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Market Research and Adoption Dynamics of Nano Fertilizers in India: Opportunities, Challenges, and Policy Insights

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Abstract

Nano fertilizers represent a transformative innovation in sustainable agriculture by enhancing nutrient use efficiency and minimizing environmental degradation. In the Indian context—where agriculture sustains a large portion of the population—the adoption of nano fertilizers such as Nano Urea and Nano DAP is gaining strategic importance. This study presents a comprehensive market research analysis of nano fertilizers in India, focusing on market dynamics, farmer awareness, regulatory frameworks, and future growth prospects. A mixed-method approach involving desk research, field surveys, and stakeholder interviews was employed. The findings indicate that while the market is expanding due to strong policy support and technological advancement, adoption remains limited due to awareness gaps, infrastructural constraints, and skepticism among farmers. The study highlights the need for targeted interventions such as field demonstrations, policy reinforcement, and improved distribution mechanisms. Nano fertilizers have significant potential to revolutionize Indian agriculture by promoting sustainability, improving productivity, and reducing dependency on conventional fertilizers.

Keywords

Nano Fertilizers, Nano Urea, Nano DAP, Sustainable Agriculture, Market Analysis, Farmer Adoption, India

Introduction

The transformation of Indian agriculture toward sustainability and efficiency has intensified the search for innovative input technologies capable of enhancing productivity while minimizing environmental externalities. Fertilizers continue to play a pivotal role in sustaining crop yields; however, their inefficient utilization has emerged as a major constraint. Conventional fertilizers exhibit low nutrient use efficiency (NUE), with nitrogen efficiency ranging between 30–35%, phosphorus 18–20%, and potassium 35–40%, resulting in substantial nutrient losses through leaching, volatilization, and runoff. These inefficiencies not only increase production costs and subsidy burdens but also contribute to soil degradation, water contamination, and greenhouse gas emissions (Subramanian & Tarafdar, 2011).

In this context, nanotechnology-based fertilizers have emerged as a promising solution to address both productivity and sustainability challenges. Nano fertilizers, engineered at the nanoscale (1–100 nm), possess unique physicochemical properties such as a high surface area-to-volume ratio and enhanced reactivity, enabling controlled nutrient release and targeted delivery within plant systems. These features significantly improve nutrient uptake efficiency and reduce environmental losses, positioning nano fertilizers as "smart nutrient systems" for modern agriculture.

India has taken a pioneering role in the development and commercialization of nano fertilizers. The introduction of nano fertilizers in 2021 marked a significant milestone in the country's efforts to enhance fertilizer efficiency, reduce dependency on imports, and rationalize subsidy expenditure. Among these innovations, Nano Urea (liquid), developed by the Indian Farmers Fertiliser Cooperative Limited (IFFCO), has gained considerable attention as the world's first commercially approved nitrogenous nano fertilizer. The product is positioned as a high-efficiency alternative to conventional urea, with claims of significantly higher NUE and reduced environmental impact. Its introduction aligns with national priorities of improving input efficiency and promoting sustainable agriculture (Subramanian et al., 2025).

The market for nano fertilizers in India is evolving rapidly, driven by policy support, institutional backing, and increasing private sector participation. The government has established a robust regulatory framework through the "DBT Guidelines for the Evaluation of Nano-based Agri Inputs and Food Products" (2020), which provides a comprehensive protocol for risk assessment, biosafety evaluation, and product validation. These guidelines encompass multi-tier testing across ecological and biological systems, including soil microbes, plants, and human health, ensuring that nano fertilizers meet stringent safety standards before commercialization. Furthermore, the inclusion of nano fertilizers under the Fertilizer Control Order (FCO) has facilitated their formal entry into the market, supported by defined quality parameters such as particle size, zeta potential, pH, viscosity, and nutrient concentration (Subramanian et al., 2025).

From a market research perspective, the nano fertilizer sector in India is characterized by a concentrated manufacturing base and an extensive distribution network. IFFCO remains the dominant player, supported by collaborations with public sector enterprises such as National Fertilizers Limited (NFL) and Rashtriya Chemicals and Fertilizers Limited (RCFL). The distribution system leverages India's cooperative structure, including Primary Agricultural Cooperative Societies (PACS), farmer service centers, and agri-input dealers, complemented by emerging digital platforms. This hybrid distribution model plays a critical role in shaping adoption dynamics, particularly in rural areas where access to information and advisory services is limited.

