



# Awareness and Perception of Farmers and Dealers on Nano Urea in Gondia District of Maharashtra, India

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

## Article Information

DOI: 10.9734/IJECC/2023/v13i102745

## Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/105278>

Original Research Article

Received: 16/06/2023

Accepted: 19/08/2023

Published: 23/08/2023

## ABSTRACT

This study investigates farmers' and traders' perceptions of nano urea in the Gondia district of Maharashtra. By providing accurate and long-lasting nutrient management, nano urea, a fertilizer based on nanotechnology, has the potential to revolutionize agriculture. Nearly 120 farmers and 50 merchants were polled as part of the study utilizing a multistage random sampling method. The findings showed that most farmers use nano urea in their fields and are aware of it. The adoption of nano urea by farmers was found to be highly correlated with education. Dealers were well aware of nano urea and eager to sell it since they recognized its benefits in terms of compatibility, storage

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capacity, and ease of use. However, some farmers voiced their displeasure with lesser paddy field yields and comprehension challenges. The paper discusses the difficulties in implementing and using nano urea in agriculture while highlighting its promise.

*Keywords: Nanotechnology; perception; adoption; nano-fertilizer.*

## 1. INTRODUCTION

The field of nanotechnology, which focuses on unique qualities of materials with nanometric dimensions, has the potential to revolutionize the food industry, biomedicine, environmental engineering, safety and security, water resources, and energy conversion. Agriculture-related nanotechnology applications are gradually turning theoretical possibilities into real-world applications. According to [1] nanotechnology involves the manipulation or self-assembly of discrete atoms, molecules, or molecular clusters into structures in order to produce materials and gadgets with novel or radically different features. The advent of nanotechnology and the creation of new nanomaterials and nanodevices present opportunities for novel agricultural applications. In order to offer "Out of the Box" answers to issues facing humanity, rich nations and countries with little resources have embraced the promising field of research known as nanotechnology. Nano-nutrients are small (1-100 nm) and have special properties and advantages. Their high surface-to-volume ratio presents a chance for more beneficial and efficient interaction at the intended locations. When they enter the plant system, they start to signal or trigger nutrient pathways, which increases crop productivity even with lower nutrient dosages. The modern-day fertilizer is liquid nano urea. Nanotechnology-based products have long been used in the commercial sector in industries like medicine, aerospace, military, pollution control, electronics, sensor-based technologies, paints, etc. In several industries, including agriculture, nanotechnology is breaking through previously unreachable obstacles. The study and development of nano-fertilizers have been done by IFFCO through its Nano Biotechnology Research Centre (NBRC) at Kalol. Nano-fertilizers have the potential to improve crop yields and leave a smaller environmental footprint while reducing the cost of applying nutritional fertilizers. Farmers are weaning themselves off of traditional urea thanks to the introduction of modern fertilizers like Nano Urea (liquid), which is sold through farmer cooperative societies and shops. As it supports

precise and sustainable agriculture, nano urea is a potential part of the 4 R approach to nutrient stewardship. It supports environmentally friendly technology because its industrial manufacturing uses little energy and resources.

Since the 19th century, global temperature has already increased by 1.10 Celsius. As a result, the environment is taking precedence, and every individual and sector in the nation must contribute in some way. As per [2] to ensure the sustainability of agriculture, indiscriminate and excessive application of fertilizers like urea needs to be balanced. To address low and falling nitrogen use efficiency, scientists have developed fertilizers with gradual, controlled release and increased efficiency. Due to their size, form, and impact, nanotechnology can play a special role in this situation. [3], examined, nanoparticles are a "smart delivery system" because of their large surface area, sorption capacity, and controlled-release kinetics to specific places. This has inspired inventors to use nanotechnology to address humanity's challenges. The idea of integrated nutrient management may change as a result of smart and intelligent nutrient management using nano-fertilizers. Singh, Meena Dharam, [4] suggested, nano fertilizers are important tools in agriculture to improve crop growth, yield, and quality parameters with increased nutrient use efficiency, and reduce wastage of fertilizers and cost of cultivation. According to [5] Nitrogen fertilizers play an important role in the cultivation of rice. Excessive and improper usage of Nitrogen fertilizer causes problems for humans and the environment. Subramanian, Kizhaeral S., et. al., [6], Given that they release nutrients gradually and steadily over a period of more than 30 days, nano-fertilizers may help increase the effectiveness with which nutrients are used while minimizing any negative side effects. It is essential for a suitable alternative source of Nitrogen with reduced harm to the environment. Nano-nitrogen fertilizers are alternatives to conventional fertilizers with slow and controlled release of nitrogen. According to [7] the use of nano-fertilizers is the most significant application of nanotechnology in agriculture to date. The goal of nano-fertilizers is to increase the

