

Warsaw 01. 08. 2023

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REVIEW

**of the doctoral dissertation by Wenping Liu, M.Sc.,
entitled "The influence of selected factors on the yield and physicochemical parameters
of flowering Chinese cabbage (*Brassica campestris* L., *ssp. chinensis* var. *utilis* Tsen et
Lee)"**

**Dissertation performed in the Department of Plant Physiology, Laboratory of Plant
Nutrition of the Faculty of Agriculture, Horticulture and Bioengineering and in the
Department of Quality Management and Food Safety, Faculty of Food Science and
Nutrition of Poznań University of Life Sciences
under the supervision of UPP Prof. Dr. Tomasz Kleiber and assistant supervisor Dr.
Małgorzata Muzolf-Panek**

The following review is in accordance with the guidance contained in the contract (NR WRO 33/2023) dated 7 July 2023.

1. Profile of the Doctoral Student

The Master's Degree was awarded to the Doctoral Candidate in May 2017 at the University of Life Sciences in Poznań, and he was subsequently admitted to the English Language Doctoral Program at the same University in October 2017. From the documents sent to me for review, it appears that the Doctoral Student had not previously undertaken doctoral studies and had not applied for the award of a doctoral degree.

As part of his compulsory doctoral studies, he taught students at the University of Life Sciences in Poznań. During his doctoral studies, he has been very active in research work, which has translated into his higher scientific potential. The doctoral student has co-authored five scientific publications, co-authored three papers in conference materials and participated in two scientific events (Poznań city-held activities – the Night of Scientists and the 2019 Silk Road Agricultural Education and Research Cooperation).

The data presented above indicates that Wenping Liu, M.Sc., is a promising young scientist who is eager to publish and present research results at Conferences.

2. Basic information about the assessed dissertation

Wenping Liu, M.Sc., presented his doctoral thesis entitled "The influence of selected factors on the yield and physicochemical parameters of flowering Chinese cabbage (*Brassica campestris* L., *ssp. chinensis* var. *utilis* Tsen et Lee" in the form of a series of four English-language thematically consistent scientific publications, published between 2021 and 2023 in scientific journals of international scope with the so-called total Impact Factor of 11.659 and a total number of points according to the Ministry of Education and Science at the date of publication of the work - 370. These are the following scientific articles:

1. Liu W., Liu Y., Kleiber T. 2021. A review of progress in current research on Flowering Chinese Cabbage (*Brassica campestris* L. ssp. *chinensis* var. *utilis* Tsen et Lee). *J. Elem.*, 26(1): 149-162. DOI: 10.5601/jelem.2020.25.4.20.
2. Liu W., Muzolf-Panek M., Kleiber T. 2022. Effect of Nitrogen Nutrition and Planting Date on the Yield and Physicochemical Parameters of Flowering Chinese Cabbage. *Agronomy*, 12, 2869. <https://doi.org/10.3390/agronomy12112869>
3. Liu W., Muzolf-Panek M., Kleiber T. 2023. Effect of Varied Nitrogen Sources and Type of Cultivation on the Yield and Physicochemical Parameters of Flowering Chinese Cabbage (*Brassica campestris* L. ssp. *chinensis* var. *utilis* Tsen et Lee). *Appl. Sci.*, 13, 5691. <https://doi.org/10.3390/app13095691>
4. Liu W., Muzolf-Panek, M., Kleiber T. 2022. The Effect of Various Foliar Treatments and Nitrogen Nutrition Levels on the Yield and Physicochemical Parameters of Flowering Chinese Cabbage. *Agronomy*, 12, 737. <https://doi.org/10.3390/agronomy12030737>

The contribution of Wenping Liu, M.Sc., is significant, although the percentage contribution of the PhD student to the individual publications has not been specifically indicated in the figures. The PhD student participated in all stages of their development, from developing the research concept, conducting experiments, observations and chemical analyses, to compiling the results and writing the manuscript. His significant contribution to the papers presented is not objectionable.

In addition to copies of the published articles, the evaluated study was accompanied by an abstract of the paper (in Polish and English) and a 48-page description of the research in English. It includes introduction, literature review, hypotheses and aim of the study, material and methods, results with discussion, conclusions and literature including 111 foreign language references. It is properly prepared and written in correct and concise language. It refers to the results published in the four papers included in the dissertation, providing a clear and comprehensible whole.

The dissertation is, in my opinion, complete and I judge its layout to be correct.

