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Market potential and challenges of water-soluble fertilizer adoption in Theni district

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Abstract

This study examines the market potential and challenges farmers face when purchasing and using water-soluble fertilizers in Theni district, Tamil Nadu. It focuses on key crops like bananas, coconuts, grapes and mangoes. Farmers in the Theni district encounter issues with conventional fertilizers, such as low nutrient efficiency, soil degradation and environmental pollution. Water-soluble fertilizers offer a promising alternative, enhancing nutrient absorption, reducing leaching and minimizing environmental impact. Despite their benefits, adoption is hindered by higher initial costs, lack of farmer awareness and the need for precision application techniques. Farms that have adopted these fertilizers report a 20-30% increase in yield and a 15% reduction in overall fertilizer use. The study highlights the potential of water-soluble fertilizers to address agricultural challenges in Theni, including nutrient deficiencies, making them a viable option for promoting sustainable farming in the region.

Keywords

agriculture; market potential; sustainable farming; Theni; water-soluble fertilizer

Introduction

In India, agriculture contributes 16% to the country's Gross Value Added (GVA) and employs about 42% of the workforce (1). With over 156 million ha of arable land and a population exceeding 1.4 billion, the nation faces significant challenges in ensuring food security and maintaining agricultural productivity (2). Fertilizers play a crucial role in Indian agriculture, ranking among the world's leading producers and consumers of essential farm inputs. However, despite substantial efforts to enhance fertilizer use, India's agricultural productivity remains below global averages (3), with key crops like rice and wheat yielding only around 60-70% of the worldwide average (4). This highlights the urgent need for more effective fertilizer management strategies to bolster food security.

Water soluble fertilizer

Water-soluble fertilizers (WSF), which dissolve entirely in water, are increasingly recognized for their efficiency and precision in delivering nutrients directly to plants through foliar application or fertigation. By providing nutrients directly to plant roots via drip irrigation, these fertilizers help maximize yield with minimal nutrient loss and shorten the time required for nutrient absorption compared to traditional solid fertilizers (5). Their 100% solubility and low salt index make them ideal for foliar sprays and fertigation, minimizing the risk of plant tissue burn and better meeting crops' nutritional needs during critical growth stages (6). These fertilizers are

particularly effective in promoting balanced nutrition, enhancing nutrient use efficiency by as much as 80-90% due to improved absorption and, in some cases, reducing soil salinity when used correctly (7). The adoption of WSFs is driven by demands for precision agriculture, water conservation and environmental sustainability, especially in regions facing stagnant crop yields caused by uneven fertilizer use, soil degradation and climate change. Furthermore, using WSFs in drip irrigation systems can significantly reduce nutrient runoff by up to 90%, contributing to sustainable farming practices in India (8). Despite their short duration of effectiveness, which requires frequent reapplications, WSFs are gaining popularity as a practical solution to the fertilizer sector's challenges, offering precise nutrient ratios that promote sustainable agricultural practices (5).

Several WSFs has developed and included by the Government of India (9). These fertilizers, available in various grades, can be used at different growth stages of crops, either alone or in combination, to enhance crop productivity. The nutrient compositions of these WSFs are tailored for specific purposes. For instance, starter grades like potassium nitrate (13-0-45) and prilled potassium nitrate (13-0-45) offer a balanced supply of nitrogen (13%) and potassium (45%), which are essential during the early growth stages. Mono potassium phosphate (0-52-34) provides a high concentration of phosphorus (52%) and potassium (34%), suitable for middle to late growth stages. Calcium nitrate (15.5-0-0) stands out with its 15.5% nitrogen and 18.8 % calcium content, making it beneficial for crops with high calcium requirements. With 22% potassium, 20% sulfur and 18% magnesium, potassium magnesium sulfate supports balanced nutrition. Mono ammonium phosphate (12-61-0) and urea phosphate (17-44-0) are phosphorus-rich options, contributing to root development and energy transfer. Other formulations, like 24-24-0, offer a balanced nitrogen and phosphorus supply. In contrast, potassium metaphosphate dimer (0-40-40) supplies both phosphorus and potassium equally, which is ideal for applications requiring both nutrients in equal measure. These grades are listed under FCO-1985 with their precise nutrient compositions, emphasizing efficient and targeted nutrient delivery to crops (Table 1) (9).

