

FEEDBACK

official opponent

Doctor of Technology Science

Professor **Tong Yuxin**

for a dissertation **Wang Xinfu (Ван Сінъфа)**

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

The development of technology and social progress are the result of people's constant quest for a better life. Eating is the first necessity for people to live a better life. The quest to have enough to eat, to be good to eat, to be clean to eat, to be varied and abundant to eat, to be healthy to eat, is endless, and the demands keep getting higher. Fresh vegetables are advocated in contemporary times as a healthy and scientific dietary culture. At present, however, vegetables grown in fields and greenhouses are at risk of being contaminated with sewage, pesticides, insect eggs and heavy metals, making them increasingly unsafe to eat. The use of artificial light plant factories for industrial and clean vegetable production has become an important objective in the development of modern agriculture and technology.

To ensure that fresh, clean vegetables could be eaten every day, Japanese

scientist Toyoki Kozai first came up with the concept of an indoor artificial light plant factory. In recent years, as technology and society have evolved, their research team, led by Wang Xinfu's scientific supervisors, has taken the lead in proposing the recommendations of the construction of building greenhouses and intelligent building greenhouse plant factories. As the research deepened, they also came up with the idea of building urban smart plant factories in urban areas and conducted a series of studies. These studies closely follow the developments of the times and meet the needs of reality, making them the most scholarly and practical scientific studies.

The theme of Wang Xinfu's dissertation is “Environmental coupled multi-factor precision regulation and optimization for the artificial light plant factory based on a growth model”. The ultimate goal of his research is to accurately regulate and optimize the production environment of artificial light plant factories through the comprehensive application of mechanization, digitization, automation, intelligence, and robotics technology, reducing the consumption of manpower, electricity, water resources, and nutrient solutions, Improve the comprehensive utilization rate, including land resources, reduce the production costs of plant industrialization and industrialization, lower market prices, and enable low-income groups to eat clean, fresh, healthy, and high-quality vegetables. This research is arguably the latest in the field of modern technological agriculture and certainly at a world-leading level.

2. Connection with scientific programs, topics, plans.

The scientific research work for this dissertation was carried out at the Department of Agricultural Engineering of the School of Engineering and Technology and the Department of Breeding and Seed Production named after M.D. Goncharova

of the Faculty of Agricultural Technologies and Nature Management, Sumy National Agrarian University, Ukraine. The research topic of Wang Xinfu's paper was conducted within the framework of the National Science Work Plans of Ukraine (No. 0121U110453 "Scientific support of technologies for growing technical crops (corn for grain)" and No. 0121U110454 "Scientific support of technologies for growing technical crops (sunlight for grain)") and the multiple science and technology work thematic programs in Henan Province of China (No. 212102110234 "Research, development and application of key technologies for plant factories in intelligent building greenhouses", No. 2221022320080 "Environment multi factor coupling regulation and optimization of urban intelligent plant factory", No. 232102111124 "Research on intelligent control technology of plant factories based on IoT and big data" and No. 22A210013 "Development of aerospace system in full artistic lighting plant factories"). The applicant, Wang Xinfu, and his scientific supervisors are the executors of several sections, and the subject of the dissertation is closely related to these programs and plans.

3. Scientific novelty of the obtained results.

1) The concepts of intelligent building greenhouses and intelligent building greenhouses plant factories are at first for time proposed, clearly defined, their strategic significance is demonstrated and development strategies are studied to provide innovative models and systematic solutions for the sustainable and clean plant production systems for urban development.

2) Based on a summary and analysis of physiological mechanisms and biological theories of plant light regulation, the applicant first used them as a

theoretical basis for the regulation of the light environment of artificial light plants and also conducted studies on the regulation of the light environment during plant growth and experimental validation.

3) For the first time, a flat IoT solution using sensors and controllable work units is provided, as well as a system architecture for building scientific big data for plant factories. A systematic study of the processes and methods for building plant growth models using IoT, big data, and deep learning techniques has been conducted in a comprehensive manner.

4) The architecture and framework of a multi-factor environmental regulation platform for artificial light plant factories based on growth models were proposed for the first time, and control system software was designed, developed, and tested.

5) A modified YOLOv3 deep learning model and algorithm is proposed for target detection of hydroponic tomato fruits in an artificial light plant factory, providing theoretical foundation and technical support for yield estimation, robotic picking, and precise regulation of the growing environment.

6) A CMRDF algorithm for plant seedling instance segmentation has been proposed for the first time. This algorithm integrates RGB-D multi-channel image data, improves the accuracy of seedling instance segmentation, and provides theoretical and technical support for smart plant growth monitoring, pest detection, production management, yield estimation, robotic manipulation, 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 this dissertation lies in the applicant proposing the concepts of intelligent building greenhouse plant factory and urban intelligent plant factory based on artificial light plant factory, and conducting relevant research, providing a theoretical basis for the development of productive agricultural systems in urban areas; exploring methods for constructing plant growth models based on deep learning algorithms, proposing a systematic framework, and providing a theoretical approach to the environmental regulation of artificial light plant factories, with an in-depth study of the tomato fruit target detection algorithm and the CMRDF plant seedling instance segmentation algorithm; studying simulations of LED light distribution and homogeneity, as well as the regulation of light and nutrient solutions in hydroponic plants, provides a theoretical approach to the coupling of multiple environmental factors for regulation. These studies have important theoretical implications for the development of modern facility farming.

