



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(5): 293-297
Received: 11-02-2026
Accepted: 15-03-2026

Vijeta PM
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Sridhara CJ
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Sridhara S
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Nandish MS
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Anjali MC
Department of Soil Science, College
of Agriculture, VC Farm, UAS,
Mandya, Karnataka, India

Corresponding Author:
Vijeta PM
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Comparative evaluation of seed priming and foliar application of nano DAP on growth, yield and quality of blackgram (*Vigna mungo* L. Hepper)

Vijeta PM, Sridhara CJ, Sridhara S, Nandish MS and Anjali MC

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5d.5519>

Abstract

A field experiment was conducted during *Kharif* 2024, at the College of Agriculture, Shivamogga, to investigate the comparative effect of seed priming and foliar application of nano DAP on blackgram (*Vigna mungo* L. Hepper). The experiment was laid out in Randomized Complete Block Design with eight treatments replicated thrice. Treatments comprised an absolute control, recommended dose of fertilizers (RDF) and others involved basal application of recommended nitrogen and phosphorus through conventional urea and DAP, respectively at 75 and 100 per cent in combination with nano DAP application by two methods (seed priming @ 3 ml l⁻¹ and foliar spray @ 4 ml l⁻¹ at 30 DAS). Among the treatments, application of 100 per cent N and P as basal, along with seed priming using nano DAP @ 3 ml l⁻¹ and foliar spray of nano DAP @ 4 ml l⁻¹ at 30 DAS (T₈) recorded significantly higher seed yield (1111 q ha⁻¹). The same treatment recorded significantly higher growth parameters viz., plant height (34.82 and 46.61 cm), number of branches per plant (4.27 and 10.87), total dry matter (5.49 and 15.67 g plant⁻¹) at 30 and 60 DAS, respectively. Further, this treatment recorded higher seed yield per plant (12.03), haulm yield (2431 kg ha⁻¹) and biological yield (3542 kg ha⁻¹), at harvest. Similarly, higher crude protein content (25.75%) and protein yield (286.05 kg ha⁻¹) were also noticed in the same treatment. However, it was statistically on par with the treatment receiving 75 per cent N and P along with seed priming using nano DAP @ 3 ml l⁻¹ and foliar application of nano DAP @ 4 ml l⁻¹ at 30 DAS (T₇). Between seed priming and foliar application, seed priming of nano DAP showed better performance over foliar application with 75 and 100 per cent recommended N and P, both. The enhanced seedling vigor and better establishment under seed priming contributed to higher productivity when compared to foliar spray.

Keywords: Nano DAP, blackgram, seed priming, foliar spray, growth, yield, quality, protein

Introduction

Pulses are the most important food crops after cereals. They belong to family Fabaceae and commonly called as grain legumes. Pulses contain two to three times more protein than cereals ranging approximately between 20 and 40 per cent (Arora, 1989) [5]. Among all the pulses, one of the important pulse crops in India is blackgram (*Vigna mungo* L.), a member of the genus *Vigna* and Papilionaceae subfamily of the Fabaceae family. This self-pollinating annual legume crop (2n = 22) is commonly called "urid bean" and has been evolved from wild plant *Phaseolus sublobatus*. It is believed that blackgram originated in India, where it is the most popular and highly valued grain legume, as supported by Chatterjee and Bhattacharya (1986) [9]. It is cultivated in all three seasons in India, viz., *Kharif*, *Rabi* and *summer*. This crop is distributed mainly in tropical to subtropical countries and it is more important to India because for the predominant vegetarian population. It fits well in mixed cropping and crop rotation system due to its shorter life cycle. Blackgram has the ideal ratio of all nutrients, viz., protein (25-26%), carbohydrates (60%), fat (1%) as well as minerals, amino acids and vitamins (Jadhav *et al.*, 2017) [15]. It is used in the preparation of dishes like dal, curries, soups, sweets and snacks. It is also used as nutritive fodder, especially for milch cattle. India is the world's largest producer of Black gram, contributing 70 per cent of the global production, followed by Myanmar and Pakistan. India produces approximately 2 million tons of blackgram from around 4 million hectares, with an average yield of 598 kg ha⁻¹ during 2023-24. In India, 80 per cent of blackgram