Despite the promising market expansion, the adoption of nano fertilizers among farmers is influenced by a complex interplay of economic, technical, and behavioral factors. Empirical studies suggest that perceived economic benefits, such as cost reduction and input efficiency, act as primary drivers of adoption, while ease of application and storage further enhance acceptance. However, adoption is

constrained by factors such as lack of awareness, limited technical knowledge, and trust deficits regarding product efficacy. Farmers often rely heavily on dealers and informal networks for information, highlighting the importance of extension systems in facilitating technology diffusion.

From a global perspective, the nano-based agricultural input market is witnessing significant growth. The nanobiostimulants sector, closely related to nano fertilizers, is projected to reach USD 9.51 billion by 2029, with a compound annual growth rate (CAGR) exceeding 11%. In India, although the market is still in its nascent stage, it is expanding steadily, driven by technological advancements, policy incentives, and increasing awareness among farmers (Mishra, 2024). However, commercialization challenges such as regulatory complexities, production scalability, and limited farmer education continue to hinder widespread adoption.

By integrating insights from market research, adoption theory, and policy analysis, this study contributes to a deeper understanding of the opportunities and challenges associated with nano fertilizers, offering actionable recommendations for stakeholders to promote sustainable agricultural transformation in India.

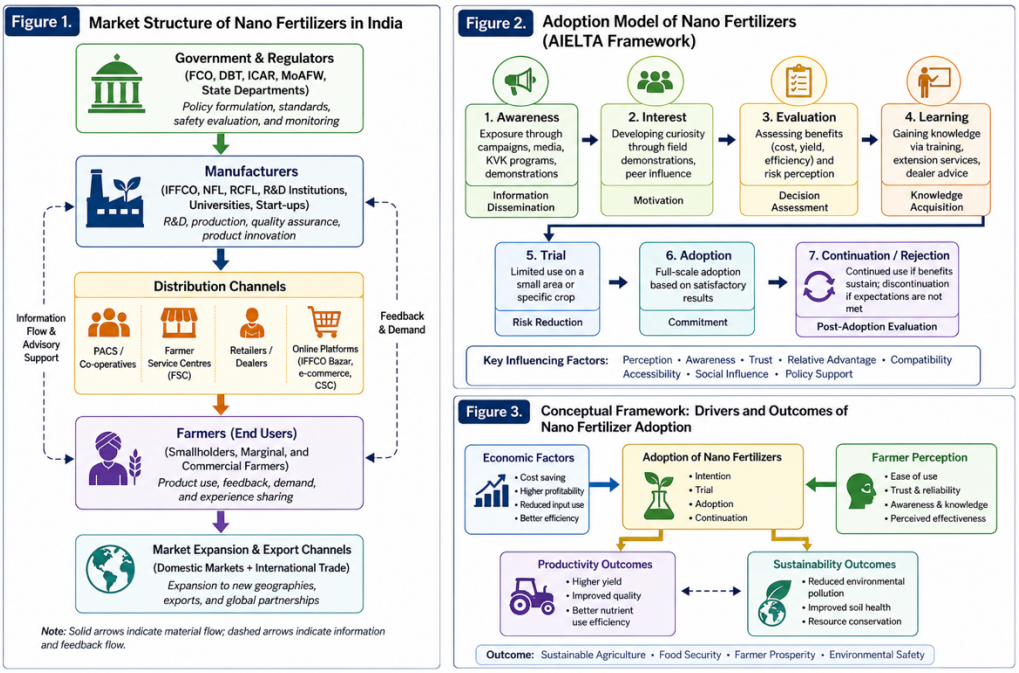
Objectives of the Study

- To analyze the market size and growth trends of nano fertilizers in India
- To identify key manufacturers and distribution channels
- To assess farmer awareness, adoption, and perception
- To evaluate regulatory and policy frameworks
- To propose strategies for enhancing adoption and commercialization

Methodology

This study employs a mixed-method approach:

- Desk Research: Review of government reports, market studies, and scientific literature
- Field Survey: Structured questionnaires to assess farmer awareness and usage
- Key Informant Interviews: Discussions with dealers and industry stakeholders
- Data Analysis: Descriptive statistics and thematic qualitative analysis
- Validation: Cross-verification with official data sources



Market Structure: Manufacturers and Distribution Channels

The nano fertilizer market in India is currently dominated by a limited number of players, with IFFCO being the pioneer and largest producer of nano urea. The establishment of production facilities, such as the Kalol plant, with a capacity of 1.5 lakh bottles per day, demonstrates the rapid scaling of manufacturing capabilities.