availability of nutrients to leaves, hence improving nutrient usage efficiency. Nano-fertilizers (NF) are more efficient and effective than conventional fertilizers due to their benefits for the quality of food crops, reduction of plant stresses, small application quantities, low costs, rapid cell penetration by plant cells, and fats for transport and representation within plant tissue [8]. A few distinctive features of nanoparticles include their enormous specific surface area [9]. Urea applied topically to leaves is a well-known method for treating acute deficiency at any stage of crop growth. The introduction of IFFCO nano-urea and recent advances in nanotechnology broaden the use of nitrogen supplementation while improving efficacy [10]. According to reports, nanoparticles have been employed to increase crop output by allowing plants to use nutrients more effectively in the form of nano fertilizers, nano pesticides, or nano herbicides [11]. The Department of Biotechnology (DBT), Government of India criteria for evaluating nano Agri-input products (NAIPs), have been verified on nano urea. These regulations have harmonized in accordance with accepted international standards and OECD procedures. According to [12] testing carried out by NABL-recognized and GLP-certified laboratories, nano urea is deemed safe for the user and the environment. As an alternative to traditional bulk nitrogenous fertilizers like urea, nano urea is, therefore, a viable, sustainable, and eco-friendly choice.

As per [13] Nanoscale urea particles are present in nano urea that are created via nanotechnology. The typical physical size of nano urea particle is between 20 and 50 nm. In its nano form, nano urea has 4% nitrogen by weight. The nitrogen in Nano Urea successfully satisfies the crop's nitrogen needs. Its use efficiency is higher than that of regular urea. For the majority of crops and plants, nano urea can be used as a source of nitrogen.

In recognition of its potential to revolutionize farming techniques, Indian farmers are actively using nano urea. Additionally, the Indian government aggressively supports the use of nanotechnology in agriculture. Farmers in the Gondia district of Maharashtra have started utilizing this cutting-edge technology, particularly for fertilizing paddy crops. To help farmers use Nano fertilizers and save time and labour, even the state's IFFCO is starting programs, farmers' meetings, and other promotional activities.

However, little is known at this time about the farmers' understanding and use of Nano urea.

This study examined the acceptance and knowledge of nano urea among farmers and dealers in the Gondia district of Maharashtra state, as well as how various demographic factors impact the outcomes. This study has been conducted with the following objectives; to analyze the awareness level among farmers and dealers about nano urea in the Gondia district of Maharashtra state, to analyze the perception of farmers and dealers regarding nano urea in the Gondia district of Maharashtra state.

## 2. METHODS AND TOOLS OF ANALYSIS

### 2.1 Study Area

Farmers and dealers in the Gondia district of Maharashtra were surveyed as part of the research to obtain information. Traditional farming methods are the mainstay of the Gondian agricultural sector, which has prevented the broad adoption of cutting-edge agricultural technologies. The lack of labour and water is another major issue that the area's farmers must deal with. As a result, the farmers in this region rely primarily on rainfed agriculture. The adoption of nano urea can help farmers in this region solve some of their biggest issues. For this investigation, a multistage random sampling technique was employed. Eight taluks in the district were used for the samples, and information was gathered from 15 farmers and 6–7 dealers in each taluk, for a total of 120 farmers and 50 retailers.

### 2.2 Percentage Analysis

Percent analysis was used to analyse demographic characteristics, awareness level, and perception of farmers about nano urea in the Gondia district of Maharashtra. Utilizing this formula, analysis has been performed.

$$\text{Percentage Analysis} = (\text{No. of samples taken} / \text{Total no. of samples}) \times 100$$

### 2.3 Chi-square Test

The chi-square test has been used to analyze the relationship between the adoption level of nano urea among farmers with the education level by using the following formula.

$$\chi^2 = \sum ((O - E)^2 / E)$$

Where:

- X<sup>2</sup> is the chi-square test statistic
- Σ is the summation operator (it means “take the sum of”)
- O is the observed frequency
- E is the expected frequency

N<sub>j</sub> is the total number of constraints ranked by the jth person.