cultivation occurs during the *Kharif* season and nearly 20 per cent during the *Rabi* season. Blackgram accounts for approximately 10 per cent of the total pulse production in India, with more than 90 per cent of its production coming from ten states: Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Uttar Pradesh, Jharkhand, Telangana, Odisha, Andhra Pradesh and Tamil Nadu (Anon, 2024).

Despite of its importance, its productivity is low in India. The low productivity of blackgram in the country can be due to several factors. These include the lack of quality seeds and short-duration varieties, growing in marginal and less fertile soil with minimal inputs and no control over pests and diseases, growing in conditions of moisture stress and storing in unfavourable conditions. Various other reasons like physiological, biochemical and inherent crop-related factors, as well as the fact that it is mainly grown in rainfed areas with inadequate management practices (Mahala *et al.*, 2001) [20]. Among all the yield limiting factors, fertility management is imperative to ensure better crop production on exhausted soils.

In pulse crops, the use of conventional fertilizers often faces several challenges that limit their effectiveness. A large amount of nutrients applied through these fertilizers is not fully utilized by plants, as they are commonly lost through processes such as leaching, runoff, volatilization and fixation in the soil. As a result, only a small portion of the nutrients becomes available to the crop, leading to lower nutrient use efficiency and reduced crop productivity. This not only increases production costs for farmers but also contributes to environmental concerns such as soil nutrient imbalance and water pollution. Smart delivery technologies that support long-term soil health and agricultural output, such as nanotechnology and nano-fertilizers, can help overcome all of these limitations (Lal, 2008) [19]. Nano fertilizer is an important input in agriculture to improve crop growth, yield and quality parameters with increased nutrient use efficiency, reduction in wastage of fertilizers and cost of cultivation. These fertilizers are applied either to soil, seeds or leaves. Applying macronutrients at the nano-scale to seeds via seed priming presents several benefits including enhanced nutrient absorption during seedling development, minimized nutrient runoff, increased seedling vitality and optimized resource utilization. Priming of nanomaterial fertilizer particles hold the material more strongly due to higher surface energy than the conventional fertilizers and thus helps in controlled release to meet the soil and crop demand, preventing rapid dissolution and minimizing losses (Manjunatha *et al.*, 2016) [23]. Foliar application promotes the direct entry of nutrients into the plant system, thus reducing the wastage of fertilizer and correcting nutrient deficiencies. Hence, foliar application of nano fertilizers leads to higher nutrient use efficiency (Mahil and Kumar, 2019) [21].

Phosphorus (P) is among the most critical nutrients for pulses. Nano DAP, a liquid fertilizer developed by Indian Farmers Fertiliser Cooperative (IFFCO). It is applied at critical crop growth stages, that effectively fulfils the phosphorus and nitrogen requirement and leads to higher crop yield and quality in comparison to conventional DAP. It contains nanoscale phosphorus and nitrogen particles; compared to conventional granular DAP; it has about 10,000 times more surface area. Particle size (<100 nm) of P-fertilizers greatly influences their agronomic effectiveness. Nano DAP contains 8 per cent nitrogen and 16 per cent phosphorus compared to 18 and 46 per cent, respectively, in conventional DAP. In this study nano DAP is applied by two different methods, to evaluate the effectiveness of Seed Priming and Foliar Application of Nano DAP on

Growth, Yield and Quality of Blackgram (*Vigna mungo* L. Hepper).

