J. Soils and Crops 33 (2) 227-232, December 2023

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

Review Article

EFFECT OF NANO FERTILIZER ON PRODUCTION OF GROUNDNUT AND GREEN GRAM IN INDIA

Gaurav R. Jadav[1], J.H. Markna[2] and V.D. Bhatt[3]

As the population of India grows, the necessity for food to survive will increase. Because of this reason, agricultural fields face further and extra problems with the amount of yield and the economical condition of farmers. The appliances of engineering in agriculture and biology can facilitate the setting to retain its diversity. Groundnut is a major oilseed crop in India and green gram is the third most significant legume crop after turmeric and chickpeas. In this particular scenario, well-advanced technology and low cost of labour work are badly required. Nano fertilizers are synthesized or changed sorts of ancient fertilizers. This nano scale ancient plant food can facilitate amplifying the productivity and quality of agricultural products. Throughout this review, we have discussed the production of groundnut and green gram crops and additional choices to extend productivity by use of nano fertilizer.

Agriculture is usually a very important pillar of developing countries. It does not solely fill the individual's abdomen but collectively it is a part of the economy. The anxiety of providing food to such an enormous population of country there should be a replacement technology giving the additional yield, lowest price, and pollution of setting. Here in this review, we focused on the production of groundnut and green gram plants in Gujarat and as well as India. India is the second one in the production of groundnuts all around the world. There are mainly four oilseeds i.e. Groundnut, soybean, sunflower, and palm oil, and all these oilseeds gained importance in recent days. Groundnuts are mostly produced in the states of Karnataka, Andhra Pradesh, Tamil Nadu, Gujarat, and Maharashtra. According to agricultural and processed food product and export development authority India has exported 514,163.880 metric tons of groundnuts to the globe for the value of Rs.469,710.02 lacs throughout the year 2021-22(Anonymous,2021b). Major export destinations are Philippines, Vietnam, Malaysia, China, and Indonesia. In Gujarat, there are mainly five districts in the Saurashtra region i.e. Junagadh, Rajkot, Amreli, Bhavnagar, and Jamnagar. The soil for cropping groundnut in Gujarat is medium black.

The Green gram (*Vigna radiata* L.) is a legume cultivated for its edible seeds and sprouts across Asia. There are many common names like Jerusalem pea, celera bean, golden gram, mung bean, etc. The green gram is a vital edible legume in Asia and is also eaten in Southern Europe and the Southern USA. The mature seeds provide an invaluable source of digestible protein for human in places where meat is lacking or where people are mostly vegetarian. Green gram production is mainly situated in Asia. India is the largest producer with more than 50% of world production but consumes virtually its entire production. The crop's main advantages are that, as a legume, it does not require fertilization for nitrogen and that it has a short growth cycle (75–90 days), requires little water and fits easily into crop rotations with cereals. It grows well under most adverse arid and semiarid conditions.

To grow groundnut and green gram conventional fertilizers are declining in quantity as well as quality. If we utilize nano fertilizer for growing groundnut and green gram can it give more yield and good quality legumes.

Importance of nano fertilizer in agriculture

Nano engineering is an important field of study and research that focuses on the design and manipulation of materials at the nano scale. This field has the potential to revolutionize many industries and technologies by providing novel solutions to current challenges (Verma *et al*.,2018). In an easy method, nano fertilizer is nano scale fertilizer which implies the scale of fertilizer is one hundred nano meters or less than it at any one dimension. For comparison, a virus is roughly one hundred nano meters (nm) in size. At the nano scale physical and chemical properties square measure disagree than bulk material. Typically, conventional fertilisers are made up of macro and micronutrients that are readily soluble in water and absorbable by plants. Since many years ago, these fertilisers have been utilised extensively in agriculture, and they are frequently used in considerable quantities to boost crop productivity. Contrarily, nano fertilisers are a more recent innovation that improve plant nutrient uptake and delivery by using nanotechnology. Typically, nanoparticles used in nano fertilisers are able to penetrate plant tissues and release nutrients more effectively. Nano scale carriers are often utilized for the economical delivery of fertilizers, pesticides, herbicides, and plant growth regulators. They will anchor the plant roots to the encompassing soil structure and organic matter therefore, reducing chemical runoff and assuaging environmental issues. These can facilitate in increasing the bio convenience of active ingredients to the plant, thereby reducing the effort and waste. Nano fertilisers have a number of potential benefits over traditional fertilisers. For instance, they might be more efficient at

