ANNOTATION
of the dissertation work
by Saltanat Maulenova
on the topic «Comparative assessment of the effectiveness of bioorganic and mineral fertilizers on the productivity of apples in the conditions of the growing soil in the south-east of Kazakhstan»
submitted for the degree of Doctor of Philosophy (PhD) in the educational program (specialty) 8D08102 – «Soil Science and agrochemistry»

Relevance of the research topic. Under the irrigated soil conditions of Southeastern Kazakhstan, the productivity of apple orchards largely depends on the balance of nutrients, irrigation regime, and activity of rhizosphere microflora. However, the complex effect of the individual and combined application of mineral fertilizers and bioorganic preparations on NPK dynamics in the soil, formation of the leaf apparatus, microbiological activity, fruit quality, and storability has not been sufficiently studied. Therefore, investigating the integrated influence of these factors and developing effective agrotechnologies for increasing the productivity of apple orchards are of high relevance.

Owing to its unique soil and climatic conditions, Kazakhstan is a strategically important region for the development of horticulture. Horticulture in the republic is considered one of the key sectors of the national economy, providing the population with high-quality, vitamin-rich products, which in turn has a positive effect on human health and life expectancy. A strategic condition for strengthening Kazakhstan's food security is the stable provision of the population with domestically produced products.

Under the conditions of Southeastern Kazakhstan, the productivity of apple orchards on irrigated dark chestnut soils is directly related mainly to nutrient balance, irrigation regime, and the activity of rhizosphere microflora. Nevertheless, the complex effect of the independent or combined application of mineral fertilizers and bioorganic compositions on NPK dynamics in the soil, development of the leaf system, microbiological processes, fruit quality, and fruit storability has not yet been fully investigated.

In this regard, optimizing the mineral nutrition of fruit trees under different irrigation regimes remains an important issue for obtaining high yields. The issues of supplying the Golden Delicious orchard with mineral fertilizers and biopreparations have not been sufficiently studied. Despite advances in fertilizer application experiments, the actual effect of organo-mineral fertilizers on apple productivity on irrigated chestnut soils in Central Asia remains insufficiently clarified. Therefore, this study is aimed at determining the complex influence of these factors, and investigating the effect of fertilizers on the growth, productivity, fruit quality, and storability of Golden Delicious apple trees grown under the conditions of Southeastern Kazakhstan is an urgent scientific task.

Purpose of the dissertation research. To comprehensively assess the agrochemical and agroecological benefits of bioorganic and mineral fertilizers in order to

improve approaches for increasing the productivity and quality of apple orchards grown on irrigated dark chestnut soils of Southeastern Kazakhstan, and to develop scientifically substantiated methods for their application to ensure soil fertility.

Research objectives:

1. To characterize the soil and climatic conditions of the study area;
2. To analyze the effect of various integrated approaches to the application of mineral and bioorganic fertilizers on the agrochemical characteristics of the soil;
3. To study the effect of the applied fertilizers on the biometric indicators of apple trees;
4. To assess the level of development of the apple tree photosynthetic apparatus by determining leaf area and establishing its relationship with fertilizer types and rates;
5. To carry out a quantitative assessment of photosynthetic pigments in plants, determine their accumulation, and identify their contribution to crop productivity;
6. To determine the yield and quality indicators of apple crops under the application of mineral and bioorganic fertilizers;
7. To calculate the economic efficiency of each fertilizer treatment and develop production recommendations.

Research methods. The study was conducted in 2020–2023 in the pomological orchard of the Talgar Republican Branch of the Kazakh Research Institute of Fruit and Vegetable Growing LLP. The research employed generally accepted methods for determining the agrochemical properties of soil, biometric and physiological indicators of plants, as well as apple yield and fruit quality. Soil agrochemical indicators (pH, humus, NPK) were determined using generally accepted methods (according to Tyurin, Machigin, and Kjeldahl).

To assess plant growth intensity, trunk diameter, shoot length, number of leaves, and leaf area were recorded. To characterize photosynthetic activity, leaf area, photosynthetic potential, net photosynthetic productivity, and chlorophyll content were determined. Yield was calculated for each tree, and fruit quality indicators were assessed through laboratory analysis. Sugar content, dry matter, and ascorbic acid were determined in the fruits. The obtained data were statistically processed using ANOVA, correlation-regression analysis, and Dospekhov's methodology.