5. Practical significance of the results of the dissertation.

The results of Wang Xinfu's dissertation have multiple practical significance: the suggestions and development strategies for the construction of intelligent building greenhouse plant factories and urban intelligent plant factories are not only applicable to the factory and clean production of plants in China and other countries around the

world, but also meet the needs of the Ukrainian public for diversified, clean, green, and healthy vegetable food production. The proposed plant modeling based on deep learning models and precise environmental control technology solutions for artificial light plant factories based on crop growth models can be used for the design and development of environmental comprehensive management systems, creating economic benefits, and can also be used for teaching courses in facility agriculture and modern agricultural technology, enriching course content. The experimental results are directly applicable to greenhouse plant cultivation and plant factory production.

6. Number of scientific publications.

Based on the results, a total of 30 academic articles have been published, including 12 Scopus or WoS core database indexes, 4 Ukrainian professional journals, 6 other international journals, 8 collections of conference papers; 11 other research achievements, including 4 Chinese patents and 7 Chinese computer software copyrights.

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

It is evident from the appendices provided in the dissertation that the main material of the publication is fully presented in 22 articles published in scientific publications and 5 papers published in international academic conferences, and important material is also provided in 4 Chinese patents and 7 computer software copyrights applied for.

The published works effectively reflect and confirm the results of the studies

conducted.

8. The degree of validity of scientific provisions.

Based on the research results obtained from the paper and the research evidence provided in the appendix, the applicant has published 30 English professional articles in scientific publications in the past four years, of which 12 were published in professional journals indexed by Scopus or Web of Science Core Collection, 4 were published in scientific journals listed in the Ukrainian list of scientific professional publications, and 6 were published in other international scientific journals, 8 papers were published in international academic conferences and presented orally or in posters at the international conferences held. 4 Chinese licensed patents and 7 Chinese computer software copyright certificates were obtained. 8 8 scientific research projects were led or involved.

The paper is a detailed study completed independently by the applicant to provide a solution for intelligent and precise regulation of the artificial light plant factory environments in the mechanical engineering field of mechanization and automation of agricultural production. The full text is in English.

In summary, these fully demonstrate that the applicant has met the validity of the scientific provisions of the Ukrainian Cabinet Ministerial 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 paper consists of 6 sections, including Introduction、SECTION 1 “Review and Related Research on a Plant Factory with Artificial Lighting”、SECTION 2

“Experimental Platforms, Materials and Methods”、SECTION 3 “Basic Research Related to Building Plant Growth Model Based on Deep Learning”、SECTION 4 “Basic Research Related to the Coupling and Precise Regulation of Multiple Environmental Factors in a Plant Factory with Artificial Lighting”、SECTION 5 “Summary and Prospect”.

The structure of the paper is reasonable and scientific, consistent with standards, clear logical thinking, detailed, systematic and complete. It has a meaningful integrity, consistency and completeness that is entirely consistent with the requirements formulated in the design.

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

There are a few points worth discussing regarding the content of the paper:

- Section 1.1 provides a clear definition of a building greenhouse, a smart building greenhouse, and a smart building greenhouse plant, and clarifies that the base of a smart building greenhouse plant is an artificial light plant, which clearly defines the object of study. The problem is that there should be differences in the precise environmental control techniques and solutions for different scales of artificial light plant factories.

- Section 1.2 analyzes and summarizes the current status and trends of intelligent development plant factories in China, clarifies the direction of modernizing and intelligent development plant factories, and identifies research topics. It is worth discussing whether the situation in Ukraine and other countries around the world is similar to that in China.

- Figures 6-10, pages 81-86 of Section 1.3 explore theoretical approaches and

structural frameworks for building plant growth models based on IoT, big data and deep learning from multiple perspectives. Figure 11 on page 88 provides an application framework for the plant growth model. These studies are very interesting and can provide theoretical and technical guidance for the construction of growth models. However, it must be noted that this still requires intensive research and continuous improvement.

- Section 1.4 proposes a multi-factor self-learning coupled precise regulation model for artificial light plant factories, which has advanced foresight and far-reaching guiding significance. This model may already be very comprehensive, but it is worth discussing that the specific steps and methods of model construction are comprehensive and complex, and further research is needed to improve it.

- The studies in Sections 3 and 4 are only a preliminary exploration and attempt to construct plant growth models and regulate environmental factors, laying the foundation for this new research direction. However, the content that needs to be studied is still very challenging.

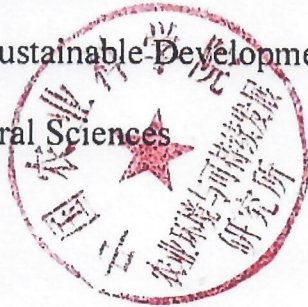
General conclusion

Dissertation work (**Wang Xinfu**) "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 dated 03.21.2022.

Official opponent:

Doctor of technical sciences, professor (Senior Researcher),
 Head of the Institute of Engineering Ecology of Crop Production Objects,
 Institute of Environment and Sustainable Development in Agriculture,
 Chinese Academy of Agricultural Sciences



Tong Yuxin

Yuxin Tong