Collaborations and technology transfer agreements with organizations such as National Fertilizers Limited (NFL) and Rashtriya Chemicals and Fertilizers Limited (RCFL) further indicate the expansion of production capacity and market reach. Additionally, international collaborations with agricultural cooperatives in countries

like Argentina and Brazil highlight the global potential of Indian nano fertilizer technology.

Beyond IFFCO, research institutions and universities, including the Tamil Nadu Agricultural University, have contributed to the development of nano fertilizer formulations, indicating a growing ecosystem of innovation in this domain.

Distribution Channels

The distribution network for nano fertilizers in India is characterized by a multi-tiered system involving:

- Primary Agricultural Cooperative Societies (PACS)
- Farmer Service Centres (FSCs)
- Retail outlets and agri-input dealers
- Digital platforms such as e-commerce portals

IFFCO's extensive cooperative network, comprising over 36,000 PACS and thousands of retail outlets, has played a critical role in ensuring widespread availability. Additionally, digital platforms have enabled distribution across thousands of postal regions, reflecting the increasing role of e-commerce in agricultural input delivery.

Empirical evidence indicates that dealers play a dominant role in influencing farmers' purchasing decisions, highlighting the importance of last-mile distribution and advisory services in shaping adoption behavior.

Adoption Dynamics of Nano Fertilizers

Drivers of Adoption

The adoption of nano fertilizers is primarily driven by:

i. Economic benefits: Reduced cost of cultivation due to lower application rates

ii. Operational convenience: Ease of handling, storage, and application

iii. Efficiency gains: Higher nutrient use efficiency (up to 80%)

iv. Environmental benefits: Reduced nutrient losses and pollution

Nano fertilizers act as "smart nutrient systems," enabling precise nutrient delivery and improving crop productivity while minimizing environmental impacts.

Field studies have demonstrated that nano urea can replace a portion of conventional urea, with one 500 ml bottle potentially substituting a 45 kg bag under optimal conditions. This has significant implications for reducing input costs and improving resource efficiency.

Constraints to Adoption

Despite the advantages, several barriers hinder widespread adoption:

i. Lack of awareness and technical knowledge
ii. Trust deficit among farmers
iii. Variability in crop-specific performance
iv. Dependence on informal advisory systems (dealers)

Studies indicate that farmers often lack clarity regarding dosage, application methods, and compatibility with existing practices. Moreover, skepticism persists regarding the ability of nano fertilizers to fully replace conventional fertilizers.

Technical Overview of Nano Fertilizers

Nano Urea Liquid (NUL)

Nano Urea is an aqueous solution containing 4% nitrogen, with particle sizes ranging between 20–50 nm. Its high surface area enhances foliar absorption efficiency (above 80%), allowing reduced application compared to conventional urea.

Nano DAP Liquid

Nano DAP contains 2% nitrogen and 5% phosphorus (P_2O_5), designed for foliar spray and seed treatment. Its nanoscale structure ensures rapid absorption and improved nutrient utilization.

Mechanism of Action

Nano fertilizers function through:

- Controlled nutrient release
- Enhanced surface interaction
- Improved plant uptake efficiency
- Reduced environmental losses

Market Analysis

The Indian nano fertilizer market was valued at approximately ₹950 crore in 2024, with a projected CAGR exceeding 12%. Growth is driven by:

- Government initiatives promoting sustainable inputs
- Increasing environmental awareness
- Rising fertilizer costs

Key Players

- Indian Farmers Fertilizer Cooperative (IFFCO)
- Coromandel International Limited
- Zuari Farm Hub Limited

IFFCO dominates the market with its Nano Urea product.