The benefits of water-soluble fertilizers include improved nitrogen use efficiency through slow-release formulations, with studies indicating a 37-52% increase compared to traditional fertilizers (10). Additionally, these fertilizers enhance nutrient uptake efficiency by allowing direct absorption through the plants' leaves, which helps to correct deficiencies quickly and minimizes nutrient loss (11).

India Water Soluble Fertilizer Scenario

The Indian market for WSFs has experienced significant growth over the years. From 1995-96 to 2020-21, the consumption of these fertilizers rose at a Compound Annual Growth Rate (CAGR) of approximately 24.71%, reflecting a steady rise in demand (12). This trend underscores the increasing importance of WSFs in enhancing agricultural productivity. Kerala leads as the largest consumer, using 70199 tons in 2020-21, while states like Madhya Pradesh and Karnataka also show considerable usage, highlighting the varied adoption of modern farming practices across the country. In 2021, Indias' total capacity for water-soluble fertilizers was 184955 tonnes, with a production output of 100809 tonnes. However, India had to rely heavily on imports to meet the growing demand, totalling 163120 tons. Despite these efforts, sales reached 262288 tonnes, falling short of the anticipated consumption need of 300000 tonnes by 37712 tonnes (12). The market for water-soluble fertilizers is categorized into various grades, with Calcium Nitrate and NPK (19-19-19) being the most prevalent. These fertilizers are vital for boosting crop yields and sustaining the agricultural sector. Overall, the growth of the Indian water–soluble fertilizer market is driven by the need to increase food production to support the countrys' growing population. As farmers continue to adopt these cost-effective and eco-friendly options, WSFs are expected to play a crucial role in promoting sustainable farming practices across India (12). The objective study was to see the trends of the selected crop and the market potential of Water-Soluble Fertilizers in the study area and challenges encountered by the farmers purchasing and using WSF in the study area.

Materials and Methods

The study was conducted in Theni district, Tamil Nadu, focusing on using WSF in agriculture. Four blocks (Andipatti, Cumbum, Periyakulam and Uthamapalayam) out of the districts' eight blocks were selected based on the primary crops grown and the WSF coverage area. Bananas, coconut, grapes and mango are the major crops in Andipatti, Cumbum, Periyakulam and Uthamapalayam blocks, covering the largest cultivated areas in the Theni district. The cultivated area for these crops increased by 2.2% (13) from 2022-23 to 2023-24, along with an 11.5% rise in micro-irrigation adoption under the PMKSY scheme (13). Since WSFs are primarily used in micro-irrigation, these blocks were selected as the focus of the study.

Table 1. FCO-approved nutrient composition of 100 % Complex water–soluble fertilizers

Name of product grade	Nutrient composition (%)					
	N	P_2O_5	K_2O	S	Ca	MgO
Potassium nitrate (13-0-45)	13	0	45	–	–	–
Mono potassium phosphate (0-52-34)	0	52	34	–	–	–
Calcium nitrate	15.5	–	–	–	18.8	–
Potassium magnesium sulphate	–	–	22	20	–	18
Mono ammonium phosphate (12-61-0)	12	61	0	–	–	–
Urea phosphate (17-44-0)	17	44	0	–	–	–
Potassium Nitrate (prilled) 13-0-45	13	0	45	–	–	–
24-24-0	24.0	24.0	–	–	–	–
Potassium metaphosphate dimer	–	40	40			

Source: Fertilizer (control) order 1985 (FAI 2023) (9)

Selection of sample farmers and dealers

Two villages were chosen for each block and 15 farmers using WSF were purposefully selected, resulting in a sample of 120 farmers. Additionally, 5 dealers were chosen from each village, with 20 dealers selected based on the availability and variety of WSF products offered.