1. Research Student, School of Applied Science and Technology, GTU, Ahmedabad, Gujarat -382424
2. Professor, VVP Engineering Collage – Rajkot, Gujarat- 360005
3. Director and Professor, School of Applied Science and Technology, GTU, Ahmedabad, Gujarat-382424

boosting plant growth and output, decreasing fertiliser consumption and environmental pollution, and enhancing soil fertility and plant nutrition.

The appliance of nano fertilizers permits to unharness of nutrients into the soil step by step and in a very controlled method, therefore preventing eutrophication and pollution of water resources (Naderi *et al.,*2012). Nano fertilizers can improve crop yield and quality with higher nutrient use potency by reducing the price of production and therefore, contributing towards agricultural sustainability (Usman *et al.*,2020). Due to pH-dependent events, chemical reaction potential, and the availability of ligands in the soil, nano fertilisers perform better than ordinary fertilisers in terms of nutrient unharnessing and stability by aggregation or sorption without altering chemical lineage (Raliya *et al.,* 2018).

A large portion of inorganic fertilizers additional to the soiled square measure lost and become unobtainable to plants. For an example 40–70%, 80–90%, and 50–90% of nitrogen (N), phosphorus (P), and potassium (K) fertilizers square measure lost and/or mounted in soils, leading to economic losses (Ombódi and Saigusa, 2000). Nano-materials on the surface of fertilizer particles create them stronger as a result of their physical phenomenon beyond ancient fertilizer particles, increasing their potency in dominant nutrient unharness (Richard, 2016).Hence, engineering has a bigger role in crop production with environmental safety, ecological property, and economic stability. The Nano-particles made with the assistance of engineering are often exploited within the price chain of the entire agriculture production system.

There are several types of nano fertilizers that are currently being developed and studied. Here are some common types of nano fertilizers:

1. **Nano chelated fertilizers**: These fertilisers contain nano sized chelating agents that are complexed with micronutrients including iron, zinc and manganese to boost their stability and availability to plants.

2. **Nano slow-release fertilizers**: These fertilisers gradually release nutrients over a long period of time, reducing nutrient loss and increasing nutrient-use efficiency.

3. **Nano-encapsulated fertilizers**: These fertilizers consist of nano-sized capsules that contain nutrients and are designed to release them slowly over time. The encapsulation also protects the nutrients from degradation and leaching.

4. **Nano bio-fertilizers**: These fertilisers contain nano-sized particles that are covered with advantageous microorganisms, such as nitrogen-fixing bacteria, which can improve plant development and lessen the need for chemical fertilisers.

5. **Nano foliar fertilizers**: These fertilisers are made to be sprayed directly into plant leaves, where they can be promptly and effectively absorbed. They are frequently used to supply micronutrients like iron, zinc, and manganese to plants.

Nano fertilizers have unique properties that make them potentially useful for improving plant growth and reducing environmental pollution. Here are some of the key properties of nano fertilizers:

1. Nano-sized particles will even tolerate the plasma membrane in plants and animals.

2. Water solubility

3. Nanotechnologists use this method to deliver at the cellular level which is simpler than the traditional methodology.

4. High surface energy

Groundnut (*Arachis hypogaea* L.) production in India

Groundnut is the main oilseed crop of the Republic of India conjointly a vital economically and export artifact. As per Indian environmental conditions, groundnut is cultivated in one or additional seasons (*Kharif, rabi,* and summer). The foremost annual land area and production comes from the *kharif* crop (June-October). India is heavily passionate about imports to fulfill its edible oil necessities and is the largest business person of vegetable oils within the world followed by China and the USA. Of all the foreign edible oils, the share of palm oil is concerning 60% followed by vegetable oil with a share of 25%, and helianthus at 12%. Import growth in respect of edible oils throughout the last decades is concerning 174%. According to the import data for edible oils for the period 2019–20, the Republic of India imported 303.5 lakh tonnes of vegetable oils totaling Rs.61,559,0 million. Domestic production of various edible oils is given in Table 1.