Distribution Channels

- Cooperative societies
- Retail fertilizer dealers
- Government-supported agricultural networks

Regulatory and Policy Framework

National Policy Environment

The Government of India has recognized nanotechnology as a strategic priority for agricultural development. Policy initiatives include:

i. Inclusion of nano fertilizers under the Fertilizer Control Order (FCO), 1985
ii. Development of guidelines for nano-based agri-inputs by the Department of Biotechnology
iii. Promotion of research and development through national programs

Institutional Support and Research Initiatives

Government institutions, including ICAR and State Agricultural Universities, play a vital role in conducting field trials, developing application protocols, and disseminating knowledge.

i. Policy recommendations have also emphasized the need for:
ii. Establishing dedicated research institutions for nanotechnology in agriculture
iii. Promoting interdisciplinary collaboration
iv. Integrating nanotechnology into agricultural education and extension systems
v. Initiatives like PM-PRANAM promote balanced fertilizer use and encourage adoption of alternatives like nano fertilizers.

Challenges in Regulatory Framework

Despite progress, several regulatory challenges remain:

i. Lack of long-term environmental impact assessments
ii. Limited clarity on standardization and quality control
iii. Need for comprehensive risk assessment frameworks

Results and Discussion

Table: Perception of Indian Farmers towards Nano Urea (N = 120)

Sl. No.	Particulars	Categories	No. of Respondents	Percentage (%)
1	Adoption of Nano Urea	Yes	104	86.66
		No	16	13.33
2	Reasons for Non-adoption	Lack of awareness/knowledge	36	30.00
		Lack of trust (credibility issue)	50	41.66
		Complexity in use/application	9	7.50
		Others	25	20.84
3	Expectation from Nano Urea	Better yield/performance	76	63.33
		Cost saving	22	18.33
		Higher profitability	18	15.00
		No expectation	4	3.33
4	Cost Saving Compared to Conventional Urea	Less than ₹500	0	0.00
		Rs. 500– Rs. 1000	104	100.00
		Above Rs. 1000	0	0.00
5	Source of Recommendation	Dealers	99	82.50
		Own experience	14	11.66
		Fellow farmers	9	7.50
		Extension agencies (KVK/SAU)	10	8.33
6	Willingness to Repurchase	Yes	60	57.69
		No	44	42.30
7	Preferred Attributes of Nano Urea	Price	9	7.50
		Packaging	2	1.66
		Product information	5	4.16
		Application method	3	2.50
		All attributes	114	95.00
8	Level of Satisfaction	Satisfied	93	89.42
		Not satisfied	11	10.57

Table: Perception Index of Indian Farmers towards Nano Urea

Sl. No.	Statements	SA	A	N	D	SD	Total Score	Mean Score	Rank
1	Nano urea reduces cost of cultivation	70	28	12	6	4	434	3.62	II
2	Nano urea increases crop yield	62	30	10	12	6	410	3.42	IV
3	Nano urea is easy to apply and handle	80	25	8	5	2	456	3.80	I
4	Nano urea is environmentally safe	65	32	10	8	5	424	3.53	III
5	Nano urea can replace conventional urea	40	35	18	15	12	336	2.80	VI
6	Nano urea improves nutrient use efficiency	58	34	12	10	6	398	3.32	V
7	Information about nano urea is adequate	30	28	20	25	17	289	2.41	VII

NB: Strongly Agree (SA) = 5, Agree (A) = 4, Neutral (N) = 3, Disagree (D) = 2, Strongly Disagree (SD) = 1

The present study examined the perception of Indian farmers towards nano urea using both descriptive statistics and a Likert-scale–based perception index. The findings provide insights into adoption behaviour, perceived benefits, constraints, and the role of institutional support in shaping farmers' attitudes toward this emerging nano-fertilizer.

Adoption and Awareness of Nano Urea

The results indicate that a substantial majority of farmers (86.66%) have adopted nano urea, reflecting a high level of diffusion of this innovation among the farming community. This suggests that nano urea has moved beyond the awareness stage into early adoption, driven by its perceived advantages and promotional efforts. Similar findings were reported by Vishakha et al. (2023), where farmers in Maharashtra exhibited high awareness and considerable adoption levels of nano urea.

However, non-adoption (13.33%) persists due to factors such as lack of trust (41.66%), inadequate knowledge (30%), and complexity in application. These findings highlight that adoption is not solely determined by availability but is strongly influenced by farmers' perceptions and confidence in the technology. Studies on agricultural innovations emphasize that perception and knowledge are critical determinants of adoption decisions (Mwangi & Kariuki, 2015; El-Shafie et al., 2024).