The scores for each rank will be translated from percent positions using the table provided by Garrett and Woodworth (1969).

## 2.4 Garette Ranking

Garette ranking has been used to rate the factors influencing the purchase of nano urea among farmers. Advantages provided by nano urea over conventional urea to farmers and dealers in the Gondia district of Maharashtra state. Garette ranking has been calculated by using the following formula.

$$\text{Position percentage} = 100 * (R_{ij} - 0.5)/N_j$$

Where:

R<sub>ij</sub> is ranking for the ith constraint given by the jth person,

## 3. RESULTS AND DISCUSSION

### 3.1 Demographic Characters of Sample Farmers

The demographic characteristics of farmers in the Gondia district of Maharashtra are presented in Table 1.

In the sample of 120 farmers all were male, those between the ages of 40-50yrs m majority (33 percent), followed by those between the ages of 30-40yrs (28 percent), 50-60yrs (18 percent), and those between the ages of 20-30 yrs (10 percent). As a result, the majority of middle-aged farmers are active in the Maharashtra state's Gondia district.

**Table 1. Farmer’s demographic characters**

Sr.no	Particulars	No. of respondents (n=120)	Percentage
1.	<b>Gender</b>		
	Male	120	100
2.	<b>Age</b>		
	20-30	12	10
	30-40	33	28
	40-50	40	33
	50-60	22	18
	>60	13	11
3.	<b>Educational status</b>		
	Primary School	40	34
	Secondary school	35	29
	Higher secondary school	28	23
	Graduate	17	14
4.	<b>Farm size</b>		
	<2.5 acre	21	18
	2.5-5 acre	28	23
	5-10 acre	43	36
	10-20 acre	21	17
	>20 acre	7	6
5.	<b>Crop cultivation pattern</b>		
	Paddy	120	100
	Maize	11	9.16
	Vegetables	10	8.33
	Watermelon	5	4.16
	Sugarcane	2	1.66
	Cucumber	1	0.83
	Turmeric	1	0.83
	Guava	1	0.83

Regarding education, 40 farmers (34 percent) had completed their primary education, 35 (29 percent) their secondary education, 28 (23 percent) their upper-level education, and 17 (14 percent) had earned a college degree. As a result, the majority of farmers in Maharashtra's Gondia area were educated up to the primary level.

The majority of 43 farmers (36 percent), had small-medium land holdings of 5 to 10 acres, followed by 28 farmers with small holdings of 2.5 to 5 acres, 21 farmers with medium holdings of 10 to 20 acres, 21 farmers with marginal holdings of less than 20 acres, and 7 farmers with large holdings of more than 20 acres (6 percent).

Due to weather and soil characteristics, paddy is the most widely grown crop in the Gondia district of Maharashtra state. Farmers also grow maize and vegetables.

### 3.2 Determination of Awareness Level among Farmers

The study on awareness level among farmers regarding nano urea is presented in Table 2.

In the Maharashtra district of Gondia, according to the survey results, practically all farmers were aware of nano urea. According to the study, farmers only know the name of nano urea; they have little technical understanding of the product, such as how much should be used per acre and how to apply it in paddy fields.

Dealers are the main source of information for farmers in Maharashtra's Gondia district, where

99 (82.5 percent) of farmers learned about nano urea from them, followed by corporate person visits (5 percent) and social media.

### 3.3 Farmer's Perception on Nano Urea

The findings of the study on farmer's perception of nano urea are presented in Table 3.

In the Gondia district of Maharashtra, out of 120 farmers surveyed, 104 farmers (86.66 percent) responded, had utilized nano urea on their farms, while 16 farmers said they hadn't and the reasons for not purchasing the nano urea 51 farmers (41.66percent) rated the main deterrents to buying nano urea as lack of trust, incomplete product knowledge, and the notion that seeing is believing.

While buying nano urea, 76 farmers (63.33 percent) said they expected good results, 22 said they wanted to save money (18.33percent), 18 said it would be more profitable than conventional urea (15 percent), and 4 said they had no expectations at all.

All 104 farmers who used nano urea said that using nano urea saved them Rs.500 compared to using regular urea, with a response rate of 100 percent.