Materials and Methods

The field experiment was conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS) of College of Agriculture, Navile, Shivamogga during *Kharif* 2024. The experimental location is situated between 13° 58' to 14° 1' N latitude and from 75° 34' to 75° 42' E longitude, at an elevation of 615 meters above mean sea level. It lies in the Southern Transition Zone (Zone-7) of Karnataka. The soil of the experimental site was sandy loam in texture with pH (6.19), EC (0.32 dS m⁻¹), organic carbon (4.98 g kg⁻¹), low available nitrogen (238 kg ha⁻¹), high phosphorus (57.64 kg ha⁻¹) and medium potassium (226.63 kg ha⁻¹). The actual total rainfall of the station during cropping period was 644.20 mm. This research experiment was laid out in Randomized Complete Block Design with eight treatments and replicated thrice. The treatments details consist of T₁: Absolute control, T₂: RDF (12.5: 25: 25 kg ha⁻¹ of N, P₂O₅, K₂O), T₃: 75% N and P + Seed priming with Nano DAP @ 3 ml/l, T₄: 100% N and P + Seed priming with Nano DAP @ 3 ml/l, T₅: 75% N and P + one foliar spray with Nano DAP @ 4 ml/l at 30 DAS, T₆: 100% N and P + one foliar spray with Nano DAP @ 4 ml/l at 30 DAS, T₇: 75% N and P + Seed priming with Nano DAP @ 3 ml/l + one foliar spray with Nano DAP @ 4 ml/l at 30 DAS, T₈: 100% N and P + Seed priming with Nano DAP @ 3 ml/l + one foliar spray with Nano DAP @ 4 ml/l at 30 DAS. Recommended farm yard manure and potassium were applied commonly for all the treatments, except absolute control (T₁). Blackgram seeds were primed using the nano-DAP at the rate of 3 ml l⁻¹. Treatment seeds were primed for 5 hours with water in seed to solution ratio of 1:3 (w/v) as per the treatment needs. Later, the primed seeds were shade dried then sowing was done. Variety used was LBG-791 (Suraksha), which is suitable for cultivation under both rainfed and irrigated conditions. This variety matures in 75-80 days and harvested at a time (synchronous maturity). From five tagged plants, growth parameters (at 30 and 60 DAS) and yield attributes (at harvest) were recorded.

Crude protein content was calculated by multiplying the nitrogen content with a correction factor 6.25. The protein yield was estimated by using the formula given below

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Seed protein content (\%)} \times \text{Seed yield (kg/ha)}}{100}$$

Results and Discussion

Growth parameters

The plant growth parameters of black gram increased with the advancement of crop age irrespective of the treatments (Table 1). A significant variation was observed among different treatments due to application of nano DAP. Between seed priming and foliar application of nano DAP, seed priming treatments recorded better performance over foliar spray, with both 75 and 100 per cent recommended dose of N and P, at 30 and 60 DAS.

At 30 DAS, seed priming with 100 per cent recommended dose of N and P treatment (T₈) recorded higher growth parameters such that plant height (34.82 cm), number of branches (4.27), leaf area (550.50 cm²) and dry matter production (5.49 g plant⁻¹), over non primed treatments. Foliar application was carried out at 30 DAS and parameters were recorded at 60 DAS.

At 60 DAS, Application of nano DAP (Seed priming + Foliar spray) along with 100 per cent N and P (T₈) was recorded

significantly enhanced the growth parameters, such as plant height (46.61 cm), number of branches (10.87), leaf area (840.42 cm²) and dry matter production (15.67 g plant⁻¹). Between seed priming and foliar spray, at 100 per cent N and P, seed priming (T₄) treatment recorded comparatively higher growth parameters, viz., plant height (42.74 cm), number of branches (9.93), leaf area (757.84 cm²) and dry matter production (14.07 g plant⁻¹), whereas foliar spray treatment recorded comparatively lower growth parameters, viz., plant height (42.25 cm), number of branches (9.85), leaf area (740.47 cm²) and dry matter production (12.46 g plant⁻¹), same trend followed at 75 per cent recommended dose also. Significantly lowest plant growth parameters were recorded in absolute control (T₁).

