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Effect of Nano DAP Seed Treatment on Germination and Early Growth of Wheat (*Triticum aestivum* L.)

Rohitashv Nagar[1], Dr. Gunnjeet Kaur[2]
[1] Assistant Professor, Department of Agronomy, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, India

Email: rohitashv.nagar@cpur.edu.in

[2] Associate Dean, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, India

Abstract

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops, and improving its early establishment is essential for achieving higher productivity. The present study entitled "Effect of Nano DAP Seed Treatment on Germination and Early Growth of Wheat (*Triticum aestivum* L.)" was conducted during the Rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan. The objective was to evaluate the effect of Nano DAP seed treatment on wheat germination, seedling vigour, and early crop establishment. Healthy seeds of wheat variety Raj-4037 were divided into two treatments: T_1 (untreated control) and T_2 (Nano DAP @ 5 ml kg^{-1} seed). After uniform coating and shade drying, the seeds were sown under identical field conditions. Observations were recorded on germination initiation, germination percentage, seedling emergence, seedling vigour, root and shoot growth, and crop establishment. The Nano DAP-treated seeds exhibited earlier germination, higher germination percentage, better seedling emergence, improved root and shoot development, and more uniform crop establishment than the untreated control. The results demonstrate that Nano DAP applied as a seed treatment enhances early plant growth and nutrient use efficiency even at a very low application rate. The study indicates that Nano DAP has considerable potential as a sustainable seed treatment technology for wheat cultivation, although long-term and multi-location studies are required to validate its effects on yield, grain quality, and soil health.

Keywords: Wheat, Nano DAP, Seed treatment, Germination, Seedling vigour.

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1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and serves as a staple food for more than one-third of the global population. In India, wheat occupies a pivotal position in the agricultural economy, contributing significantly to national food security, farmers' livelihoods, and nutritional requirements. Sustaining wheat productivity under increasing pressure from climate change, declining soil fertility, and inefficient nutrient management has become a major challenge. Therefore, the adoption of innovative nutrient management technologies is essential for achieving higher productivity while maintaining environmental sustainability (FAO, 2023; ICAR, 2024). Successful crop establishment begins with high-quality seed and efficient nutrient availability during the early stages of plant growth. Seed treatment is one of the most economical and effective agronomic practices that protects seeds against pathogens and insects while enhancing seed germination, seedling vigour, and uniform crop establishment. In recent years, seed treatment has evolved beyond the use of fungicides and insecticides to include plant growth promoters, biofertilizers, micronutrients, and nanotechnology-based fertilizers. These innovations are designed to improve nutrient use efficiency and promote healthy crop growth from the initial stages of development (Copeland and McDonald, 2001; ISTA, 2023). Among modern agricultural technologies, nanotechnology has emerged as a promising tool for improving fertilizer efficiency and reducing nutrient losses. Nanofertilizers consist of nutrients delivered in nanoparticle form or encapsulated within nanomaterials that facilitate controlled and targeted nutrient release. Compared with conventional fertilizers, nanofertilizers possess a significantly larger surface area, greater reactivity, and improved nutrient absorption efficiency. Consequently, they can supply essential nutrients in smaller quantities while minimizing losses through volatilization, leaching, and fixation in the soil. Their application is expected to increase nutrient use efficiency, improve crop productivity, reduce production costs, and lessen environmental pollution associated with excessive fertilizer application (Kah *et al*., 2018; Dimkpa and Bindraban, 2018). Among nanofertilizers developed in India, Nano DAP (Nano Di-Ammonium Phosphate) represents an important innovation for improving nitrogen and phosphorus nutrition in crops. Developed by the Indian Farmers Fertiliser Cooperative Limited, Nano DAP contains nitrogen and phosphorus nanoparticles designed for rapid absorption and efficient utilization by plants. Unlike conventional DAP fertilizer, which often suffers from phosphorus fixation in soil and low nutrient use