Table 1. Domestic production of edible oils (2021-2022)

Crop	Production (MT)
Mustards	36,44,000
Soybean	20,82,000
Groundnut	22,92,000
Sunflower	84000
Sesame	2,38,000
Niger seed	10,000
Castor	5,66,000

(Anonymous,2023)

Nine oilseeds are the main supply of oil within the country. Among 9 major oilseeds, soybean, groundnut and mustard contribute to over ninetieth of total oilseeds production within the country.

Gujarat is the top state for groundnut cropping, according to the Indian Oilseeds and Turnout Export Promotion Council. In Gujarat, 9 districts are growing groundnut i.e. Rajkot, Junagadh, Dwarka, Amreli, Jamnagar, Gir Somnath, Banaskantha, Bhavnagar, Kutch. Nano fertilizer is promising and most effective technology to increase availability of nutrients for plants. In Table 2 there are important results of nano fertilizer on groundnut crop with different concentrations of nanoparticles.

Table 2 . Effect of different nano fertilizers on groundnut

Nano material	Type	Concentration Range	Impacts on crop	References
Nano-Sulphur (S)	Soil	10 to 40 kg ha^{-1}	Increased soil sulphur availability	(Thirunavukkarasu\ *et al.,*2018)
Iron oxide (Fe_2O_3), Copper oxide (CuO), and Titanium oxide (TiO_2) NPs)	Soil	50 and 500 mg kg^{-1}	Alter the peanut crop yield and amino acid content	(Rui *et al.*,2018)
Zinc (Zn) and Calcium (Ca) Nano-chelates	Foliar	2 and 1.5 g l^{-1}	Increased oleic acid content in oil and yield	(Nobahar *et al.,* 2019)
Nano calcium (Ca^{2+})	Soil	100, 75, 50, 25, and 12.5% of $Ca(NO_3)_2$	Nano $Ca(NO_3)_2$ had the lowest effect on seed yield , protein yield and oil yield	(Hamza *et al.*, 2021) *et al.*, 2021)
Nano Zinc, Calcium, and Silica	Foliar	50 to 2000 ppm	Increased leaf area, total dry matter and pod yield	,
Boron (B) and Calcium (Ca)	Foliar	200 ppm	Yield, growth, and seed biochemical composition significantly improved	(Abdelghany *et al.,* 2022)
Nano Zinc (Zn)	Foliar	0, 50, and 100 mg l^{-1}	Enhanced vegetative growth, photosynthesis, and thus, leading to an enhanced pod yield and improvement in peanut quality	(Al-yasari and Mi-yasari, 2022)
Nano Fe_3O_4	Foliar	20 mg l^{-1}	Enhanced the solubility of peanuts *a* shells to improve the biogas and methane yields	(Olatunji *et al*., 2022)

Green gram (*Vigna radiate* L.) production in India

Green gram is a nice supply of prime quality super molecule. In Saurashtra and North Gujarat, green gram has been grown. South Gujarat is where the black mug is grown. As a single crop or intercrop, green gram is a suitable bean crop. As a short-term crop, it is essential in the closed cropping system. The most popular crop in the practical cropping system is the green gram crop, provided there is an adequate irrigation infrastructure. As per the Indian surroundings conditions green gram crop is cultivated in 3 completely different seasons *kharif, rabi* and summer.

Due to a number of causes, including the introduction of new crop types, increasing use of fertilisers and pesticides, and better agricultural techniques, the production of green gram in India has greatly increased over time. In addition, the government has been encouraging farmers to grow pulses, such as green gram, by offering them subsidies and other incentives. Since that it can be grown on insufficient acreage and offers a reliable source of revenue, green gram is a crucial crop for small and marginal farmers. The populace, especially vegetarians, rely on the crop as a source of protein.