Economic Perception: Cost Reduction and Profitability

Economic considerations emerged as a major driver of positive perception. All respondents who adopted nano urea reported cost savings in the range of Rs. 500– Rs. 1000 compared to conventional urea. Correspondingly, the Likert-scale analysis shows a high mean score for the statement "nano urea reduces cost of cultivation" (Mean = 3.62, Rank II).

This aligns with earlier studies indicating that nano-fertilizers improve nutrient use efficiency and reduce input costs, thereby lowering the cost of cultivation (Subramanian et al., 2015; Vijayakumar et al., 2022).

However, the perception of yield improvement (Mean = 3.42) and profitability (15%) was comparatively moderate. This suggests that farmers differentiate between cost-saving benefits and yield enhancement, with the latter being less certain and often dependent on crop type and management practices. Vishakha et al. (2023) similarly reported that nano urea performed better in crops like vegetables and maize but showed inconsistent results in paddy cultivation.

Technical Perception: Ease of Use and Efficiency

The highest-ranked perception statement was "nano urea is easy to apply and handle" (Mean = 3.80, Rank I), indicating that operational convenience plays a crucial role in farmers' acceptance. The small packaging size, ease of spraying, and reduced storage

requirements contribute to this positive perception. The perception that nano urea improves nutrient use efficiency (Mean = 3.32) reflects moderate technical awareness among farmers. Scientific evidence supports this view, as nano-fertilizers function as controlled-release systems that enhance nutrient absorption and minimize losses (Periakaruppan et al., 2023). Despite these advantages, the relatively low mean score for "nano urea can replace conventional urea" (Mean = 2.80, Rank VI) indicates that farmers do not perceive it as a complete substitute. Instead, it is often used as a supplementary input, which is consistent with empirical findings from field-level studies (Vishakha et al., 2023).

Environmental Perception and Sustainability

Farmers expressed a favorable perception of the environmental safety of nano urea (Mean = 3.53, Rank III). This reflects increasing awareness regarding sustainable agricultural practices and the environmental consequences of excessive chemical fertilizer use. Previous research has shown that nano-fertilizers reduce nitrogen losses, minimize environmental pollution, and improve ecological efficiency (Abobatta, 2018; Nawaz, 2023). These characteristics make nano urea a promising component of climate-smart and sustainable agriculture.

Information Gap and Extension Constraints

One of the most critical findings is the low mean score for "information about nano urea is adequate" (Mean = 2.41, Rank VII), indicating a significant knowledge gap among farmers. Although awareness is high, farmers lack detailed technical knowledge regarding dosage, timing, and crop-specific application.

The dominance of dealers as the primary source of information (82.5%) further suggests that informal channels play a more influential role than formal extension systems. This reliance on dealers may lead to partial or incorrect understanding of the

technology. Similar observations were reported by Vishakha et al. (2023), where farmers depended heavily on dealers for guidance.

Extension literature emphasizes that inadequate dissemination of scientific knowledge can hinder effective adoption and lead to suboptimal outcomes (El-Shafie et al., 2024).

Satisfaction and Continuity of Adoption

A high proportion of farmers (89.42%) reported satisfaction with nano urea, indicating that the technology meets expectations in terms of cost efficiency and ease of use. However, willingness to repurchase (57.69%) is relatively moderate, suggesting that satisfaction does not always translate into continued use. This discrepancy may be attributed to variability in performance across crops and agro-climatic conditions. Empirical evidence shows that while nano urea performs well in certain crops, its effectiveness may be limited in others, particularly paddy (Vishakha et al., 2023).

Key Insights

- Strong policy push is driving market growth
- Awareness and trust remain major barriers
- Distribution networks play a crucial role

Nano fertilizers demonstrate clear advantages over conventional fertilizers in terms of efficiency and sustainability, but adoption is uneven.

Challenges and Limitations

- Limited farmer awareness
- Inadequate field demonstrations
- Skepticism regarding long-term benefits
- Poor rural distribution infrastructure
- Price sensitivity among small farmers

- Lack of region-specific performance data

10. Conclusion

Nano fertilizers represent a significant advancement in agricultural technology, offering improved efficiency, reduced environmental impact, and enhanced crop productivity. While the Indian market shows promising growth supported by favorable policies, widespread adoption requires addressing structural challenges such as awareness, accessibility, and scientific validation.