99 farmers (82.5percent) said they followed the advice of the dealer when applying fertilizer to their farm; 14 farmers (11.66percent) said they relied on prior experience; and 9 farmers (7.5percent) said they followed advice from progressive farmers at universities or the KVK.

**Table 2. Awareness level among farmers**

Sr. no.	Particular	No. of respondents (n=120)	percentage
1.	<b>Awareness level</b>		
	Yes	120	100
2.	<b>Source of Awareness</b>		
	TV	4	3.33
	Field demonstration	1	0.83
	Radio	1	0.83
	Farmers meeting	2	1.66
	Social media	4	3.33
	Newspaper	1	0.83
	Company person visit	6	5
	Leaflets/Posters/Banners	2	1.66
Dealers	99	82.5	

**Table 3. Farmers' perception of nano urea**

Sr.no	Particulars	No. of respondents (n=120)	Percentage
1.	<b>Adoption level</b>		
	Yes	104	86.66
	No	16	13.33
2.	<b>Reasons for not purchasing nano urea</b>		
	Lack of credibility	0	0
	Not appealing	0	0
	Don't have enough product information	36	30
	Trust Factor	50	41.66
	seeing believing	27	22.5
	prefer dealer endorsement	9	7.5
	not understandable	1	0.83
	Late information	0	0
	Others	0	0
3.	<b>Expectations while purchasing Nano urea</b>		
	Good result	76	63.33
	Save cost	22	18.33
	Profitable	18	15
	Others	4	3.33
4.	<b>Cost saving with nano urea compared to conventional urea</b>		
	<500	104	100
	500-1000	0	0
	>1000	0	0
5.	<b>Farmers follow recommendations for doses from</b>		
	Agri officer	4	3.33
	State Agri University/KVK	6	5
	Fellow progressive farmer	9	7.5
	Own knowledge from previous experience	14	11.66
	Dealers	99	82.5
6.	<b>Willingness to repurchase nano urea</b>		
	Yes	60	57.69
	No	44	42.30
7.	<b>Specifications of nano urea liked by farmers</b>		
	Product information	5	4.16
	Packaging	2	1.66
	Its benefits	2	1.66
	Application methods	3	2.5
	Price	9	7.5
	everything	114	95
8.	<b>Satisfaction after using nano urea</b>		
	Yes	93	89.42
	No	11	10.57

Out of 104 farmers who have used nano urea 60 farmers (57.69 percent) responded to their readiness to repurchase nano urea and 44 farmers (42.30 percent) responded because of confidence issues and underwhelming paddy field results. Moreover, farmers in the

Maharashtra district of Gondia mainly used conventional farming methods.

Out of 120 farmers, 114 (95 percent) said they appreciated all the nano urea's specifications, followed by 9 (7.5 percent) who said they preferred the product's price compared to that of conventional urea, and 5 (4.16 percent) who said they preferred the latter's product details.

Out of 104 farmers who adopted nano urea, 11 (10.57.5 percent) claimed they are not at all happy with the products and services, as opposed to 93 (89.42 percent) who are absolutely happy. The majority of the dissatisfied farmers are paddy farmers, while the happy farmers plant vegetables and corn in their fields.

### 3.4 Association between Education and Adoption Level

The level of education of farmers has traditionally influenced their willingness to adopt new agricultural technologies.

H0: The null hypothesis states that there is no connection between farmers' education levels and their use of nano urea.

H1: There is a substantial correlation between farmers' educational attainment and their use of nano urea.

According to Table.4, the chi-square value is 8.636 and the P value is less than 0.05. The chi-square test results show a substantial correlation between farmers' use of nano urea and their degree of education.

### 3.5 Factors Influencing Nano Urea Purchase Rated by Farmers

The findings on factors influencing nano urea purchase rated by farmers are presented in Table 5.