Here are some of the reasons why green gram is important

Nutritional value: A good source of protein, vitamins, and minerals is green gram. It is a healthful dietary option because it is also low in fat and high in fibre.

Health benefits: Many health advantages of green gram have been linked to it, including better digestion, a decrease in inflammation, and control of blood sugar.

Crop diversification: Since that it can be farmed on insufficient lands and offers a reliable source of income, green gram is a crucial crop for smallholder farmers. Moreover, it is a helpful crop for crop rotation and diversification, enhancing soil health and lowering the pressure from pests and diseases.

Cultural significance: Green gram is an important food in many cultures and cuisines, and is often used in dishes such as soups, salads, and curries.

Environmental sustainability: Green gram is a legume crop that can fix atmospheric nitrogen, which lessens the need for nitrogen fertilisers and improves the health of the soil and the environment.

Green gram is made in the super molecule (20-30% DM) and starch (>45%DM) with a coffee lipide content (less than a pair of DM), and variable however typically amounts of fiber (crude fiber 5% DM). The by-product of the leguminous plant alimentary paste process contains 11-23% crude super molecule, 0.4-1.8% ether extract, 13-36% crude fiber, 0.30-0.68% calcium, and zero.17-0.39% phosphorus counting on the leguminous plant material. Green grams contain many anti-nutritional factors (trypsin inhibitors, chymotrypsin substance, tannins, and lectins). India is the major producer of green gram within the world. It is cultivated on 4.5 million hectares with the production of 2.5 million tonnes and productivity of 548 kg ha^{-1} and contributing 10% of pulse production (Anonymous,2021a). The following are some significant outcomes of nano particles on green gram (Table 3).

Table 3. Effect of different nanofetilizers on green gram

Nano material	Type	Concentration Range	Impacts	References
Copper(Cu)	Foliar	0 to 1000 mg l^{-1}	Bioaccumulation and copper availability increased with the treatment of NPs	(Lee *et al*., 2008)
$Pb(NO3)_2$ NPs	Soil	50 ppm to 120 ppm	Increased length and fresh weight of stem and fall in the total content of phenols	(Saeideh and Rashid, 2014)
Fe - EDDHA	Soil	10 to 250 ppm	The greatest shoot dry weight, shoot fresh weight were founded in nano iron chelate	(Torbat, 2014)
TiO_2 NPs	Foliar	10 mg l^{-1}	Significantly increased shoot length , root length, root area , root nodule,chlorophyll content and total soluble leaf protein	(Raliya *et al.,* 2015)
Nano TiO_2-activated carbon composite	Water	0 to 500 mg l^{-1}	Promoted the seed germination and also reduced the germination time	(Singh *et al.,*2016)
Boron (B)	Foliar	0,90,180 ml l^{-1}	Length of the plant (cm), number of pods (pods $plant^{-1}$), number of seeds (seed pod^{-1}),total yield (t ha^{-1}) get significant positive effect of nano treated plant	(Ibrahim and Farttoosi, 2019)
ZnO and MgO NPs	Soil	5 mg	Increased seed germination by nano Zn and Mg treated pods	(Rani *et al.,* 2020)
Super paramagnetic Fe NPs	Foliar	1 µ $ml^{-1}$and 10 µ ml^{-1}	Increased length of root and shoot at lower concentrations	(Samrot *et al.,* 2020)
MgO NPs	Water	100 mg l^{-1}	Improved seed germination and seedling vigour	(Vijai Anand *et al.,* 2020)
ZnO NPs	Foliar	20 mg l^{-1}	Improved yield and quality with higher protein	(Sahoo *et al.,* 2021)
Nano Fe	Soil	0, 1, 2 g l^{-1} or 0,0.05 or 0.10 mol	Significantly increase in plant height (cm), No. of leaves $plant^{-1}$, shoot DW (mg $plant^{-1}$)	(Hussein, 2022)
Magnesium (Mg)	Foliar	25 µg ml^{-1} to 100 µg ml^{-1}	Strong antifungal activity was found against the mung bean	(Abdallah *et al.,* 2022)
ZnO NPs	Foliar	100 to 1200 ppm	Enhanced the seed germination ,seedling growth, dry weight	(Modi *et al.,* 2022)
CuO NPs	Soil	0 to 500 mg l^{-1}	High concentrations of nanoparticles gave negatory effect on plant	(Kavitha *et al.,* 2022)