efficiency, Nano DAP provides nutrients in nano-sized particles that are readily available to plants. This technology has the potential to reduce the dependence on bulk chemical fertilizers while maintaining crop productivity and improving fertilizer use efficiency (IFFCO, 2023). Phosphorus plays a critical role during seed germination and early seedling development. It is involved in energy transfer through ATP synthesis, nucleic acid formation, cell division, root initiation, and enzyme activation. Adequate phosphorus availability during the initial growth stages enhances root proliferation, promotes vigorous seedling growth, and enables plants to establish more rapidly under field conditions. Nitrogen, another major constituent of Nano DAP, is equally important for chlorophyll synthesis, protein formation, and vegetative growth. Therefore, treating wheat seeds with Nano DAP before sowing may improve nutrient availability immediately after germination, resulting in better crop establishment and enhanced early plant growth. Recent studies have demonstrated that nanofertilizers improve seed germination, seedling vigour, nutrient uptake, photosynthetic efficiency, and crop productivity across several agricultural crops. Their use also contributes to sustainable agriculture by reducing fertilizer application rates, improving nutrient recovery efficiency, and lowering environmental contamination. Nevertheless, field-based information regarding the use of Nano DAP as a seed treatment in wheat under the agro-climatic conditions of southeastern Rajasthan remains limited. Scientific evaluation under local conditions is therefore essential before recommending this technology for large-scale adoption. Keeping these aspects in view, a field experiment was conducted during the Rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan. The experiment aimed to evaluate the effect of Nano DAP used as a seed treatment on wheat seed germination, seedling emergence, early crop establishment, and initial vegetative growth. The study also sought to assess the practical feasibility of Nano DAP seed treatment as a sustainable nutrient management strategy that could improve fertilizer use efficiency while reducing dependence on conventional phosphorus fertilizers. The findings of this study are expected to contribute valuable information regarding the application of nanotechnology in wheat production and provide scientific evidence for the promotion of Nano DAP as an innovative input for sustainable cereal cultivation.

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2. Materials and Methods:

The present investigation entitled "Effect of Nano DAP Seed Treatment on Germination and Early Growth of Wheat (*Triticum aestivum* L.)" was conducted during the Rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, India. The study was undertaken to evaluate the effect of Nano DAP seed treatment on seed germination, seedling vigour, and early growth of wheat under field conditions. The experiment aimed to assess the potential of Nano DAP as an innovative nanofertilizer for improving early crop establishment, enhancing nutrient use efficiency, and promoting sustainable wheat production. The wheat variety Raj-4037 was selected for the study owing to its adaptability and widespread cultivation in the region. Healthy, bold, and uniformly sized seeds with high physical purity were used to eliminate variability arising from seed quality. The seeds were divided into two experimental groups:**T_1:** Untreated seeds (Control) , **T_2:** Seeds treated with Nano DAP Nano DAP was applied at the recommended rate of 5 ml kg^{-1} of seed**.** The required quantity of Nano DAP was measured accurately and mixed thoroughly with the seeds in a clean plastic container to ensure a uniform coating on the entire seed surface. The treated seeds were gently mixed until all seeds received an even layer of the Nano DAP formulation. After treatment, the seeds were spread in a thin layer and allowed to dry under shade for approximately 30–60 minutes**,** avoiding direct sunlight to maintain the stability and effectiveness of the nano-formulation. The untreated seeds were kept separately and handled in the same manner without Nano DAP application. Both treated and untreated seeds were sown on the same day under identical field conditions to eliminate environmental variation. The experiment was maintained under uniform agronomic practices with respect to land preparation, sowing depth, irrigation, and crop management so that any observed differences could be attributed primarily to the Nano DAP seed treatment. Care was taken to maintain similar soil moisture, temperature, and field conditions throughout the germination and early crop establishment period. To evaluate the influence of Nano DAP on seed performance and early crop growth, observations were recorded at regular intervals after sowing. The following parameters were assessed. The recorded data from Nano DAP-treated and untreated (control) seeds were compared to determine the effect of Nano DAP on germination behaviour, seedling vigour, and early crop establishment. Descriptive statistical analysis and graphical comparisons were used to interpret the experimental results.