Main provisions. Proven scientific hypotheses and other conclusions that constitute new knowledge:

1. Dynamics of nutrient content in chestnut soils;
2. Changes in the biometric indicators of apple crops under the influence of mineral and bioorganic fertilizer application;
3. Level of development of the apple tree photosynthetic apparatus as determined by leaf area;
4. Determination of photosynthetic pigment content in plants, study of the dynamics of their accumulation, and their role in yield formation;
5. Yield and quality indicators of apple crops under the application of mineral and bioorganic fertilizers;

6. Economic efficiency of the applied mineral and bioorganic fertilizers.

Description of the main research results. The results of the conducted study showed that the application of bioorganic and mineral fertilizers under the conditions of irrigated dark chestnut soils in Southeastern Kazakhstan had a positive effect on the growth, development, productivity, and fruit quality of apple crops. The initial agrochemical indicators of the soil demonstrated a low level of nutrient supply. In particular, the humus content in the surface layer ranged from 2.21 to 1.26%, while total nitrogen content was 0.106–0.061%. Nitrate nitrogen content was determined at 10.2–8.5 mg/kg, and mobile phosphorus content at approximately 16.0–14.0 mg/kg.

The application of bioorganic and mineral fertilizers had a positive effect on soil humus content. During the study, the highest values were observed in the “Background + BioSok Energy Plus” and “Background + Vermicompost” treatments. In the “Background + BioSok Energy Plus” treatment, humus content was 2.24%, increasing by 0.06% compared with the initial level. In the “Background + Vermicompost” treatment, humus content reached 2.27%, which was 0.09% higher than the initial value. This proves that bioorganic fertilizers contribute to the accumulation of organic matter in the soil and to the stabilization of soil fertility.

The research results showed that in the fertilized treatments, the content of the main nutrient elements in the soil was higher than in the control. The average seasonal content of readily hydrolysable nitrogen in the dark chestnut soil under apple trees in the control treatment was 4.8 mg/kg in the 0–30 cm layer and 2.79 mg/kg in the 30–60 cm layer, whereas in the fertilized treatments this indicator varied, respectively, within 9.2–9.1 mg/kg and 7.9–5.6 mg/kg. The average seasonal content of mobile phosphorus in the control was 1.53 mg/100 g in the 0–30 cm layer and 1.17 mg/100 g in the 30–60 cm layer, while in the treatments with bioorganic and mineral fertilizers it accumulated, respectively, within 3.45–4.05 mg/100 g and 1.95–3.25 mg/100 g. The content of exchangeable potassium in the control treatment was 20.61 mg/100 g in the 0–30 cm layer and 22.4 mg/100 g in the 30–60 cm layer, whereas in the fertilized treatments it ranged, respectively, within 34.1–48.9 mg/100 g and 33.2–44.1 mg/100 g. This indicates that the fertilizers ensured the accumulation of nutrients in the root-zone layer.

The application of bioorganic and mineral fertilizers also had a positive effect on soil microbiological activity. The abundance of total microorganisms, bacteria of the genus Pseudomonas, and ammonifying bacteria in the soil varied depending on the fertilizer type. The highest values were determined in the treatment involving the combined application of NPK and BioSok Energy Plus: the total number of microorganisms reached 2.40×10^6 CFU/g, Pseudomonas bacteria reached 4.0×10^6 CFU/g, and ammonifying bacteria reached 2.0×10^5 CFU/g. In addition, according to the number of microscopic fungi, the NPK + BioSok Energy Plus, NPK + Vermicompost, and NPK + Agroflorin treatments showed high efficiency in increasing the biological activity of the soil.

The application of bioorganic and mineral fertilizers to Golden Delicious apple trees contributed to the improvement of plant biometric indicators. In the fertilized

treatments, trunk diameter ranged from 1.40 to 1.77 cm, and leaf area ranged from 2.36 to 2.90 cm^2. In addition, shoot length increased within the range of 1.61–1.75 cm. This indicates that the fertilizers enhanced the vegetative growth of apple trees and positively affected the formation of the leaf apparatus.

The study of the photosynthetic activity of Golden Delicious apple leaves revealed significant differences between fertilizer treatments. According to the three-year average data, the net photosynthetic productivity of apple leaves in the control treatment was 5.20 mg $CO_2/dm^2/h$, whereas in the fertilized treatments it varied within 6.17–6.93 mg $CO_2/dm^2/h$. The content of chlorophyll a+b in the control averaged 1.41 mg/g, while in the fertilized treatments it ranged from 1.70 to 1.91 mg/g. The highest values were recorded in the "Background + BioSok Energy Plus" treatment, where net photosynthetic productivity reached 6.93 mg $CO_2/dm^2/h$ and chlorophyll a+b content was 1.91 mg/g. This demonstrates the effectiveness of BioSok Energy Plus fertilizer in increasing plant photosynthetic activity.

The studied fertilizers had a pronounced effect on increasing apple yield. According to the three-year average data, yield in the fertilized treatments ranged from 250 to 295 c/ha, whereas in the control treatment it was 180 c/ha. The additional yield obtained as a result of fertilizer application varied within 39–64%. The highest productivity was observed in the treatments where bioorganic and mineral fertilizers were applied in combination, proving that they improved the nutritional conditions of apple trees and enhanced the yield formation process.