3. Substantive evaluation of the dissertation

Evaluation of the research issue addressed

I will first address the desirability of the dissertation topic undertaken by Wenping Liu, M.Sc. Vegetables are a very important food group whose significance for proper nutrition and human health can hardly be overestimated. This has been confirmed in the latest Polish and world nutritional recommendations. The nutritional value of vegetables varies greatly and depends on the species, variety and degree of ripeness. In Poland, despite the ever-increasing range of lesser-known vegetables, the dominant vegetables are those that are simple and low-risk to grow, show high post-harvest stability, and are firmly rooted in dietary habits and culinary tradition. The inclusion of new vegetable species and varieties in the menu could satisfy human body's needs for biologically active substances with nutritional and health-promoting effects. Another reason for the low interest in new vegetable species could be a lack of knowledge about their climatic requirements or growing conditions.

When introducing a new, unknown vegetable species into cultivation in Poland, it seems very important to know the nutritional requirements and cultivation method of this plant. In particular, cultivation under controlled conditions should provide specific information on the cultivation method and the content of individual macro- and micro-nutrients in the nutrient solution, so that a good quality yield with optimal nutrient content can be obtained.

Nitrogen fertilisation has the greatest effect on plant yield. Applying this nutrient results in the greatest increase in plant weight. It is therefore necessary to look for fertilisation methods that increase the yield of vegetables and do not reduce their active substance content.

Therefore, I consider it reasonable for the PhD student to undertake research on the introduction of a new vegetable plant (flowering Chinese cabbage) and to develop the possibility of growing it in Poland under controlled conditions.

I conclude that the choice of the topic of the dissertation should be considered apt and fully justified by the current state of knowledge and the needs of practice.

Aim of the thesis and research methods used

The reviewed dissertation can be placed in the mainstream of research on the influence of cultivation factors on the yield and quality of vegetable crops grown under cover.

The research hypotheses and objectives of the study were clearly formulated by the PhD student.

Wenping Liu, M.Sc., set himself three research hypotheses namely:

1. Modification of plant nutrition with nitrogen, both its intensity and source of the nutrient, influences yield of flowering Chinese cabbage
2. Foliar treatment with salicylic acid, V, Li, Si and Se affects the yield of flowering Chinese cabbage
3. flowering Chinese cabbage shows suitability for soilless cultivation, both in a substrate (mixture of mineral soil + peat; pot cultivation) and in a hydroponic system

The overarching objective of the PhD student's research was to determine the optimum level of nitrogen, cultivation season and cultivation system on the growth and physicochemical parameters of flowering Chinese cabbage. In order to achieve the stated objective and verify the research hypotheses set, Wenping Liu, M.Sc., distinguished specific objectives, which were:

- Determining the optimum nutritional requirements for flowering Chinese cabbage and obtaining a high-quality yield for consumers of this vegetable.
- Investigating the effects of nitrogen sources and rates on growth and quality traits of flowering Chinese cabbage.
- Investigating the effects of two levels of nitrogen fertilisation and foliar application on yield and quality of flowering Chinese cabbage.

The first published paper (1) presented the current state of research on the origin, cultivation and biological value of flowering Chinese cabbage.

The second paper (2) presents a study to assess the level of fertilisation with Nitrogen (50, 70, 90, 110 and 130 mg N per dm⁻³) on the response of plants grown in two different systems (substrate and hydroponic) in spring and autumn.

Another research problem (publication 3) was to investigate the effects of different nitrogen fertilisers and also increasing nitrogen rates (50, 70 and 90 mg N dm⁻³) on the yield and physicochemical parameters of flowering Chinese cabbage grown in two different soilless systems.

The last paper (4) investigated the effect of two levels of nitrogen fertilisation (70 and 90 mg N dm⁻³) and foliar treatments (Se, Si, Li, V and salicylic acid) on the yield and physicochemical parameters of flowering Chinese cabbage grown in two soilless cultivation systems.

I consider the selection of plant material and the research methods used to be appropriate, allowing the set objectives to be met. The PhD student demonstrated knowledge of diverse analytical methods, the use of which significantly increased the value of the results obtained.

Statistical analyses of the results were performed using Statistica 13.3. Data were subjected to principal component analysis (PCA), and analysis of variance (ANOVA), and the least

significant differences were determined using Duncan's test at a confidence level of 0.05. Pearson's correlation between the parameters studied was also determined.

Research achievements

In the first (2021) review publication of current research on flowering Chinese cabbage, the PhD student pointed out that this vegetable is characterised by its high biological value. Among other compounds, it contains glucosinolates, polyphenolic compounds, amino acids, fatty acids, reducing sugars and vitamin C, the content of which is influenced by a number of agrotechnical factors. Nitrogen fertilisation is key to yield, and a balanced application of phosphorus, potassium and other elements can also affect yield. Similarly, other factors such as organic fertilisation or the application of appropriate plant protection can increase yield and improve quality.