A balanced approach integrating technology, policy, and farmer engagement is essential to unlock the full potential of nano fertilizers in achieving sustainable agriculture.

Recommendations

- Conduct large-scale field demonstrations
- Strengthen farmer awareness campaigns
- Improve rural distribution networks
- Introduce affordable packaging options
- Ensure strict quality control measures
- Promote public-private partnerships for innovation

References

- IMARC Group (2024). India Nano Fertilizer Market Report
- Ministry of Chemicals and Fertilizers, Government of India (2024)
- Department of Biotechnology (2023). Nano-Agri Input Guidelines
- IFFCO (2024). Nano Urea Technology Report
- Mordor Intelligence (2024). Market Overview
- Bruinink & Stark (2006). Environmental Science & Technology
- Abobatta, W. F. (2018). Nanotechnology application in agriculture. ***Acta Scientific Agriculture***, 2(6), 99–102.
- El-Shafie, E. M., Ata, R. M., & Allam, S. F. M. (2024). Egyptian farmers' awareness of nanotechnology and their readiness to utilize its applications. ***Journal of the Scientific Society for Agricultural Extension***, 28(1).
- Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers. ***Journal of Economics and Sustainable Development***, 6(5), 208–216.
- Nawaz, M. (2023). Role of nanobiotechnology in sustainable agriculture. ***Agricultural Reviews***, 44(2), 120–128.
- Periakaruppan, R., et al. (2023). Nanotechnology in sustainable agriculture: Applications and challenges. ***Environmental Nanotechnology Journal***, 15(3), 45–60.
- Subramanian, K. S., et al. (2015). Nanofertilizers for balanced crop nutrition. ***Journal of Agricultural Science***, 7(3), 1–10.
- Vijayakumar, P., et al. (2022). Applications of nanotechnology in agriculture and food systems. ***Journal of Nanotechnology Research***, 10(2), 55–68.
- Vishakha, K., et al. (2023). Awareness and perception of farmers and dealers on nano urea in Gondia district of Maharashtra. ***International Journal of Environment and Climate Change***, 13(10), 981–991.

- Beluhova-Uzunova, R., et al. (2019). Bioeconomy and sustainable agriculture.
- El-Shafie, E. M., Ata, R. M., & Allam, S. F. M. (2024). Farmers' awareness of nanotechnology applications.
- IFFCO. (2021). Nano Urea (Liquid): Product and marketing report.
- Mwangi, M., & Kariuki, S. (2015). Factors influencing agricultural technology adoption.
- Subramanian, K. S., & Tarafdar, J. C. (2011). Nanotechnology in Indian agriculture.
- Turlakova, T. (2021). Bioeconomy and agricultural sustainability.
- Vijayakumar, P., et al. (2022). Nanotechnology applications in agriculture.
- Vishakha, K., et al. (2023). Farmers' perception of nano urea in Maharashtra.
- BIO Web of Conferences. (2025). Nano fertilizers and sustainable agriculture.
- Frank, M., & Husted, S. (2024). Is India's largest fertilizer manufacturer misleading farmers and society using dubious plant and soil science? ***Plant and Soil, 496***, 257–267. https://doi.org/10.1007/s11104-023-06191-4
- Mishra, H. (2024). Nanobiostimulants and precision agriculture: A data-driven approach to farming and market dynamics. In V. Singh, R. A. Bhat, & G. H. Dar (Eds.), ***Nanobiostimulants***. Springer. https://doi.org/10.1007/978-3-031-68138-7_16
- Subramanian, K. S., Rajkishore, S. K., Praghadeesh, M., Pradeep, D., & Srinivasan, G. (2025). Regulatory frameworks, guidelines, and policies to promote nanofertilizers: Current status in India and abroad. In A. K. Patra (Ed.), ***Nanofertilizers in agriculture*** (Sustainability sciences in Asia and Africa). Springer, Singapore. https://doi.org/10.1007/978-981-97-8112-6_7
- Subramanian, K. S., & Tarafdar, J. C. (2011). Nanotechnology in Indian agriculture: Prospects and constraints. ***Indian Journal of Agricultural Sciences, 81***(10), 887–89