements for design.

The dissertation provides the research work conducted by the author over the past four years around the themes and tasks jointly developed with the supervisor, including a literature review on artificial light plant factories and their environmental regulation, basic theories, algorithms, and experimental results on environmental light and nutrient regulation technology.

The dissertation includes a cover, abstract, table of contents, symbol list, introduction, literature review, methods, results, discussions, conclusions, references, and appendices, fully meeting the requirements of the Ministry of Education and Science of Ukraine and Sumy National Agrarian University for the structure, content,

and format of PhD dissertations, and complying with academic writing and typesetting standards.

The structure of the dissertation is clear and hierarchical, the parts are closely connected and the logic is strong. The purpose and questions of the dissertation are clear, and the research methodology is sound and innovative. The results are adequate, accurate, and contribute substantially, which is in line with the objectives of the dissertation. The dissertation provides a comprehensive literature review and basic theoretical research on the cutting-edge research in the field of artificial light plant factories and their environmental regulation technologies, reflecting the innovation of the research. All parts of the dissertation are complete, no key information or analysis is omitted, major aspects of the research field are fully covered, and a comprehensive and in-depth exploration of the research issues is given.

10. Discussion clauses, comments and wishes regarding the content.

The dissertation thoroughly analyzed a large number of literature on artificial light plant factories and their environmental regulation technologies, compared and studied the development of greenhouses, comprehensively studied the system composition and framework of building greenhouses, intelligent building greenhouses plant factories, and urban intelligent plant factories, and further explored the theory and technology of precise regulation and optimization of multiple factors, as well as their applications in artificial light plant factories. Covering key content such as environmental factors, growth models, and regulatory strategies. The organic integration of the results into the framework of the dissertation ensures that the results are consistent with the objectives and model of the dissertation, highlighting the points

of innovation and improvement.

The discussion section of the dissertation is clear and coherent and can clearly convey the research ideas and experimental results. The discussion involved an in-depth academic analysis, including an in-depth understanding of the results, interpretation of the theoretical foundations, and possible application directions. The discussion also reflects the author's critical thinking, ability to self-assess the limitations of the research and suggest future improvements.

I hope that the dissertation can further deepen and continue to carry out research on various prediction models for plant growth based on deep learning, as well as models for precise regulation and optimization of environmental multi factor coupling, especially for some key aspects of automated, digital, and intelligent precise environmental regulation technology research, providing more in-depth explanations and analysis. It is hoped that the industrialization and commercialization of artificial light plant factories will be further promoted to create greater economic benefits and social value.

General conclusion

Dissertation work of Wang Xinfa on the topic “Environmental coupled multi-factor precise regulation and optimization for the artificial light plant factory based on a growth model", which was submitted for defense to the specialized academic council for obtaining the degree of Doctor of Philosophy in the field of knowledge 13 - mechanical engineering with a specialty 133 - machines and means of mechanization and automatic of agricultural production according to its relevance, scientific and theoretical level, main results of validity, main provisions and the results published in

professional publications, the novelty of the formulation and the practical significance meet the requirements of the order of the Ministry of Education and Culture of Ukraine No. 40 of January 12, 2017 "On approval of requirements for the preparation of a dissertation" and Resolution of the Cabinet of Ministers of Ukraine of January 12, 2022 No. 44 "On approval of the Procedure for awarding a degree doctor of philosophy and cancellation of the decision of the one-time specialized academic council of the institution of higher education, scientific institution on awarding the degree of doctor of philosophy" with changes introduced in accordance with Resolution of the Cabinet of Ministers No. 341 dated03.21.2022.

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