Farming work is also underway to make the right choice of a cultivar that is tolerant to heavy metal accumulation and abiotic stresses.

In the second publication (2022), which investigated the effects of nitrogen nutrition on plants and cabbage planting date on yield and physicochemical parameters, Wenping Liu, M.Sc., showed that planting date varied plant nutrition. Higher contents of elements such as N, K, Ca, Fe, Mn and Na were found in the leaves of flowering Chinese cabbage in substrate in the autumn cultivation compared to the spring cultivation. Similar trends were found when the plants were grown in a hydroponic system. The content of components such as P, K, Ca, Fe, Zn, Cu and Na in cabbage leaves was higher in autumn cultivation than in the spring one.

Regarding the application of differentiated nitrogen fertilisation, the PhD student demonstrated that nitrogen nutrition had a positive effect on yield. Taking the average of both cultivation dates, the highest yields were obtained with a nitrogen fertilisation level ranging from N-50 mg dm⁻³ to N-90 mg dm⁻³ in the nutrient solution or substrate. More intensive N fertilisation (N-110 mg dm⁻³ and N-130 mg dm⁻³) did not significantly change plant yields. Furthermore, Wenping Liu, M.Sc., found that the content of phenolic compounds increased with increasing nitrogen levels up to the average nitrogen content in the nutrient solution (N-90 mg dm⁻³ and/or N-110 mg dm⁻³). The highest nitrogen content in the nutrient solution (N-130 mg dm⁻³) did not increase the content of phenolic compounds in cabbage leaves compared to medium and low levels of this nutrient. It was concluded that by introducing an appropriate dose of nitrogen in the nutrient solution, a high yield with a high content of bioactive compounds could be obtained. The PhD student also indicated that the cultivation date of flowering Chinese cabbage also influenced the leaf content of phenolic compounds and antioxidant activity.

The highest value of the above parameters was obtained for the cultivation of the vegetable in spring in the substrate medium.

The research achievements of the dissertation presented for evaluation include those concerning the effects of different forms of nitrogen and increased nitrogen dosage on the yield and selected chemical properties of flowering Chinese cabbage grown in two different systems (substrate and hydroponics) (publication 3, 2023).

It was found that plants grown in hydroponic cultivation had a higher yield than those grown in the substrate in pots. An increase in the level of nitrogen fertilisation significantly increased the yield of plants grown in the substrate compared to plants growing in the hydroponic system. The different forms of nitrogen significantly affected plant nutrition and the macro- and micronutrient content (N, P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu) of the plant material. The highest content of plant pigments (chlorophyll *a*, *b* and carotenoids) was obtained in the yield in the substrate where urea was applied and nitrogen was at the level of N-90 mg dm⁻³, which

was correlated with the level of Mn in the plants. However, the pigment content in the cultivation in the substrate was not correlated with the colour parameters ($L^*a^*b^*$).

In the hydroponic cultivation, the highest plant pigment content occurred in the combination where nitrogen was present in the form of magnesium nitrate at a dose of $N-70 \text{ mg dm}^{-3}$.

Furthermore, chlorophyll *b* content was highly correlated with colour measurement parameters (L^* and b^*). The highest antioxidant activity and phenolic compound content was observed in plants from the substrate combination treated with magnesium nitrate at N doses ($N-70 \text{ mg dm}^{-3}$ and $N-90 \text{ mg dm}^{-3}$), as well as with ammonium and sodium nitrate at $N-90 \text{ mg dm}^{-3}$. In hydroponic cultivation, the highest DPPH (2,2-diphenyl-1-picrylhydrazyl) activity was observed in flowering Chinese cabbage where nitrogen occurred in the form of sodium nitrate at $N-70 \text{ mg dm}^{-3}$ and $N-90 \text{ mg dm}^{-3}$. When grown in the substrate using urea with nitrogen doses of $N-50 \text{ mg dm}^{-3}$ and $N-70 \text{ mg dm}^{-3}$, DPPH and TEAC activities increased significantly except for TEAC (Trolox equivalent antioxidant capacity), where there was a significant decrease.

The research in Publication 4 (2022) investigated the effects of different foliar treatments (Se, Si, Li, V and SA) and nitrogen fertilisation levels (70 and 90 mg N dm^{-3}) on the yield and quality of flowering Chinese cabbage grown in two independent systems - a substrate (a mixture of mineral soil and peat) and hydroponics (mineral wool). The factors analysed had diverse and multidirectional effects on plant yield, growth and quality. The results obtained differed in terms of the plant growing system. The PhD student showed that the yield of flowering Chinese cabbage in the substrate as well as in the hydroponic cultivation was significantly influenced by foliar spraying of plants and the level of nitrogen fertilisation. Plants grown in the hydroponic system had higher yields than those grown in the substrate. Flowering Chinese cabbage plants sprayed with selenium and silicon were characterised by high chlorophyll *a* and *b* content, carotenoids and high antioxidant activity (FRAP) when grown in the substrate and high TEAC, DPPH and FRAP activity when grown hydroponically.