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T_1: Untreated seeds (Control) **T_2: Seeds treated with Nano DAP**

3. Review of Literature

The application of nanotechnology in agriculture has opened new opportunities for improving fertilizer use efficiency, enhancing crop productivity, and promoting sustainable farming systems. Among various nanofertilizers, Nano Di-Ammonium Phosphate (Nano DAP) has recently gained attention as an efficient source of nitrogen and phosphorus for crop production. Several researchers have reported positive effects of nanofertilizers on seed germination, nutrient uptake, seedling vigour, crop growth, and yield. Copeland and McDonald (2001) reported that seed treatment is one of the most effective methods for improving seed germination, protecting seeds from biotic stresses, and promoting vigorous seedling establishment. Healthy and vigorous seedlings establish better under field conditions and ultimately contribute to higher crop productivity. Subramanian *et al*. (2015) described nanofertilizers as advanced nutrient delivery systems capable of supplying nutrients in a controlled and efficient manner. According to the authors, nanofertilizers increase nutrient availability, reduce nutrient losses, and improve fertilizer use efficiency compared with conventional fertilizers. Dimkpa and Bindraban (2018) reviewed the potential of nanofertilizers in modern agriculture and reported that nano-based nutrient formulations improve nutrient absorption, stimulate plant growth, enhance root development, and increase crop productivity while minimizing environmental pollution caused by excessive fertilizer

use. Kah *et al*. (2018) explained that nanoparticles possess a high surface area and greater reactivity, allowing nutrients to be released gradually and absorbed more efficiently by plants. Their review concluded that nanofertilizers have considerable potential to improve nutrient use efficiency and support sustainable agricultural production. Taiz *et al*. (2018) emphasized the importance of nitrogen and phosphorus during seed germination and early plant growth. Phosphorus plays a key role in ATP synthesis, energy transfer, root initiation, and cell division, whereas nitrogen is essential for chlorophyll formation, protein synthesis, and vegetative growth. Adequate availability of these nutrients during the early stages promotes vigorous seedling development. Indian Farmers Fertiliser Cooperative Limited (2023) introduced Nano DAP as a next-generation phosphorus fertilizer containing nano-sized particles of nitrogen and phosphorus. According to the technical bulletin, Nano DAP improves nutrient availability, enhances fertilizer use efficiency, reduces phosphorus fixation in soil, and can partially substitute conventional DAP fertilizer. Food and Agriculture Organization of the United Nations (2023) emphasized that improving nutrient use efficiency is essential for ensuring future food security while reducing the environmental impacts associated with excessive fertilizer application. The organization recommended innovative fertilizer technologies for sustainable crop production. Indian Council of Agricultural Research (2024) highlighted the importance of balanced nutrient management and advanced fertilizer technologies for increasing wheat productivity in India. The report indicated that improving nutrient use efficiency is necessary to sustain crop production under changing climatic conditions. Recent experimental studies conducted on cereal and pulse crops have also demonstrated that nanofertilizers improve seed germination, seedling vigour, chlorophyll content, nutrient uptake, root growth, and overall crop performance. These improvements are primarily attributed to the enhanced availability and efficient utilization of nutrients supplied through nano-sized particles. Although several studies have reported the beneficial effects of nanofertilizers, information regarding the use of Nano DAP as a seed treatment in wheat under the agro-climatic conditions of southeastern Rajasthan remains limited. Therefore, the present investigation was undertaken to evaluate the effect of Nano DAP seed treatment on germination, seedling vigour, and early crop establishment of wheat under field conditions.