Growth parameters were significantly influenced by the application of nano DAP as seed priming and foliar spray along with basal conventional fertilizers. Because, phosphorus (P) is an essential nutrient both as a part of several key plant structural compounds and in the numerous biochemical reactions in plants. P is noted especially for its role in capturing and converting the sun's energy into useful plant compounds; thus, P is essential for the general health and vigour of plants (Badini *et al.*, 2015) [7]. Combined application of conventional DAP along with nano DAP seed priming and foliar spray at earlier vegetative stage favoured better crop growth by absorbing through stomata leads to increased enzymatic activity in leaves, which converts nano nitrogen into protein, amino acids and growth hormones, this encourages cells growth, might be responsible for the better plant height (Samui *et al.*, 2022) [27]. The improvement in plant height under optimal nano DAP seed priming can be ascribed to enhanced seedling vigour. This enhanced vigour might be associated with quicker germination and better early growth traits of seedlings. Such responses could be linked to the efficient supply and utilization of phosphorus, which is vital for early seedling establishment. Comparable results were also reported by Niu *et al.* (2013) [24] and Ashoknarayanan *et al.* (2021) [6] in blackgram. Similar findings were also reported by Kumar *et al.* (2016) [18], Akshay (2021) [2] in rice, Girigoud *et al.* (2023) [14] in pigeonpea, Khemshetty *et al.* (2024) [17] and Sarika *et al.* (2025) [28] in chickpea.

Yield parameters

The yield and yield attributes of blackgram were significantly influenced by the application of conventional fertilizers and nano DAP by two different methods of application as depicted in Table 2. Results revealed that, the treatment receiving 100 per cent N and P as a basal along with seed priming using nano DAP @ 3 ml l⁻¹ along with foliar application of nano DAP @ 4 ml l⁻¹ at 30 DAS (T₈) recorded significantly higher seed yield per plant (12.03 g), seed yield (1111 kg ha⁻¹) and haulm yield (2431 kg ha⁻¹) biological yield (3542 kg ha⁻¹). In combination with 100 per cent N and P, higher seed yield (1023 kg ha⁻¹), haulm yield (2238 kg ha⁻¹) and biological yield (3261 kg ha⁻¹) were recorded in the treatment with seed priming (T₄), compared to foliar spray (T₆) treatment. 75 per cent recommended N and P also followed the same trend. Further the treatments involving application of nano DAP either seed priming or foliar spray were recorded higher yield compared to RDF (T₂). Test weight and harvest index were recorded as non significant. Overall, the results indicated that seed priming with nano DAP was more effective than foliar spray. Treatments involving nano DAP application recorded higher yield parameters than RDF. Significantly lowest yield parameters were recorded in absolute control treatment (T₁).

This increased yield might be due to integration of nano DAP

that results in better nutrient uptake supported good plant growth, including height, dry matter build-up and important processes like photosynthesis. This helped the plants to produce more food and move it to the useful parts such as seeds. As a result, more assimilates were shifted to seeds, which increased biomass and yield traits. Similar results were also reported by Kailas *et al.* (2017) [16] and Choudhary *et al.* (2018) [10]. Using both conventional DAP and nano DAP, as a seed priming at sowing and as a foliar spray during the reproductive phase, helps the plant to produce more photosynthates and move them to the developing pods. This increase in photosynthesis results in more sugars and starches, which are then effectively translocated to the pods. As a result, the pods develop better, finally higher pod weight and seed weight. These results are in line with the findings of Manjili *et al.* (2014) [22] and Abdelghany *et al.* (2022) [1]. El-Azizy *et al.* (2021) [11] found increased biological yield in broad bean due to application of nano phosphorus. Sachin (2023) [26], in their study found increased seed yield with nano DAP seed priming in maize over RDF alone.