The information provides prioritized factors that influence farmers' adoption of nano urea. Rank scores and Garrett's mean scores are used to group the variables. The factor "Advice from the

**Table 4. Education level and adoption cross-tabulation**

		Adoption		
			No	Yes
Education	Higher Secondary	Count	1	27
		Expected Count	3.733333	24.26667
		percent of Total	0.833333	22.5
	Primary	Count	3	37
		Expected Count	5.333333	34.66667
		percent of Total	2.5	30.83333
	Secondary	Count	7	28
		Expected Count	4.666667	30.33333
		percent of Total	5.833333	23.33333
	UG	Count	5	12
		Expected Count	2.266667	14.73333
		percent of Total	4.166667	10
Total	Count	16	104	
	Expected Count	16	104	
	percent of Total	13.33333	86.66667	
<b><math>\chi^2</math> Value = 8.636</b>		<b>P value =0.035</b>		

**Table 5. Factors influencing the purchase of nano urea**

Sr. no.	Factors	Garette score	Rank
1	Advice from dealer	71.98	I
2	Company person	58.125	II
3	Nutrient composition	52.93	III
4	Advice from fellow farmer	50.51	IV
5	Product performance	46.08	V
6	price(cost/acre)	43.25	VI

dealer" received the highest position, demonstrating its importance in influencing farmers' decisions to adopt nano urea, with a Garrett mean score of 71.98. With a Garrett mean score of 58.125, the factor "Company person visit" came in second place. The Garrett mean score for "nutrient composition" was 52.93, placing it third. With a Garrett mean score of 50.51, "Advice from a fellow farmer" came in fourth place. A 46.08 Garrett mean score for "Product Performance" placed it fifth. The Garrett mean score for "Price" was 43.25, placing it sixth.

### 3.6 Advantages of Nano Urea over Conventional Urea Rated by Farmers

The findings of the advantages of nano urea over conventional urea rated by farmers are presented in Table 6.

Nano urea has good compatibility with other growth regulators, therefore in farmers' perceptions, they are utilising it as a top-up with other nutrients rather than perceiving it as a replacement for conventional urea. "Solubility" is ranked first by farmers with a garette score of 63.86, surpassing conventional urea. With a garette score of 61.83, "environment-friendly"

came in second. Farmers have found that nano urea does not pollute the soil. Farmers ranked "Storage" third, giving it a garette score of 60.51. According to farmers, nano urea occupies less space than regular urea. Farmers ranked "Ease in handling" fourth, giving it a garette score of 59.77. Farmers ranked "product performance" fifth with a garette score of 56.66 because it produces good results for vegetables and maize crop but not for paddy. "Yield" was ranked sixth by farmers with a garette score of 53.67; according to farmers, it is not producing the outcomes that are expected in rice fields. With a garette score of 46.76, "price" was ranked seventh by farmers. Although nano urea costs less than regular urea, farmers find it very difficult to understand how a 500 ml bottle can replace a 45 kg urea bag. Farmers placed "reduction in input cost" eight, with a garette score of 35.57. Farmers felt that lowering the price of nano urea didn't effectively contribute to reducing input costs since a sprayer is required to spray, and labour costs are also involved.

### 3.7 Dealer's Demographic Characters

The findings of the dealers' demographic characters are presented in Table 7.

**Table 6. Advantages of nano urea over conventional urea rated by farmers**

Sr.No.	Factors	Garette score	Rank
1	Solubility	63.86	I
2	Environment friendly	61.83	II
3	Storage	60.51	III
4	Ease in Handling	59.77	IV
5	product performance	56.66	V
6	Yield	53.67	VI
7	Price(cost/acre)	46.76	VII
8	Reduction in input cost	35.57	VIII

**Table 7. Dealers' demographic characters**

Sr.no	Particulars	No. of respondents (n=50)	Percentage
1.	<b>Age</b>		
	Age 20-30	8	16
	Age 30-40	19	38
	Age 40-50	12	24
	Age 50-60	4	8
	Age >60	7	14
2.	<b>Education</b>		
	Primary	0	0
	Secondary	0	0
	Higher Secondary	0	0
	UG	50	100



Out of 50 dealers surveyed, the majority are between the ages of 30 and 40, with 12 dealers being between the ages of 40 and 50, 8 being between the ages of 20 and 30, 7 being beyond the age of 60, and 4 being between the ages of 50 and 60. In the Maharashtra state's Gondia district, every trader has a bachelor's degree.

### 3.8 Dealer's Awareness Level on Nano Urea

The findings of dealer's awareness level of nano urea are analysed and presented in Table 8.

According to Table 8, all dealers (100 percent) are aware of nano urea, and 48 merchants (96 percent) are selling it in the Maharashtra district of Gondia.

### 3.9 Dealer's Perception on Nano Urea

The results of the analysis and presentation of dealers' perceptions of nano urea are shown in Table 9.