It was found that, when grown in the substrate, plants treated with salicylic acid showed high radical scavenging activity (TEAC values at nitrogen levels of $N-70 \text{ mg dm}^{-3}$) and had high contents of nitrogen, chlorophylls *a*, *b* and carotenoids. In contrast, in the hydroponic cultivation, plants sprayed with salicylic acid achieved low antioxidant activity and low chlorophyll pigment content.

The work submitted for review cannot be objected to, the results of these experiments and the way they are presented have been previously assessed by specialists, reviewers and publishers so this has been omitted from the review.

However, out of my duty as a reviewer, considering the study as a whole, I take the liberty of pointing out the issues noticed while reading the text.

In the description in the self-reference in Chapter I, in the introduction, when stating the nitrogen-containing fertilisers, only in one case (ammonium nitrate) was the name and chemical formula given. Why is the chemical formula not given with the names of the other fertilisers?

In Chapter II on literature review, the author states that about 40 species of vegetables are grown in Poland, which is not quite true, because according to the monograph "World Vegetables", nearly 400 species of vegetables are grown in the world, and in Poland about 60 vegetables of which about 40 are commercially cultivated. The PhD student also reports (after Central Statistical Office 2022) that the dominant species in cultivation are cabbage, onion, beetroot, tomato, cucumber and cauliflower, while following the data in Table 1. one can learn that currently carrots have a dominant position in vegetable cultivation, being one of the main species grown for processing.

In the following chapter III Hypotheses and research objectives, the chemical symbol for selenium is used twice, while the chemical symbol for silicon is missing. This error is also repeated in the English and Polish summaries.

In Chapter IV, Material and methods, the author, writing about the composition of the potting soil, used at least three different pieces of information: mixture of peat and sand or mixture of loamy sand and peat or mineral soil and peat. May I ask for clarification as to which composition of the soil is correct?

The planning of the experiments is not entirely clear to me (how many factors in an experiment, what number of combinations, how many repetitions per combination?) Both in the self-reference and in the published articles this is not explained. It mainly talks about repetitions in each experiment, but these experiments are multifactorial (at least two-factorial), so there are also combinations. Please provide clarification on the experiments planning.

Bearing in mind that experiments with nitrogen fertilisation (different doses and different fertilisers) have been carried out with the plant, which is a vegetable, where among other things the leaves are consumed, it would be good to analyse the plant material for the nitrate content of the cabbage leaves. I do understand that this was not the subject of the study, but on this occasion it would be good to check whether the amount of nitrates in the cabbage leaves exceeds the nutritional standards.

After reviewing the evaluated dissertation, I can conclude that Wenping Liu, M.Sc., has the necessary knowledge of methodological workshop and laboratory work. He has also demonstrated a high level of skill in analysing and interpreting the results of his research as evidenced by the scientific articles submitted for evaluation. They are comprehensive, well-written supported by appropriately selected current literature. They are part of the current global trend of research on the cultivation of vegetables under covers. The dissertation presented for review constitutes a valuable original scientific study, as it was realised by means of well-chosen research techniques, which made it possible to obtain valuable and reliable results. The obtained results of the dissertation have a high cognitive value and make an original contribution to the development of knowledge on the cultivation of vegetables under covers and fit very well into the current trend of research on the introduction to cultivation of little-known valuable vegetables with high health-promoting values.

4. Summary and final conclusion

In conclusion of the review, I would like to emphasise that the aforementioned comments of a debatable nature do not affect my high evaluation of this dissertation. In my opinion, the overall body of work, i.e. the number of publications, participation in Conferences and the dissertation presented for evaluation meets the requirements for doctoral dissertations.

At the same time, I state that, in my opinion, the dissertation of Mr. Wenping Liu, M.Sc. meets the requirements specified in the relevant provisions of the Act of 14 March 2003 on Scientific Degrees and Academic Title and on Degrees and Title in Art (DZ. U. No. 65, item 595, as amended) in conjunction with Article 179 (1) of the Act of 3 July 2018. Provisions introducing the Act - Law on higher education and science (DZ. U. of 30 August 2018, item 1669). Accordingly, I request the Council of the Discipline of Agriculture and Horticulture of the University of Life Sciences in Poznań to admit Mr. Wenping Liu to the further stages of the doctoral dissertation.

Warsaw, 1 August 2023

Janina Gajc-Wolska