Data collection methods

Primary data were collected through structured interviews with farmers and dealers to assess challenges related to WSF usage. Secondary data, including cropping patterns and village selection criteria, were obtained from the Joint Director of Agricultures' office and official government websites. This comprehensive data collection approach provided insights into WSF usage and agricultural practices in the Theni district. To estimate the market potential projection of WSF, the chain ratio approach is used as given in Equation 1:

$$MPc = QA \times Dr \qquad \text{(Eqn .1)}$$

Where,

MPc - Market potential for WSF in Theni district, in tonnes.

QA= Total projected area for banana, coconut, grapes and mango under WSF usage.

Dr= Recommended dose of WSF for banana, coconut, grapes and mango, in kg/ha.

To determine the qualified market potential, the following formula was applied as given in Equation 2 (14):

$$QMP(c) = QA \times PA(c) \times Dr \qquad \text{(Eqn. 2)}$$

Where,

QMP(c) = Qualified market potential for banana, coconut, grapes and mango in tonnes.

QA = Total projected area under selected crops in ha.

PA (c) = Percentage of the area where WSF is anticipated to be applied to these crops.

Dr = Recommended dose of selected crop in kg/ha.

The constraints associated with WSF usage were estimated using the Garret Ranking method with the following formula as given in Equation 3 (15):

$$\text{Percent position} = 100 \times (R_{ij}-0.5)/N_j \times 100 \qquad \text{(Eqn. 3)}$$

Where,

R_{ij} = Rank given to the i^{th} factor by the j^{th} individual.

N_j = Number of factors ranked by the j^{th} individual.

Results and Discussion

Trend in area of selected crop in Theni district, Tamil Nadu (From 2004 to 2024)

Table 2 shows that the area (in 100 ha) under the cultivation of four crops-Banana, Coconut, Grapes and Mango-has been tracked from 2004-05 to 2023-24. Additionally, the table includes the coefficients of determination (R^2) and CAGR for each crop. The area under banana cultivation has shown a significant upward trend, starting at 28.42 hundred ha in 2004-05 and rising to 71.09 hundred ha in 2023-24. This indicates a robust growth pattern, with a CAGR of 3.07% and an R^2 value of 0.602. This suggests a moderate correlation between time and the increase in banana cultivation because of the market demand. Similarly, the area under coconut farming has increased notably, from 149.03 hundred ha in 2004-05 to 240.71 hundred ha in 2023-24. This steady growth is reflected in a high R^2 value of 0.949, signifying a strong correlation over the years. The CAGR for coconut stands at 2.31%, indicating consistent growth.

Table 2. Area under selected Crops in Theni district (Area 100 ha)

Year	Banana	Coconut	Grapes	Mango
2004-05	28.42	149.03	17.83	81.73
2005-06	33.28	153.42	19.37	85.82
2006-07	41.02	159.35	20.13	88.14
2007-08	45.27	165.76	20.93	88.98
2008-09	48.46	169.99	20.44	90.80
2009-10	57.79	181.73	20.47	90.24
2010-11	59.65	187.15	19.60	92.98
2011-12	57.67	191.16	19.21	94.05
2012-13	60.10	199.68	17.79	95.01
2013-14	59.96	199.07	17.33	95.39
2014-15	60.43	200.68	17.63	95.48
2015-16	59.14	204.66	17.13	95.69
2016-17	56.13	209.31	17.10	96.76
2017-18	51.34	211.17	17.08	96.68
2018-19	52.61	214.45	17.15	95.66
2019-20	59.66	213.18	16.97	94.54
2020-21	61.22	217.98	17.96	93.84
2021-22	64.03	226.52	17.00	94.71
2022-23	67.32	232.54	17.41	92.36
2023-24	71.09	240.71	16.85	89.79
R^2	0.602	0.949	0.569	0.391
CAGR	3.069928	2.310249	–0.9498	0.468355

