ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

The Impact of Slow-Release Nitrogen Fertilizer Combined with Organic Fertilizer on Oat Yield and Quality

Xuefeng Wang, Shihua Gao, Runlian Wang, Huijuan Cheng, Huimin Ma, Xueyu Wang, Junying Wu*

Vocational and Technical College of Inner Mongolia Agricultural University, Baotou, 014109, China
**Corresponding author: wxflang@163.com*

Abstract: *With the advancement of sustainable agriculture, improving crop yield and quality while reducing environmental pollution has become a key research focus in agricultural production. The combined application of slow-release nitrogen fertilizer and organic fertilizer, as an innovative fertilization technique, optimizes nitrogen supply and soil environment through their synergistic effects, thereby improving crop yield and quality. This study investigates the effects of combined slow-release nitrogen fertilizer and organic fertilizer on the growth and quality of oats (Avena sativa). The experimental results show that slow-release nitrogen fertilizer promotes the growth rate and yield of oats, while organic fertilizer enhances photosynthetic capacity and stress resistance by providing organic matter and improving soil structure. The combination of both significantly increases oat forage yield, calcium and potassium content in hay, protein content in grains, mineral absorption, and dietary fiber levels, thus enhancing the overall quality of oats. The study indicates that the combined use of slow-release nitrogen fertilizer and organic fertilizer not only improves crop growth efficiency but also enhances soil health, offering high ecological and economic value.*

Keywords: *Slow-Release Nitrogen Fertilizer; Organic Fertilizer; Oats; Yield; Quality*

1. Introduction

With the global increase in food demand and the pressure of environmental protection, agricultural production faces a dual challenge of improving crop yield while reducing chemical fertilizer use. Slow-release nitrogen fertilizer and organic fertilizer, as two important types of fertilizers, each have unique advantages in agricultural production. Slow-release nitrogen fertilizer controls the release rate of nitrogen, reduces nitrogen loss, and improves nitrogen use efficiency, thus helping to reduce environmental pollution. Organic fertilizer, on the other hand, improves soil quality by providing rich organic matter, promoting soil microbial activity, and enhancing crop resistance to stress. However, the effect of using slow-release nitrogen fertilizer or organic fertilizer alone is limited. The combined use of both may create a synergistic effect, improving both crop yield and quality. Therefore, the objective of this study is to explore the comprehensive impact of combined slow-release nitrogen fertilizer and organic fertilizer on the growth and quality of oats, providing a theoretical basis for achieving high-yield and high-quality oat production.

2. Characteristics and Mechanisms of Slow-Release Nitrogen Fertilizer and Organic Fertilizer

2.1 Chemical Structure and Release Characteristics of Slow-Release Nitrogen Fertilizer

Slow-release nitrogen fertilizers are a type of fertilizer that slowly releases nitrogen sources through physical, chemical, or biological processes. The purpose is to extend the nitrogen supply time, reduce nitrogen loss, and mitigate environmental pollution. The chemical structure of slow-release nitrogen fertilizers typically involves polymers or coating materials that gradually decompose or hydrolyze in the soil environment, precisely controlling the release rate of nitrogen. For example, common coating materials include polyolefins, sulfur-based compounds, and other polymers, which regulate nitrogen release through effective isolation, ensuring that crops can continuously and evenly absorb nitrogen during their growth. The release characteristics of slow-release nitrogen fertilizers are influenced by

ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

various factors, including soil temperature, humidity, microbial activity, and soil pH. As soil temperature and humidity increase, the release rate of slow-release nitrogen fertilizers generally accelerates, which explains the significant effects of applying slow-release fertilizers during warm seasons. Moreover, the use of slow-release nitrogen fertilizers helps significantly improve nitrogen use efficiency, reducing nitrogen loss through volatilization, leaching, or runoff, optimizing nitrogen supply in agricultural production, thereby achieving precise fertilization, enhancing crop growth performance, and reducing environmental pollution [1].