Quality parameters

Table. 3 presents the data showing significant differences in crude protein content and protein yield among the various treatments as influenced by nano DAP application. The highest crude protein content (25.50%) and protein yield (286.05 kg ha⁻¹) were achieved in the treatment T₈, closely followed by T₇, where nano DAP was applied both as seed priming and foliar spray. In the treatments nano DAP application with 100 per cent N and P (T₄ and T₆), seed priming treatment (T₄) recorded comparatively higher crude protein content (23.75%) and protein yield (242.87 kg ha⁻¹), over foliar spray treatment (T₆), which recorded crude protein content (23.63%) and protein yield (240.69 kg ha⁻¹). The treatments with seed priming produced better quality parameters over foliar spray, while foliar spray treatments showed improvement over RDF (T₂) and absolute control (T₁) but remained lower than seed priming. Among all the treatments, treatments involving nano DAP application recorded good quality parameters over RDF and absolute control treatment. Significantly lowest crude protein content (15.81%) and protein yield (80.95 kg ha⁻¹) were recorded in absolute treatment (T₁).

Nitrogen plays a key role in building proteins and phosphorus helps in forming important coenzymes needed for protein making. Together, they improved the protein content and protein yield. Similar results were reported by El-Ghany *et al.* (2021) [12], Farhana *et al.* (2022) [13] and Bhavyashree (2024) [8]. Amirnia *et al.* (2014) [3] reported that application of nanoparticles in a number of crops has evidenced for enhanced physiological activities, gene expression and protein level indicating their potential use in crop improvement. Yacoub *et al.* (2020) [29] reported improved protein content in soybean due to application of nano P particles. Seed priming with nano DAP helps in absorption of nitrogen and phosphorus more easily at the early growth stage because the nutrients are present in very small nano-sized particles. This improves root growth and nitrogen fixation in the plant, which helps in producing more amino acids and finally increases the protein content in blackgram seeds. Sharifi *et al.* (2016) [25] revealed that seed priming and foliar spray of nano fertilizers significantly increased the crude protein content.

Conclusion

The present investigation showed that application of nano DAP significantly influenced growth, yield and quality of blackgram.

Between seed priming and foliar spray of nano DAP, seed priming of nano DAP treatments performed better than foliar application in enhancing the crop performance. Application of 100 per cent recommended nitrogen and phosphorus as basal along with nano DAP seed priming @ 3 ml l⁻¹ followed by one

foliar spray of nano DAP @ 4 ml l⁻¹ at 30 DAS recorded higher growth and yield parameters of blackgram. Since seed priming is cost effective (lower dose and application cost) and easy application, it is found to be effective.

Table 1: Growth parameters of blackgram as influenced by seed priming and foliar application of nano DAP

Treatments	Plant height (cm)		Number of branches plant ⁻¹		Leaf area plant ⁻¹ (cm ²)		Total dry matter production (g plant ⁻¹)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
T ₁	26.50	34.14	2.23	6.99	354.42	560.37	3.43	9.07
T ₂	30.11	37.81	3.47	8.57	418.59	626.36	4.59	10.59
T ₃	29.87	38.35	3.40	8.71	408.30	643.77	4.57	11.65
T ₄	33.98	42.74	3.87	9.93	519.79	757.84	5.24	14.07
T ₅	29.66	38.07	2.83	8.64	404.48	636.77	4.41	10.87
T ₆	32.15	42.25	3.80	9.85	505.43	740.47	5.04	12.46
T ₇	32.53	44.89	3.83	10.13	514.55	800.26	5.15	14.30
T ₈	34.82	46.61	4.27	10.87	550.50	840.42	5.49	15.67
S. Em. ±	1.18	1.20	0.18	0.30	15.37	20.43	0.15	0.47
CD @ 5%	3.59	3.63	0.55	0.91	46.63	61.97	0.46	1.43

Table 2: Yield and yield attributes of blackgram as influenced seed priming and foliar application of nano DAP