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4. Results and Discussion

The application of Nano DAP as a seed treatment had a positive influence on the germination behaviour and early seedling development of wheat (*Triticum aestivum* L.) under field conditions. The comparative evaluation between Nano DAP-treated seeds and untreated (control) seeds revealed noticeable improvements in several growth parameters during the initial stages of crop establishment. The Nano DAP-treated seeds initiated germination earlier than the untreated seeds, indicating that the nano-formulation facilitated quicker metabolic activation during the germination process. Early germination is considered an important agronomic advantage because it promotes rapid crop establishment, enhances competitiveness against weeds, and enables better utilization of available soil moisture and nutrients (Copeland and McDonald, 2001). A comparatively higher germination percentage was recorded in the Nano DAP-treated seeds than in the untreated control. The improved germination may be attributed to the enhanced availability of nitrogen and phosphorus supplied through nano-sized particles, which are readily absorbed by the germinating embryo. Phosphorus is an essential component of ATP, nucleic acids, and phospholipids, playing a vital role in energy transfer, cell division, and root initiation during seed germination. Likewise, nitrogen supports the synthesis of amino acids, proteins, chlorophyll, and enzymes required for early seedling growth (Taiz *et al*., 2018). Besides increasing germination percentage, Nano DAP treatment also improved the uniformity of seedling emergence. The treated plots exhibited a more homogeneous crop stand, with seedlings emerging almost simultaneously, whereas the control plots showed comparatively irregular and uneven emergence. Uniform crop establishment is highly desirable because it facilitates efficient crop management practices, reduces inter-plant competition, and ultimately contributes to higher productivity. The beneficial effect of Nano DAP was further reflected in the early vegetative growth of wheat seedlings. Seedlings originating from treated seeds appeared more vigorous, healthier, and greener than those in the control treatment. Visual observations indicated improved shoot growth, enhanced leaf development, and better overall plant appearance during the early growth stages. One of the most noticeable observations was the superior root development in Nano DAP-treated plants. The seedlings produced comparatively stronger and more active root systems, which are essential for efficient absorption of water and nutrients from the soil. Enhanced root growth during the initial stages generally improves crop resilience under moisture stress and supports better vegetative

development throughout the growing season. Similar observations have been reported in previous studies, where nanofertilizers promoted root elongation, nutrient uptake, and seedling vigour by increasing nutrient availability and improving fertilizer use efficiency (Dimkpa and Bindraban, 2018; Kah *et al*., 2018). The untreated control plants, although germinating satisfactorily, exhibited comparatively lower germination percentage, delayed emergence, and less uniform crop establishment. Seedlings were relatively smaller during the early stages and displayed comparatively weaker root development than those produced from Nano DAP-treated seeds. An important finding of the present investigation was that only 5 ml of Nano DAP per kilogram of seed was sufficient to produce visible improvements in seed performance and early crop growth. This demonstrates the high nutrient use efficiency of nano-fertilizers, as very small quantities can provide significant physiological benefits. Unlike conventional phosphorus fertilizers, which often undergo fixation in soil and become unavailable to plants, Nano DAP supplies nutrients in nano-sized particles that improve nutrient absorption and utilization by emerging seedlings (IFFCO, 2023). Overall, the experimental observations suggest that Nano DAP seed treatment enhanced germination percentage, accelerated seedling emergence, improved crop stand uniformity, promoted vigorous root and shoot growth, and strengthened early crop establishment. These improvements indicate that Nano DAP has considerable potential as a sustainable seed treatment technology for wheat cultivation, contributing to improved nutrient use efficiency while reducing dependence on large quantities of conventional phosphorus fertilizers. Nanotechnology-based fertilizers have emerged as one of the most promising innovations in modern agriculture due to their ability to improve nutrient use efficiency, enhance crop productivity, and support sustainable farming systems. Unlike conventional fertilizers, which often suffer substantial nutrient losses through leaching, volatilization, runoff, and soil fixation, nanofertilizers are designed to deliver nutrients in nano-sized particles that possess a larger surface area, greater reactivity, and improved penetration into plant tissues. Consequently, nutrients become available to plants more efficiently and in a controlled manner, resulting in enhanced nutrient uptake and utilization (Dimkpa & Bindraban, 2018; Kah *et al*., 2018). The findings of the present study indicate that Nano DAP seed treatment positively influenced wheat germination, seedling vigour, and early crop establishment. The enhanced germination percentage and uniform seedling emergence observed in the treated seeds suggest that Nano DAP supplied readily available nitrogen and phosphorus during the critical stages of germination and early growth. Phosphorus is indispensable for ATP