Source: Department of Horticulture, Theni and Department of Economics and Statistics. (13, 16)

The area under grape cultivation presents a more fluctuating trend, with an initial rise from 17.83 hundred ha in 2004-05 to a peak of 20.93 hundred ha in 2007-08, followed by a general decline to 16.85 hundred ha by 2023-24. The negative CAGR of -0.95% reflects this overall decrease and the R^2 value of 0.569 indicates a moderate fit of the trendline. The area for mango cultivation has experienced a gradual increase from 81.73 thousand ha in 2004-05 to a peak of 96.76 thousand ha in 2016-17, followed by a slight decline to 89.79 thousand ha in 2023-24. The CAGR of 0.47% denotes a marginal growth rate, while the R^2 value of 0.391 suggests a relatively weak correlation (Fig. 1-4).

Projection of area of banana, coconut, grapes and mango in Theni District

To project the area allocated to bananas, coconut, grapes and mangoes in the Theni district, growth rates were calculated using CAGR for 20 years of time series data from 2004-05 to 2023-24.

From Table 3, the CAGRs for these crops were estimated as 3.069% for banana, 2.310% for coconut, -0.949% for grapes and 0.468% for mango. Based on these growth rates, the projected area under banana is expected to be 7322.27 ha. Similarly, the regions estimated for coconut, grapes and mango in the year 2024-25 are 24624.26 ha, 1669.83 ha and 9014.91 ha respectively and the total area of projection is 42631.65 ha in Theni district for 2024-25.

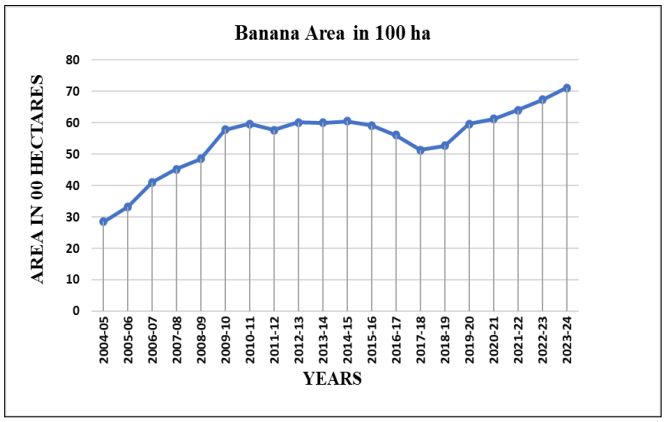

Fig. 1. Trends in area under Banana in Theni district during 2004-05 to 2023-24 (13, 16).

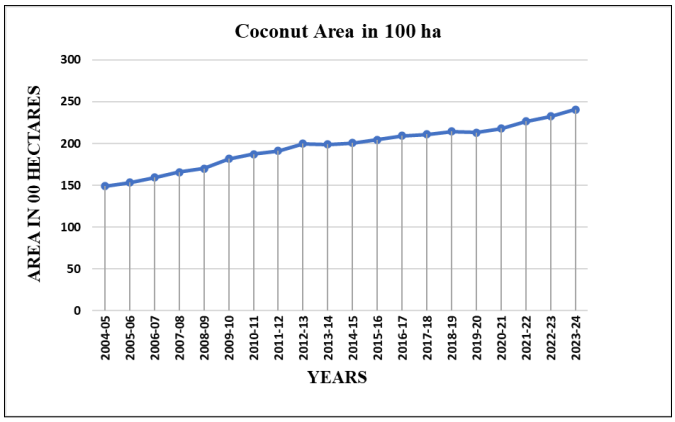

Fig. 2. Trends in the area under Coconut in Theni district during 2004-05 to 2023-24 (13, 16)