Nano Urea	Water sprayed	4 ml l^{-1}	Positive impact on yield, fertility co-efficient (%), number of pods $plant^{-1}$ and number of seeds pod^{-1}	(Saitheja *et al.,* 2022)
nZnS and nZnO	Soil	0, 0.01, 0.1, 1 and 10 mg kg^{-1}	Zn availability for plant and increased fruit Zn content	(Thapa *et al.* ,2023)
$nCeO_2$ + nSe	Soil	25 to 250 mg l^{-1}	Significantly increased pod number, grain weight, seed number, yield, Zn, Fe and Se storage in grains	(Kamali *et al.,* 2023)

From above information, it is stated that groundnut and green gram productivity and quality can be enhanced by use of nano fertilizer.Micronutrient fertilisers, commonly referred to as microfertilizers, are composed of vital trace elements like zinc, copper, and boron. For healthy plant growth, these micronutrients must be present in minute quantities, but their overuse can have negative environmental effects. Micro fertilisers can accumulate in the environment and cause issues like eutrophication, which is an overabundance of nutrients in water bodies that can promote the growth of harmful algae and other aquatic plants.Fertilizers that comprise nitrogen, phosphorus, and potassium are known as macronutrient fertilisers because these elements are needed in greater quantities than micronutrients. These nutrients can also pollute the environment if they are used in excess. In water bodies, too much nitrogen can result in eutrophication, whereas too much phosphorus can promote the development of hazardous algae blooms. When these undesirable algae blooms decay and die, they deplete the water's oxygen supply.Therefore, it is important to use fertilizers in moderation and follow proper application techniques to avoid pollution. Additionally, alternatives to chemical fertilizers, such as nano fertilizer can be used to reduce the risk of pollution.

The prodigious applications of applied science within the field of agriculture are sure as shoot making hope for a higher future. Their higher effectualness, improved productivity, lower input usage, least value, and low environmental pollution may ultimately facilitate the farmers to beat these day issues. To extend yield with lesser quantity of losing fertilizers and manpower in seed and legumes nano fertilizers are a very important resolution.

REFERENCES

Abdallah, Y., M. Hussien, M. O. Omar, R. M. Elashmony, D. H. M. Alkhalifah and W. N. Hozzein, 2022. Mung bean (*Vigna radiata* L.) treated with magnesium nanoparticles and its impact on soilborne *Fusarium solani* and *Fusarium oxysporum* in clay soil. Plants **11**: 1514.

Abdelghany, A. M., A. A. El-Banna, E. A. Salama, M. M. Ali, A. A. Al-Huqail, H. M. Ali, L. S. Paszt, G. A. El-Sorady and S. F. Lamlom, 2022. The individual and combined effect of nanoparticles and biofertilizers on growth, yield, and biochemical attributes of peanuts (*Arachis hypogea* L.). Agron.**12**: 398.

Al-yasari, B. and M. Mi-yasari, 2022. Response of peanut to weed control management and nano-zinc foliar application in growth, yield, and quality traits. SABRAO J. Breed. Genet.**54**(5): 1191-1201.

Anonymous, 2021a.Green Gram Annual Report from https://angrau.ac.in/

Anonymous,2021b.Exports from india of groundnut from DGCIS annual report https://apeda.gov.in/apedawebsite/

Anonymous, 2023. Annual report- 2023 from department of food and public distribution (Ministry of Consumer Affairs, Food & Public Distribution) government of india https://dfpd.gov.in/E.

Hamza, M., M. Abbas, A. Abd Elrahman, M. Helal and M. Shahba, 2021. Conventional versus nano calcium forms on peanut production under sandy soil conditions. Agric.**11**:767.