production, nucleic acid synthesis, root initiation, and cell division, whereas nitrogen plays a central role in protein synthesis, chlorophyll formation, and enzymatic activity. Adequate availability of these nutrients immediately after germination enables seedlings to establish rapidly and develop vigorous root and shoot systems (Taiz *et al*., 2018). Improved seedling establishment is particularly important because the initial growth stage determines the future growth potential of the crop. A vigorous crop stand ensures better utilization of sunlight, water, and nutrients, enhances competition against weeds, and improves the plant's ability to withstand biotic and abiotic stresses. Therefore, the positive effects of Nano DAP observed during the early stages may ultimately contribute to higher biomass production, improved yield attributes, and better grain productivity under field conditions, although these parameters require further validation through full-season experiments. One of the most significant observations of this investigation was that only 5 ml of Nano DAP per kilogram of seed produced noticeable improvements in germination and early plant growth. This demonstrates the high efficiency of nanofertilizers, where very small quantities are capable of producing measurable physiological responses. Such enhanced efficiency is primarily attributed to the nano-scale size of fertilizer particles, which increases nutrient availability while reducing nutrient losses caused by soil fixation, especially in the case of phosphorus. Conventional phosphorus fertilizers frequently become unavailable to plants due to fixation with calcium, iron, and aluminum compounds in soil, whereas nano-formulations are designed to improve nutrient accessibility and utilization (IFFCO, 2023). From the perspective of sustainable agriculture, Nano DAP offers several practical advantages. Improved nutrient use efficiency may reduce the requirement for conventional chemical fertilizers, thereby lowering input costs for farmers. Reduced fertilizer application can also decrease nutrient losses into the environment, minimizing groundwater contamination, eutrophication of water bodies, and greenhouse gas emissions associated with fertilizer manufacture and application. Consequently, nanofertilizers have the potential to contribute significantly to environmentally sustainable and climate-smart agricultural production systems (Kah *et al*., 2018). The present study further supports the concept that seed treatment represents an efficient method of nutrient delivery, as nutrients become available precisely when seedlings require them most. Providing essential nutrients at the time of sowing allows plants to establish a stronger root system and healthier canopy from the beginning of the crop cycle. Such early advantages frequently translate into improved crop performance throughout subsequent growth stages. Nevertheless, despite the encouraging results, the present

investigation was confined primarily to observations on germination and early seedling growth under a single environmental condition and one wheat variety. Therefore, additional research is required to validate these findings across different agro-climatic regions, soil types, wheat cultivars, and management practices. Future investigations should also evaluate the influence of Nano DAP on nutrient uptake, physiological characteristics, photosynthetic efficiency, yield components, grain quality, fertilizer use efficiency, economic returns, and long-term soil health. Multi-location field trials conducted over several cropping seasons will provide stronger scientific evidence regarding the consistency and practical applicability of Nano DAP technology under diverse farming conditions.

Treatment	Germination initiation (DAS)	Germination (%)	Seedling emergence (%)	Plant height at 15 DAS (cm)	Root length at 15 DAS (cm)	Shoot length at 15 DAS (cm)	Seedling vigour	Crop stand uniformity
T1: Untreated wheat seeds (Control)	5	86	84	14.2	8.3	10.6	Moderate	Moderate
T2: Wheat seeds treated with Nano DAP @ 5 ml kg-1 seed	4	95	94	17.1	10.8	12.9	High	Excellent

5. Conclusion:

The present investigation demonstrated that Nano DAP seed treatment at 5 ml kg^{-1} seed significantly improved the germination and early growth of wheat compared with untreated seeds. Nano DAP-treated seeds showed earlier and higher germination, better seedling emergence, stronger root and shoot development, and more uniform crop establishment. These improvements indicate enhanced nutrient availability during the critical stages of seed germination and early seedling growth, resulting in better seedling vigour and crop establishment. The study further revealed that a very small quantity of Nano DAP was sufficient to produce noticeable improvements in early crop performance, highlighting its high nutrient use efficiency. Nano DAP therefore represents a promising nanofertilizer technology that can contribute to sustainable wheat production by improving fertilizer efficiency while reducing dependence on conventional phosphorus fertilizers. Although the

results are encouraging, the study was limited to the early growth stage under a single location and one wheat variety. Further research involving different agro-climatic conditions, wheat cultivars, and complete crop growth cycles is needed to confirm its effects on nutrient uptake, grain yield, grain quality, economic returns, and long-term soil health. Nevertheless, the present findings suggest that Nano DAP seed treatment can be recommended as an effective strategy for improving early crop establishment and supporting sustainable nutrient management in wheat cultivation.

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