The average number of clients per day for nano urea, according to all 48 dealers who sold nano urea, is less than five. From 48 dealers who are selling nano urea only 23 (47.91 percent) dealers reported receiving repeat orders for nano urea, and 25 (52.08 percent) farmers reported not receiving repeat orders for nano urea. This is due to the crop cultivation patterns in the Gondia district of Maharashtra state. Compared to conventional urea, paddy farmers are not seeing the outcomes they had hoped for from nano urea. Meanwhile, nano urea is giving better outcomes for maize and vegetable growers.

**Table 8. Dealers' awareness level on nano urea**

Sr.no	Particulars	No. of respondents (n=50)	Percentage
1.	<b>Awareness</b>		
	Yes	50	100
	No	0	0
2.	<b>Selling nano urea</b>		
	Yes	48	96
	No	2	4

**Table 9. Dealer's perception of nano urea**

Sr.no	Particulars	No. of respondents (n=50)	Percentage
1.	<b>The average footfall of customers per day for nano urea</b>		
	<5	48	100
	5-10	0	0
	10-20	0	0
	>20	0	0
2.	<b>Getting repeat orders of nano urea</b>		
	Yes	23	47.91
	No	25	52.08
3.	<b>Future trend of nano urea</b>		
	Increase	37	74
	Decrease	5	10
	Remain constant	8	16
	Increase Rapidly	0	0
4.	<b>Willingness to sell nano urea</b>		
	Yes	50	100
	No	0	0
5.	<b>Satisfaction of dealers with the price of nano urea</b>		
	Yes	42	87.5
	No	6	12.5

**Table 10. Advantages of nano urea over conventional urea ranked by dealers**

Sr. No.	Factors	Garett score	Rank
1	Less storage space	70.38	I
2	ease of handling	62.88	II
3	Compatibility	50.04	III
4	saving in Labour Cost	48.18	IV
5	NU Efficiency	45.38	V
6	Yield	36.08	VI

Out of the 50 dealers questioned, 37 dealers (74 percent) indicated that the trend for nano urea will continue to rise due to its advantages. Five (10 percent) sellers said it will decline because it was failing to affect paddy farms and farmers' perceptions of traditional techniques. Eight merchants (16 percent) said they expected it to stay the same.

In the Maharashtra district of Gondia, nearly every single one of the 50 dealers (100 percent) is ready to sell nano urea. When asked if they are satisfied with the pricing of nano urea, From 48 dealers who have sold nano urea, 42 dealers (87.5 percent) said yes, while 6 dealers (12.5 percent) said no because they would like a greater profit margin.

### 3.10 Advantages of Nano Urea over Conventional Urea Ranked by Dealers

The advantages of nano urea over conventional urea ranked by dealers are presented in Table 10.

With a score of 70.38, 50 dealers in the Maharashtra district of Gondia gave the "Less space storage" the highest grade. According to the dealers, nano urea requires less storage space than traditional urea and aids in the efficient management of storage space in stores. With a Garett score of 62.88, "ease of handling" is the second most important factor. Nano urea bottles are much easier to handle than regular urea bottles. With a garett score of 50.04, "compatibility" is the third most important element. Nano urea is particularly compatible with other growth regulators and is most effective when combined with IFFCO's Sagarika. "Saving in labour cost" is the fourth-ranked component, with a garett score of 48.15. Nano urea is less labour-intensive than regular urea and easier to handle as well, saving dealers money. The fifth-ranked factor is "NU efficiency" with a garett score of 45.38, while the sixth-ranked factor is "Yield" with a garett score of 36.08, which, in

the opinion of the dealers, fails to deliver the expected results in Paddy fields.

## 4. CONCLUSION

In the Gondia district of Maharashtra, the study looked into how farmers and dealers felt about nano urea and what they knew about it. The findings showed that most farmers have used nano urea on their fields and were aware of it. Farmers' use of nano urea was found to be significantly correlated with education. The recommendations of dealers and corporate employees, the content of the nutrients, and convenience of handling were the key determinants of the acquisition of nano urea. Farmers liked nano urea because of its solubility, storage advantages, and environmental friendliness. However, some farmers voiced their displeasure at lesser yields in paddy fields and the complexity of its application. Dealers were eager to sell nano urea and well aware of its potential. It is expected to be advantageous in terms of interoperability, storage capacity, and ease of use.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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