Hussein, H. A.2022. Impact of Nano and Non-Nano Iron on Growth and Nutritional Content of Mung Bean (*Vigna radiata* L.).Academia,**1060 :** 012029.

Ibrahim, N. K. and H. A. K. Al Farttoosi, 2019. Response of mung bean to boron nanoparticles and spraying stages (*Vigna radiata* L.). Plant Arch.**19**: 712-715.

Kamali-Andani, N., S. Fallah, J. R. Peralta-Videa and P. Golkar, 2023. Selenium nanoparticles reduce Ce accumulation in grains and ameliorate yield attributes in mung bean (*Vigna radiata* L.) exposed to CeO_2. Environ. Pollut.**316** :120638.

Kavitha, K., J. Arockia John Paul, P. Kumar, J. Archana, H. Faritha Begam, N. Karmegam and M. Biruntha, 2022. Impact of biosynthesized CuO nanoparticles on seed germination and cyto-physiological responses of *Trigonella foenum-graecum* and *Vigna radiata*. Mater. Lett.**313**:131756.

Lee, W. M., Y. J. An, H. Yoon and H. S. Kweon, 2008. Toxicity and bioavailability of copper nanoparticles to the terrestrial plants mung bean (*Phaseolus radiatus*) and wheat (*Triticum aestivum*): plant agar test for water insoluble nanoparticles. Environ. Toxicol. Chem.**27** : 1915-1921.

Modi, S., V. K. Yadav, N. Choudhary, A. M. Alswieleh, A. K. Sharma, A. K. Bhardwaj, S. H. Khan, K. K. Yadav, J.K. Cheon and B.H. Jeon, 2022. Onion peel waste mediated-green synthesis of zinc oxide nanoparticles and their phytotoxicity on mung bean and wheat plant growth. Materials **15**: 2393.

Naderi, M. Hikal, R. Baeshen, A. Hussin, A. Bratovcic, H. Sany, K. Tkachenko, S. Sabra, S. Ahl, 2012. Application of Nanotechnology in Agriculture and Refinement of Environmental Pollutants. J. Nanotechnol.**11**: 18-26.

Nobahar, A., H. R. Zakerin, M. Mostafavi Rad, S. Sayfzadeh and A. R. Valadabady, 2019. Response of yield and some physiological traits of groundnut (*Arachis hypogaea* L.) to topping height and application methods of Zn and Ca nano-chelates. Commun. Soil Sci. Plant Anal.**50**: 749-762.

Olatunji, K. O., D. M. Madyira, N. A. Ahmed and O. Ogunkunle, 2022.Effect of combined particle size reduction and Fe3O4 additives on biogas and methane yields of Arachis hypogea shells at mesophilic temperature. Energies,**15**: 3983.

Ombódi, A. and M. Saigusa, 2000. Broadcast application versus band application of polyolefin coated fertilizer on green peppers grown on andisol. J. Plant Nutr.**23**: 1485-1493.

Prasad, T. N. V. K. V., A. N. Kumar, M. Swethasree, M. Saritha, G. Satisha, P. Sudhakar, B. R. Reddy, B. P. Girish, N. Sabitha and B. V. B. Reddy, 2022. Combined Effect of Nanoscale Nutrients (Zinc, Calcium, and Silica) on Growth and Yield of Groundnut (*Arachis hypogaea* L.). Lett. Appl. Nano Bio. Sci. **12**(3):84

Raliya, R., P. Biswas and J. Tarafdar, 2015. TiO_2 nanoparticle biosynthesis and its physiological effect on mung bean (*Vigna radiata* L.). Biotechnol. Rep.**5**:22-26.

Raliya, R., V. Saharan, C. Dimkpa and P. Biswas, 2018. Nanofertilizer for Precision and Sustainable Agriculture: Current State and Future Perspectives.J. agric. Food Chem.**66**: 6487-6503.

Rani, P., G. Kaur, K. V. Rao, J. Singh and M. Rawat, 2020. Impact of Green Synthesized Metal Oxide Nanoparticles on Seed Germination and Seedling Growth of *Vigna radiata* (Mung Bean) and *Cajanus cajan* (Red Gram). J. Inorg Organomet. Polym. Mater.**30**: 4053-4062.