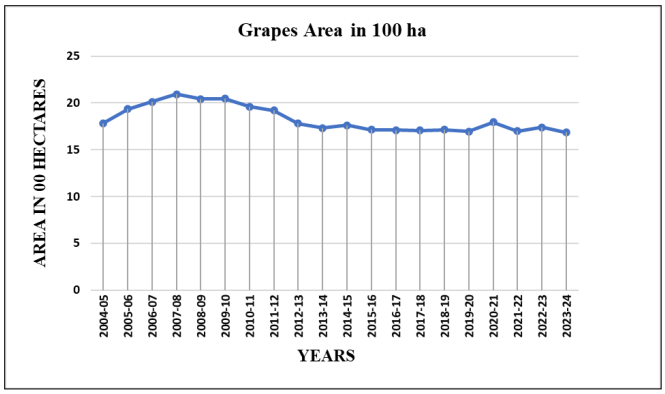

Fig. 3. Trends in the area under Grapes in Theni district during 2004-05 to 2023-24 (13, 16).

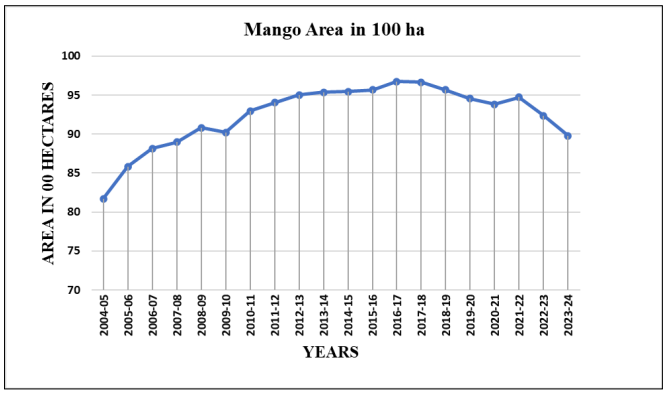

Fig. 4. Trends in the area under Mango in Theni district during 2004-05 to 2023-24 (13, 16).

Table 3. Projected area of selected crops

Sl.No.	Crop	CAGR	Area of Projection for 2024-25
1.	Banana	3.069%	7322.27
2.	Coconut	2.310%	24624.63
3.	Grapes	-0.949%	1669.83
4.	Mango	0.468%	9014.91
Total Area of Projection			42631.65

Source: Department of Horticulture, Theni and Department of Economics and Statistics (13, 16)

Requirement of water-soluble fertilizers as fertigation

The requirement of WSF was evaluated using chain ratio methods, with details provided in Table 4.

Table 4 shows that the WSF requirements for selected crops are specified by the types of fertilizers used: 19:19:19, 12:61:0 and 13:0:45 of NPK. For bananas, which cover 7550.73 ha, the recommendation is 600 kg/ha of NPK-19:19:19, 300 kg/ha for 12:61:0 and 300 kg/ha of NPK-13:0:45, leading to a total fertilizer requirement of 1200 kg/ha and a total of 9060.88 tonnes. Coconut, with the largest area of 25195.92 ha, requires 500 kg/ha of NPK-19:19:19, 250 kg/ha of NPK-12:61:0 and 250 kg/ha of NPK-13:0:45, totalling 1000 kg/ha and 25195.92 tonnes. Grapes, grown on 1677.02 ha, need 300 kg/ha of NPK-19:19:19, 150 kg/ha of NPK -12:61:0 and 150 kg/ha of NPK-13:0:45, amounting to 600 kg/ha and 1006.21 tonnes. Mangoes, cultivated on 9064.40 ha, have a requirement of 400 kg/ha of NPK-19:19:19, 200 kg/ha of NPK-12:61:0 and 200 kg/ha of NPK-13:0:45, summing up to 800 kg/ha and 7251.51 tonnes. The total fertilizer requirement for all crops (banana, coconut, grapes and mango) is 42514.5 tonnes.