2.2 Nutrient Supply Characteristics and Soil Improvement Function of Organic Fertilizer

Organic fertilizers, as natural fertilizers, primarily come from plants, animals, or microorganisms, and their nutrients are mainly present in the form of organic compounds. Unlike fast-acting inorganic fertilizers, the nutrients in organic fertilizers are gradually released through microbial decomposition. This process not only provides crops with long-term and stable nitrogen, phosphorus, potassium, and other trace elements, but also improves soil biological activity. As the application rate increases, organic fertilizers significantly enhance the organic matter content in the soil, improve the soil's physical and chemical properties, and strengthen the soil's moisture retention, aeration, and nutrient retention capacity, thus providing a more favorable growth environment for crops. Long-term use of organic fertilizers can reduce soil pH imbalances, effectively slow down soil compaction, salinization, and other phenomena, and promote sustainable soil utilization. In addition, organic fertilizers play a crucial role in promoting microbial communities. Research shows that the application of organic fertilizers increases the activity and diversity of beneficial soil microorganisms, thus enhancing soil biological fertility and providing strong support for healthy crop growth. Therefore, organic fertilizers not only serve as a key means to increase crop yield in agricultural production, but also play an irreplaceable role in soil improvement and ecological environmental protection.

2.3 Synergistic Mechanism of Combined Use of Slow-Release Nitrogen Fertilizer and Organic Fertilizer

The combined use of slow-release nitrogen fertilizer and organic fertilizer has significant synergistic effects, optimizing nitrogen use efficiency, improving soil environment, and enhancing crop growth performance. The main role of slow-release nitrogen fertilizer is to provide a stable and continuous nitrogen supply for crops, preventing excessive nitrogen loss or volatilization, while organic fertilizer provides rich organic matter to improve soil fertility and moisture retention. The combination of both maximizes the effectiveness of the fertilizers.

Firstly, slow-release nitrogen fertilizer can effectively extend the release cycle of nitrogen sources, reducing nutrient loss caused by nitrogen volatilization or leaching, thus ensuring that crops can continuously obtain sufficient nitrogen throughout their growth cycle. Meanwhile, organic fertilizer gradually releases nitrogen, phosphorus, potassium, and other nutrients through slow decomposition, and due to its rich organic matter content, it further enhances the soil’s moisture retention, permeability, and nutrient retention capacity, providing crops with a more stable growing environment.

Secondly, the combined use of slow-release nitrogen fertilizer and organic fertilizer can effectively improve soil structure. While slow-release nitrogen fertilizer continuously provides nitrogen, organic fertilizer improves the soil’s organic matter content, promotes the activity and diversity of soil microbial communities, and enhances the soil’s biological activity, fertility, and resistance to compaction. This complementary effect not only prevents soil compaction but also reduces environmental pollution while improving fertilizer use efficiency and optimizing crop growth conditions.

Finally, the synergistic application of slow-release nitrogen fertilizer and organic fertilizer can achieve a dual improvement in yield and quality. Studies have shown that under the combined action of both, crop nitrogen absorption efficiency is significantly improved, root and leaf growth is promoted, and due to the improved soil environment, crops also show stronger resistance to stress and diseases [2].

3. Effects of Slow-Release Nitrogen Fertilizer and Organic Fertilizer on Oat Growth

3.1 Impact of Slow-Release Nitrogen Fertilizer on Oat Growth Rate

As a novel type of fertilizer, the design of slow-release nitrogen fertilizer aims to provide a

ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

continuous and stable nitrogen supply by delaying the release of nitrogen, optimizing the nitrogen nutrient supply for crops. Oats, being a crop with a high nitrogen demand, require sufficient nitrogen throughout their growth to support basic physiological activities such as cell division, chlorophyll synthesis, and photosynthesis. Slow-release nitrogen fertilizers can slowly release nitrogen over a longer period, avoiding the nitrogen loss or pollution issues caused by the rapid release of conventional fast-acting nitrogen fertilizers. The use of slow-release nitrogen fertilizers not only ensures a balanced supply of nitrogen to crops but also avoids the negative effects of over-fertilization on plant growth. Specifically, the application of slow-release nitrogen fertilizers can significantly extend the nutrient growth phase of oats, thereby increasing the leaf area and photosynthetic capacity of the plants, promoting biomass accumulation.