Bioorganic and mineral fertilizers also had a positive effect on the quality indicators of apple fruits. In the fertilized treatments, the content of ascorbic acid increased compared with the control and ranged from 11.45 to 15.32. The highest value was determined in the treatment involving the combined application of mineral fertilizers and the bioorganic fertilizer BioSok Energy Plus, reaching 15.32. In addition, the "Background + Vermicompost" treatment showed higher accumulation of sugars and dry matter, and fruit storability reached up to 6 months. This confirms the effectiveness of bioorganic fertilizers in improving the marketable and biochemical quality of apple fruits.

Overall, the research results proved that the combined application of mineral fertilizers with bioorganic preparations under irrigated dark chestnut soil conditions is an effective agrotechnological approach that makes it possible to increase soil fertility, enhance microbiological activity, improve the growth and photosynthetic activity of apple trees, increase yield, and improve fruit quality. The highest results were observed in the NPK + BioSok Energy Plus and NPK + Vermicompost treatments.

Justification of the novelty and importance of the obtained results. For the first time under the conditions of irrigated dark chestnut soils of Southeastern Kazakhstan, the effect of applying bioorganic and mineral fertilizers on the content of the main nutrients in the soil and its microbiological activity was assessed for apple crops. In addition, the influence of different fertilization methods on apple productivity and physiological status, fruit quality, and storability under irrigated soil conditions of Southeastern Kazakhstan was comprehensively determined. The potential for optimizing the irrigation regime

through digital monitoring of soil moisture was demonstrated. Effective rates and methods of applying various mineral and bioorganic fertilizers were established, and the distribution of nutrients according to plant developmental phases was clarified.

Obtaining a high yield of the Golden Delicious apple variety, adapted to the natural and climatic features of Southeastern Kazakhstan, on irrigated soils through the use of bioorganic and mineral fertilizers is an important result of the study. On the basis of the proposed agrotechnology, apple fruit yield increased by 39–64% compared with the control treatment. The application of the bioorganic fertilizer Biosok Energy Plus together with mineral fertilizers at a rate of 300 ml dissolved in 5 liters of water for pre-planting root treatment, two foliar sprayings during vegetative growth, and root and foliar application, as well as the application of Vermicompost together with mineral fertilizers at a rate of 90 kg/ha in spring before bud break along tree rows, contributed to an increase in apple fruit yield to 285–295 c/ha.

The developed methodological approaches are suitable for applied and research purposes. The obtained results contribute to increasing crop productivity, optimizing the costs of bioorganic and mineral fertilizers, ensuring rapid return on investment, and achieving high profitability in apple production. The data collected during the study are of significant interest for the development of agricultural science and encourage farmers to introduce its achievements into production practice.

Compliance with scientific development directions or state programs. The study was carried out in 2021–2023 in the pomological orchard of the Talgar Republican Branch of the Kazakh Research Institute of Fruit and Vegetable Growing LLP within the framework of the project “Development of organic farming technologies for the cultivation, digitalization and export of agricultural crops, taking into account regional characteristics” (IRN BR10764907). The research corresponds to priority areas of science in soil science, agrochemistry, organic agriculture, and fruit growing.

The results of the work are aimed at solving the tasks of preserving the fertility of irrigated soils, ensuring the effective use of bioorganic and mineral fertilizers, increasing apple yield and quality, and supporting the sustainable development of domestic fruit growing.

Description of the doctoral student's contribution to the preparation of each publication. The direction, purpose, research objectives, and methods of this dissertation work were determined by the author under the supervision of the scientific advisors. The doctoral student actively participated in the development of the research programme and methodology for the integrated application of mineral and bioorganic fertilizers in the cultivation of apple trees adapted to the climatic features of the southeastern region of Kazakhstan, took part in field experiments, and demonstrated a high level of responsibility.

The doctoral student fully fulfilled the goals and objectives of her work. She selected effective methods for conducting observations, recording, and analysis, and achieved specific results. In addition, she actively participated in research work, mastered

the methodology of conducting field and production experiments, as well as the methodological requirements for research in the field of agricultural science.

The doctoral student's work was aimed at the theoretical and practical solution of the assigned tasks, conducting experimental studies, performing observations and calculations, and analyzing and summarizing the obtained results. Based on the dissertation materials, 10 scientific works were published, including 1 article in an international journal indexed in the Scopus and Web of Science databases (personal contribution: methodology development, data analysis, writing of the main text); 4 articles in publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan (personal contribution: field research, writing of the main text, statistical processing, formulation of conclusions); and 5 abstracts in the proceedings of international conferences (personal contribution: preparation of reports and presentations).

Volume and structure of the dissertation. The total volume of the dissertation is 142 pages, including an introduction, 7 chapters, conclusions, and production recommendations. The work contains 21 tables, 15 figures, and 8 appendices. The list of references includes 217 sources.