Table 4. Estimated requirement of water–soluble fertilizer

Crop	Area (ha)	Recommendation level (Kg/ha/yr)*				Requirement (Tonnes) 2024-25
		19:19:19	12:61:0	13:0:45	Total	
Banana	7550.73	600	300	300	1200	9060.88
Coconut	25195.92	500	250	250	1000	25195.9
Grapes	1677.02	300	150	150	600	1006.21
Mango	9064.40	400	200	200	800	7251.51
Total Requirement						**42514.5**

* Source: Indian Institute of Horticultural Research (IIHR), Central Plantation Crops Research Institute (CPCRI), National Research Centre for Grapes (NRCG), National Research Centre for Banana (NRCB) (17- 20)

Qualified market potential

Table 5 shows the qualified market potential of the selected crops. For bananas, with an area of 7550.73 ha, the recommendation levels are 600 kg/ha for 19:19:19, 300 kg/ha for 12:61:0 and 300 kg/ha for 13:0:45, totalling 1200 kg/ha. With 4% of the area under water-soluble fertilizers, the qualified market potential is 362.44 tonnes. Coconut, covering 25195.92 ha, has recommendation levels of 500 kg/ha for 19:19:19, 250 kg/ha for 12:61:0 and 250 kg/ha for 13:0:45, amounting to 1000 kg/ha. With 12% of the area adopting these fertilizers, the market potential is 3023.51 tonnes. Grapes grown on 1677.02 ha require 300 kg/ha for 19:19:19, 150 kg/ha for 12:61:0 and 150 kg/ha for 13:0:45, totalling 600 kg/ha. With a 6% adoption rate, the market potential is 60.37 tonnes. Mangoes, with an area of 9064.40 ha, need 400 kg/ha for 19:19:19, 200 kg/ha for 12:61:0 and 200 kg/ha for 13:0:45, summing up to 800 kg/ha. With 9% of the area using these fertilizers, the market potential is 652.64 tonnes. Overall, the total qualified market potential for water-soluble fertilizers across selected crops (banana, coconut, grapes, mango) is 4098.95 tonnes.

Table 5. Qualified market potential

Crop	Area (ha)	Recommendation level (Kg/ha/yr)*				Area under water-soluble fertilizer in 2024		Qualified Market Potential (Tonnes) 2024-25
		19:19:19	12:61:0	13:0:45	Total	%	ha	
Banana	7550.73	600	300	300	1200	4%	284.36	362.44
Coconut	25195.92	500	250	250	1000	12%	2888.52	3023.51
Grapes	1677.02	300	150	150	600	6%	101.1	60.37
Mango	9064.40	400	200	200	800	9%	808.11	652.64
Total qualified market potential								4098.95

***** Source: Indian Institute of Horticultural Research (IIHR), Central Plantation Crops Research Institute (CPCRI), National Research Centre for Grapes (NRCG), National Research Centre for Banana (NRCB) (17- 20)

Challenges encountered by farmers during the purchase and use of WSF

Farmers in the Theni district are key drivers of the growing demand for water-soluble fertilizers due to their effectiveness in improving crop yields. However, this demand is significantly hindered by various factors. High costs and the initial investment required make these fertilizers less accessible. Additionally, challenges such as a lack of technical knowledge, insufficient salesperson guidance, difficulties in storage and handling, limited access to credit facilities and issues with timely availability contribute to reduced usage.

To better understand these challenges, a current study was conducted to identify and rank the problems farmers face when using WSFs. Farmers were asked to prioritize these issues and the Garrett ranking technique was employed to determine the severity of each factor. The mean scores from this analysis highlighted the most critical constraints, including high cost, lack of technical knowledge, lack of salesperson guidance, high initial investment, storage challenges, credit facility limitations and timely availability.