Nitrogen is one of the main nutrients for plant growth. It not only directly participates in the development of oats but also affects root growth patterns by regulating plant hormone levels. The slow release of nitrogen from slow-release fertilizers ensures that plants receive adequate nutrition during different growth stages, avoiding growth limitations or aging caused by uneven nitrogen supply or over-application. Studies have shown that after the application of slow-release nitrogen fertilizers, oat plant height, stem thickness, and spike length efficiency all significantly increase, thereby enhancing both grass yield and grain yield. Under conditions of drought or low soil fertility, healthy plant development is particularly crucial, and slow-release nitrogen fertilizers can effectively promote the adaptability of oats in adverse conditions, ensuring stable growth.

3.2 Promotion of Oat Plant Growth and Leaf Area Index by Organic Fertilizer

Organic fertilizers, with their rich organic matter and various trace elements, promote oat growth and development in multiple ways after application. First, organic fertilizers, through their slow nutrient release characteristics, provide oats with a continuous and stable supply of nitrogen, phosphorus, potassium, and other nutrients, thereby ensuring that crops meet their nutritional needs at all growth stages. Compared to traditional chemical fertilizers, organic fertilizers release nutrients more slowly, avoiding nutrient excess or loss in the short term, which helps maintain healthy oat growth [3].

The soil improvement effects of organic fertilizers are equally important. By increasing the organic matter content in the soil, organic fertilizers can improve the physical properties of the soil, such as enhancing its water retention, aeration, and structural stability. A good soil structure provides an ideal growing environment for oat roots, promoting root expansion and effective absorption of water and nutrients. Furthermore, organic fertilizers stimulate soil microbial activity, increasing the diversity and function of soil microbial communities, which enhances soil biological activity and forms a healthy soil ecosystem, providing more stable growing conditions for oats.

Regarding the leaf area index (LAI), studies show that oats treated with organic fertilizers exhibit a significant increase in leaf area, and photosynthetic efficiency in the leaves is improved. The leaf area index is an important indicator of plant photosynthetic efficiency. A larger leaf area increases the surface area available for photosynthesis, thereby enhancing the plant's carbon fixation capacity and promoting biomass accumulation. The increase in oat leaf area index, especially during the nutrient growth phase, directly affects later growth and yield performance. Organic fertilizers, by improving the nutritional status and growing environment of oats, enhance their photosynthetic ability, providing ample biological energy for their growth.

3.3 Comprehensive Effects of Combined Application of Slow-Release Nitrogen Fertilizer and Organic Fertilizer on Oat Growth Indicators

The combined application of slow-release nitrogen fertilizer and organic fertilizer fully leverages their complementary advantages, synergistically promoting oat growth in multiple aspects. Slow-release nitrogen fertilizers, through their stable nitrogen release characteristics, ensure the continuous supply of nitrogen during oat growth, avoiding adverse effects on crop growth caused by either excess or insufficient nitrogen in the short term. Organic fertilizers, on the other hand, provide organic matter and various trace elements, improving soil physical and chemical properties, enhancing soil fertility, and increasing soil's water and nutrient retention capacity, thus providing more stable support for oat growth [4].

In terms of oat growth indicators after combined application, studies show that oats treated with both slow-release nitrogen fertilizer and organic fertilizer exhibit significant improvements in important growth indicators, including root development, stem growth, and leaf area index. The synergistic effect

ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

of slow-release nitrogen fertilizer and organic fertilizer allows oats to receive ample nitrogen and other nutrients for an extended period, promoting their growth rate, especially in drought or nutrient-poor environments. The combination of both fertilizers effectively enhances the stress resistance of oats. The expansion of roots and improvement in water absorption capacity ensure that oats can maintain good growth even under relatively dry soil conditions.

Moreover, the combined use of slow-release nitrogen fertilizer and organic fertilizer plays an important role in increasing oat biomass accumulation. By extending the nitrogen release period, slow-release nitrogen fertilizer provides oats with a more balanced nitrogen supply, avoiding nutrient imbalances caused by over-application of nitrogen fertilizers. Meanwhile, organic fertilizers improve soil structure and enhance microbial activity, providing a stable environment for healthy oat growth. The combination of both not only accelerates oat growth rate but also improves growth quality, laying a solid foundation for later yield and quality.