Treatments	Seed yield plant ⁻¹ (g)	Test weight (Weight of 1000 seeds in g)	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
T ₁	5.93	47.95	512	1105	1617	31.66
T ₂	8.95	48.10	924	1996	2920	31.64
T ₃	9.67	48.95	931	2038	2969	31.36
T ₄	11.01	50.03	1023	2238	3261	31.37
T ₅	9.2	48.53	926	2022	2948	31.41
T ₆	10.73	49.20	1019	2231	3250	31.35
T ₇	11.51	50.80	1028	2309	3337	30.81
T ₈	12.03	51.03	1111	2431	3542	31.37
S. Em. ±	0.33	1.49	28.14	61.95	88.08	1.08
CD @ 5%	1	NS	85.35	187.9	267.15	NS

Table 3: Crude protein content (%) and protein yield of blackgram as influenced by seed priming and foliar application of nano DAP

Treatments	Crude protein content (%)	Protein yield (kg ha ⁻¹)
T ₁	15.81	80.95
T ₂	21.31	196.83
T ₃	21.56	200.66
T ₄	23.75	242.87
T ₅	21.44	198.56
T ₆	23.63	240.69
T ₇	25.5	262.15
T ₈	25.75	286.05
S. Em. ±	0.67	9.42
CD @ 5%	2.05	28.59

References

- Abdelghany AM, El-Banna AAA, Salama EAA, Ali MM, Al-Huqail AA, Ali HM, *et al.* The individual and combined effect of nanoparticles and biofertilizers on growth, yield and biochemical attributes of peanuts (*Arachis hypogaea* L.). *Agronomy*. 2022;12(2):398.
- Akshay KK. Synthesis and characterization of nano iron from green biomass and evaluation of its effect on aerobic rice (*Oryza sativa* L.). Bengaluru: University of Agricultural Sciences; 2021.
- Amirnia R, Bayat M, Tajbakhsh M. Effects of nano fertilizer application and maternal corm weight on flowering at some saffron (*Crocus sativus* L.) ecotypes. *Turkish Journal of Field Crops*. 2014;19(2):158-168.
- Anonymous. ANGRAU blackgram outlook report: June to May 2023-24. 2024. p. 1.
- Arora PP. Genetic divergence studies and scope for improvement in chickpea. In: National Symposium on Front Line in Pulse Research; 1989. Conference presentation.
- Ashoknarayanan S, Sundareswaran S, Raja K, Moorthy PS. Engineered zinc oxide quantum dots for enhancing seed germination and seedling vigour in blackgram (*Vigna mungo* L.). *Pharma Innovation Journal*. 2021;10(11):312-318.
- Badini SA, Baloch HN, Khan M, Baloch SU, Baloch SK, Bashir W, *et al.* Effect of phosphorus levels on growth and yield of chickpea (*Cicer arietinum* L.) varieties. *Journal of Natural Sciences Research*. 2015;5(3):1-7.
- Bhavyashree. Effect of nano-DAP on growth, yield and quality of soybean (*Glycine max* L. Merrill). Shivamogga: University of Agricultural and Horticultural Sciences; 2024.
- Chatterjee BN, Bhattacharya KK. Principles and practices of grain legumes production. New Delhi: Oxford and IBH Publishing Co.; 1986. p. 434.
- Choudhary DK, Karmakar S, Kumar B. Intercession of legume based intercropping and nano phosphorus as managerial input for upland of Jharkhand. *International Journal of Advanced Research*. 2018;6(12):1137-1143.
- El-Azizy FA, Habib AAM, Abd-El Baset AM. Effect of nano phosphorus and potassium fertilizers on productivity and mineral content of broad bean in North Sinai. *Journal of Soil Sciences and Agricultural Engineering*. 2021;12(4):239-246.
- El-Ghany MFA, El-Kherbawy MI, Abdel-Aal YA, El-Dek SI, El-Baky TA. Comparative study between traditional and nano calcium phosphate fertilizers on growth and production of snap bean (*Phaseolus vulgaris* L.) plants.