Table 6 presents constraints ranked by impact, with high cost as the top concern, scoring 69.49, highlighting the financial burden high fertilizer costs impose on farmers. The second major challenge, "Lack of technical knowledge," scores 65.87, indicating an inadequate understanding of fertilizer usage. Following this, the lack of salesperson guidance ranks third with 53.23, underscoring the critical need for knowledgeable sales personnel to provide guidance and support; without this, farmers struggle to make informed purchasing decisions. The "High initial investment" required for fertilizers is ranked fourth, with a score of 45.75, emphasizing the financial barrier that the upfront costs of fertilizers present to farmers. Ranked fifth, with a score of 44.61, is the issue of "Storage of solid fertilizers." Proper storage is essential for maintaining fertilizer quality and difficulties in this area can compromise its effectiveness. The sixth constraint, "Credit facility," scores 43.68, reflecting how limited access to credit restricts farmers' ability to purchase fertilizers, affecting their agricultural productivity. Lastly, "Timely availability" of fertilizers is ranked seventh with a score of 28.3.

Although it is less critical than the other factors, timely access remains essential, as delays in obtaining fertilizers can disrupt planting schedules and reduce crop yields. This ranking highlights the diverse challenges farmers face, from financial pressures to issues related to knowledge and infrastructure, all of which impact their ability to utilize fertilizers effectively.

Table 6. Challenges faced by the sample farmer

Sl.No	Challenges	Score	Rank
1.	High cost	69.49	I
2.	Lack of technical Knowledge	65.87	II
3.	Lack of salesperson guidance	53.23	III
4.	High initial investment	45.75	IV
5.	Storage and handling of water–soluble fertilizer	44.61	V
6.	Credit facility	43.68	VI
7.	Timely availability	28.3	VII

Conclusion

The present study revealed the significant market potential of WSF in the Theni district, Tamil Nadu, particularly for key crops such as bananas, coconut, grapes and mango. The findings highlight a growing demand for the WSF for these selected crops. However, the study also identifies key barriers to adoption, including the high cost of WSF, the lack of technical knowledge among farmers and the need for precision application techniques. The district's analysis of crop area trends and projections indicates an estimated total requirement of 42514.5 tonnes of WSF, underlining substantial market demand.

Despite these challenges, the qualified market potential for WSF in the Theni district is currently projected at 4098.95 tonnes, demonstrating a viable opportunity for enhancing sustainable farming practices in the region. Although the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) scheme launched in 2016 in Theni district, WSF adoption for banana, coconut, grapes and mango remains limited to only 4% to 12% of the cultivated area. High costs, lack of technical knowledge and other constraints hinder broader use, highlighting the need for focused strategies to address these barriers. The road ahead for India's water-soluble fertilizer (WSF) industry looks promising, driven by increasing awareness among farmers about the benefits of WSFs, such as higher nutrient efficiency and improved crop yields. Expanding micro-irrigation systems under government schemes like the PMKSY further boosts the demand for WSFs.

Additionally, the increasing focus on sustainable agriculture and the need to optimize water usage in farming will likely accelerate the adoption of these fertilizers. However, challenges such as high costs, the need for technical knowledge and infrastructure development must be addressed to realize the industrys' potential fully. Ongoing government support, technological advancements and farmer education will be crucial to driving growth in Indias' WSF industry.

Suggestions

Increasing farmer awareness through targeted training programs is essential for effective WSF adoption. Implementing government subsidies or facilitating bulk purchasing options could significantly reduce costs, making WSFs more accessible to farmers. Improving credit access with low-interest loans will support hesitant farmers. Promoting precision farming will optimize WSF use, reduce waste and boost yields. Lastly, enhancing storage and distribution infrastructure will ensure timely availability and maintain fertilizer quality in the Theni district.

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Authors' contributions

SS conceptualized the concept, employed methodology, collected data, performed statistical analysis and wrote manuscripts. BR did the literature review, defined the problem and derived the objectives and overall supervision of the work. DN contributed to editing the manuscript and conceptualizing the work. GR contributed by correcting formal analysis and with necessary data collection. LK assisted in the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to improve the English language and for grammar correction. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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