4. The Effects of Controlled-Release Nitrogen Fertilizer and Organic Fertilizer on Oat Quality

4.1 The Impact of Controlled-Release Nitrogen Fertilizer on Oat Nutritional Components and Protein Content

The application of controlled-release nitrogen fertilizer not only affects the growth rate of oats but also determines, to some extent, the accumulation and quality of its nutritional components. Nitrogen is one of the most crucial nutrients for plant growth, particularly in protein synthesis. The slow-release characteristic of controlled-release nitrogen fertilizer ensures that crops receive a stable nitrogen supply over a long period, promoting the synthesis and accumulation of proteins in oat plants. During the grain development stage, a stable nitrogen supply helps increase the protein content in the grains, improving the nutritional value of oats.

Specifically, the combined application of controlled-release nitrogen fertilizer and organic fertilizer has a more significant effect on oat protein. Since nitrogen is a key element in protein synthesis, the moderate supply of controlled-release nitrogen fertilizer promotes the assimilation of nitrogen in oat leaves, which is further converted into proteins within the plant. Studies show that under controlled-release nitrogen fertilizer application, the protein content in oat grains significantly increases,which enhances the nutritional quality of oats and lays a foundation for their potential as a dual-purpose grain and fodder crop. Compared to conventional fast-acting nitrogen fertilizers, controlled-release nitrogen fertilizers effectively avoid protein fluctuations caused by excessive nitrogen application, ensuring balanced protein accumulation throughout the growth cycle[5].

Moreover, controlled-release nitrogen fertilizer also plays a regulatory role in other nutritional components of oats, such as fat, carbohydrates, and soluble sugars. Adequate nitrogen supply enhances photosynthesis in oats, thus improving the efficiency of carbohydrate synthesis. This positively contributes to the formation of grain quality and the accumulation of nutritional components. Therefore,controlled-release nitrogen fertilizer not only increases oat protein content but also optimizes the overall nutritional value of oats by promoting the coordinated accumulation of other nutrients.

4.2 The Improvement Effect of Organic Fertilizer on Oat Mineral Content and Dietary Fiber

As an important soil amendment, organic fertilizer not only provides necessary nutrients for crops but also influences the absorption of minerals and dietary fiber content in oats by improving soil structure and biological activity. In oat fields treated with organic fertilizer, the mineral content and dietary fiber levels in oats generally show significant increases, demonstrating the unique advantages of organic fertilizer in enhancing oat quality.

Organic fertilizer contains a rich variety of minerals, and its application provides oats with essential trace elements such as calcium, magnesium, sulfur, iron, and zinc. These minerals are absorbed by the oat roots and transported to various plant tissues, where they participate in physiological metabolism and structural development, enhancing disease resistance and promoting mineral accumulation in oat grains. Studies show that oats treated with organic fertilizer exhibit significantly increased mineral content, especially in terms of calcium and phosphorus accumulation. This not only enhances the nutritional value of oats but also improves their health benefits[6].

Organic fertilizer also plays a crucial role in increasing dietary fiber content. Dietary fiber is an important component of oats as a health food, offering various health benefits such as lowering blood

ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

lipids and regulating intestinal function. Organic fertilizer, with its rich organic matter content, improves soil structure, which enhances the effective absorption of water and nutrients by oat roots, thus providing better growing conditions for oats. This not only increases the biomass accumulation of oats but also enhances their ability to synthesize dietary fiber, leading to a significant increase in dietary fiber content. Therefore, the combined application of organic fertilizer not only optimizes oat mineral composition but also improves their overall quality as a functional food.

4.3 The Combined Effect of Controlled-Release Nitrogen Fertilizer and Organic Fertilizer on Oat Quality

The combined application of controlled-release nitrogen fertilizer and organic fertilizer significantly optimizes the overall quality of oats. The synergistic effect of both fertilizers enhances the nutritional value, flavor quality, and processing adaptability of oats from multiple aspects. First, controlled-release nitrogen fertilizer provides a stable nitrogen supply to oats, helping to increase the accumulation of protein and other nutrients. Organic fertilizer, on the other hand, improves soil conditions and enhances the accumulation of minerals and dietary fiber, thereby comprehensively enhancing the overall quality of oats.