- Nanomaterials. 2021;11(11):2913.
13. Farhana, Munis MFH, Alamer KH, Althobaiti AT, Kamal A, Liaquat F, *et al.* ZnO nanoparticle-mediated seed priming induces biochemical and antioxidant changes in chickpea to alleviate fusarium wilt. *Journal of Fungi*. 2022;8(7):753.
 14. Girigoud A, Naik A, Siddaram, Bhat SN, Bellakki MA. Effect of nano-DAP on growth and yield of pigeonpea under rainfed condition. *Pharma Innovation Journal*. 2023;12(12):1536-1539.
 15. Jadhav SM, Takankhar VG, Raja D, Kumbhar CS. Influence of foliar nutrition on growth characters of blackgram (*Vigna mungo* L.) under rainfed condition. *Agriculture Update*. 2017;12(8):2015-2020.
 16. Kailas H, Rao KN, Balanagoudar S, Sharanagouda H. Effect of conventional and nano micronutrient fertilizers on yield and economics of pigeonpea (*Cajanus cajan* L. Millsp.). *International Journal of Current Microbiology and Applied Sciences*. 2017;8(9):185-193.
 17. Khemshetty A, Patil DH, Rathod PS, Patil AS, Basavaraj K. Studies on nano-DAP on growth, yield and quality of chickpeas under rainfed conditions of Northeastern Dry Zone of Karnataka. *Journal of Experimental Agriculture International*. 2024;46(3):139-145.
 18. Kumar HN, Salkinkop SR, Angadi SS. Enhancing groundnut (*Arachis hypogaea* L.) productivity through foliar nutrition. *Journal of Farm Sciences*. 2016;29(2):190-193.
 19. Lal R. Promise and limitations of soils to minimize climate change. *Journal of Soil and Water Conservation*. 2008;63(4):113-118.
 20. Mahala CPS, Dadheech RC, Kulhari RK. Effect of plant growth regulators on growth and yield of blackgram at varying levels of phosphorus. *Crop Research*. 2001;18(1):163-165.
 21. Mahil EIT, Kumar BNA. Foliar application of nano fertilizers in agricultural crops: a review. *Journal of Farm Sciences*. 2019;32(3):239-249.
 22. Manjili MJ, Bidarigh S, Amiri E. Study on effect of foliar application of nano chelate molybdenum fertilizer on yield and yield components of peanut. *Egyptian Academic Journal of Biological Sciences*. 2014;5(1):67-71.
 23. Manjunatha SB, Biradar DP, Aladakatti YR. Nanotechnology and its applications in agriculture: a review. *Journal of Farm Sciences*. 2016;29(1):1-13.
 24. Niu YF, Chai RS, Jin GL, Wang H, Tang CX, Zhang YS, *et al.* Responses of root architecture development to low phosphorus availability: a review. *Annals of Botany*. 2013;112(2):391-408.
 25. Sharifi R, Mohammadi K, Rokhzadi A. Effect of seed priming and foliar application with micronutrients on quality of forage corn (*Zea mays* L.). *Environmental and Experimental Biology*. 2016;14(6):151-156.
 26. Sachin. Effect of conventional and nano DAP on growth and yield of maize (*Zea mays* L.) [MSc thesis]. Shivamogga: University of Agricultural and Horticultural Sciences; 2023.
 27. Samui S, Sagar L, Sankar T, Manohar A, Rahul A, Sagar M, *et al.* Growth and productivity of rabi maize as influenced by foliar application of urea and nano-urea. *Crop Research*. 2022;57(3):136-140.
 28. Sarika K, Ramesh G, Srinivasulu K, Latha M. Effect of nano DAP on growth, yield attributes and yield of chickpea (*Cicer kabulium*). *International Journal of Research in Agronomy*. 2025;8(4):20-25.
 29. Yacoub NM, Ismail SA, Raslan M, Khedr MH. The effect of using nanoparticles phosphorus and zinc on quality and quantity of soybean (*Glycine max* L.). *Plant Archives*. 2020;20(2):8863-8876.