Richard ,C. John, E. S. N., Alfred Y. Itah, 2016. Impact of crude oil on soil nitrogen dynamics and uptake by legumes grown in wetland ultisol of the niger delta, Nigeria. J. Environ. Prot.**7**: 739-740.

Rui, M., C. Ma, J. C. White, Y. Hao, Y. Wang, X. Tang, J. Yang, F. Jiang, A. Ali, Y. Rui, W. Cao, G. Chen and B. Xing, 2018. Metal oxide nanoparticles alter peanut (*Arachis hypogaea* L.) physiological response and reduce nutritional quality: a life cycle study. Environ. Sci. Nano.**5**: 2088-2102.

Saeideh, N. and J. Rashid, 2014. Effect of silver nanoparticles and $Pb(NO_3)_2$ on the yield and chemical composition of mung bean (*Vigna radiata).* J.Stress Physiol. Biochem.**10**: 316-325.

Sahoo, S. K., G. K. Dwivedi, P. Dey and S. Praharaj, 2021. Green synthesized ZnO nanoparticles for sustainable production and nutritional biofortification of green gram. Environ. Technol. Innov.**24**: 101957.

Saitheja, V., M. Senthivelu, G. Prabukumar and V. B. R. Prasad, 2022. Maximizing the productivity and profitability of summer Irrigated greengram (*Vigna radiata* L.) by combining basal nitrogen dose and foliar nutrition of nano and normal urea. Int. J. Plant Soil Sci.**34**:109-116.

Samrot, A. V., C. SaiPriya, J. Selvarani, J. C. PJ, Y. Lavanya, P. Soundarya, S. P. RB, P. Sangeetha and R. J. Varghese, 2020. A study on influence of superparamagnetic iron oxide nanoparticles (SPIONs) on green gram (*Vigna radiata* L.) and earthworm (*Eudrilus eugeniae* L.). MRX**7**: 055002.

Singh, P., R. Singh, A. Borthakur, P. Srivastava, N. Srivastava, D. Tiwary and P. K. Mishra, 2016. Effect of nanoscale TiO_2-activated carbon composite on *Solanum lycopersicum* (L.) and *Vigna radiata* (L.) seeds germination. Energy Ecol. Environ.**1**: 131-140.

Thapa, M., R. Sadhukhan, A. Mukherjee and P. K. Biswas, 2023. Effects of nZnS vs. nZnO and $ZnCl_2$ on mungbean [*Vigna radiata* (L.) R. Wilczek] plant and Bradyrhizobium symbiosis: A life cycle study. NanoImpact,**29**: 100440.

Thirunavukkarasu, M., K. Subramanian, P. Kannan and T. Balaji, 2018. Response of nano-sulphur to the groundnut. Int. J. Commun. Syst.**6**: 2067-2072.

Torbat Heydarieh, I., 2014. Comparison effect of nano-iron chelate and iron chelate on growth parameters and antioxidant enzymes activity of mung bean (*Vigna radiate* L.). Adv. Environ. Biol. **8**: 916-930.

Usman, M., M. Farooq, A. Wakeel, A. Nawaz, S. A. Cheema, H. u. Rehman, I. Ashraf and M. Sanaullah, 2020. Nanotechnology in agriculture: Current status, challenges and future opportunities. Sci. Total Environ. **721**: 137778.

Verma, S. K., A. K. Das, M. K. Patel, A. Shah, V. Kumar and S. Gantait, 2018. Engineered nanomaterials for plant growth and development: A perspective analysis. Sci. Total Environ.**630**: 1413-1435.

Vijai Anand, K., A. R. Anugraga, M. Kannan, G. Singaravelu and K. Govindaraju, 2020. Bio-engineered magnesium oxide nanoparticles as nano-priming agent for enhancing seed germination and seedling vigour of green gram (*Vigna radiata* L.). Mater. Lett.**271**: 127792.

Rec. on 23.02.2023 & Acc. on 20.03.2023