The joint application of controlled-release nitrogen fertilizer and organic fertilizer can synergistically regulate oat nutritional components, making the ratio of key nutrients such as protein, minerals, and dietary fiber more balanced, ensuring oats have a higher nutritional density. Furthermore, the combination also improves the taste and texture of oats. After the application of controlled-release nitrogen fertilizer, oat grains become fuller, firmer, and have a smoother texture, while organic fertilizer enhances their dietary fiber content, giving oats a better taste and chewability. This makes them especially suitable for the development of health foods and functional foods.

Regarding processing adaptability, the combined use of controlled-release nitrogen fertilizer and organic fertilizer also helps improve the fodder quality and grain varieties of oats. The stable nitrogen supply promotes the integrity and uniformity of oat grains, while the application of organic fertilizer improves the nutritional stability of oats and their storage performance after processing. This allows oats to maintain high quality during storage, transportation, and processing, reducing the risk of quality deterioration.

In conclusion, the combined application of controlled-release nitrogen fertilizer and organic fertilizer optimizes oat quality through multiple pathways, not only increasing the protein content of oat grains but also improving the accumulation of minerals and dietary fiber. This enhances the overall nutritional, flavor, and processing performance of oats, making them more competitive in the market.

5. Conclusion

This study indicates that the combined application of controlled-release nitrogen fertilizer and organic fertilizer has a significant effect on increasing oat yield and improving quality. Controlled-release nitrogen fertilizer provides a stable nitrogen supply, prolongs the effective nitrogen supply time, and promotes the growth of oat roots and nutrient absorption. Organic fertilizer, by improving soil structure and increasing soil fertility, enhances oat photosynthesis efficiency and resistance to stress. The combined use of these two fertilizers not only increases protein content, mineral absorption, and dietary fiber levels in oats but also improves the crop's adaptability to environmental changes. Future research can further explore the interaction between different fertilization methods and oat varieties, as well as optimize fertilization timing and application amounts to achieve a more efficient and environmentally friendly oat production model.

Acknowledgement

Science Research Project of Higher Education Institutions in Inner Mongolia Autonomous Region – Mechanism of Improving Quality and Efficiency of Nitrogen Transport in Oats with Different Genotypes, Project No.: NJZY21524

Topic: Study on the Optimization of Water-Saving Irrigation System Based on the Oat Grass-Crop Planting Mode; Project No.: NJZY22533

ISSN 2616-5910 Vol. 6, Issue 1: 79-84, DOI: 10.25236/AJALS.2025.060111

References

[1] Yao, Q., Tang, X., Xiao, M., et al. (2025). Effects of Combined Application of Controlled-Release Nitrogen Fertilizer and Organic Fertilizer on Crop Growth and Soil Nutrients in Rice-Wheat Rotation System. Journal of Zhejiang A&F University, 1-18.
[2] Li, J. (2024). Effects of Controlled-Release Nitrogen Fertilizer Application Rate on Nitrogen Metabolism and Yield in Wheat. Agricultural Engineering Technology, 44(16), 14-15.
[3] Gu, W., Gao, Z. (2023). Effects of Controlled-Release Nitrogen Fertilizer Ratio and Reduced Application on Wheat Yield and Benefits. Anhui Agricultural Bulletin, 29(12), 16-20.
[4] Ma, Q. (2023). Mechanisms of Yield Formation and Nitrogen Efficiency Regulation in Rice-Wheat System with Controlled-Release Nitrogen Fertilizer Applied Twice. Yangzhou University.
[5] Zou, Q., Gu, X., Li, Y., et al. (2022). Effects of Controlled-Release Nitrogen Fertilizer Application Rate on Winter Wheat Yield and Nitrogen Utilization Efficiency. Journal of Water Resources and Water Engineering, 33(04), 217-224.
[6] Chen, J. (2020). Study on the Synergistic Effect of Controlled-Release Nitrogen Fertilizer and Biological Organic Fertilizer on Oat Growth. Inner Mongolia Agricultural University.