International Journal of Plant & Soil Science

Volume 38, Issue 4, Page 41-50, 2026; Article no.IJPSS.153844
ISSN: 2320-7035

Assessment of Farmers' Knowledge on Soil Sampling Procedures and Soil Test Based Nutrient Management in Karimnagar District of Telangana, 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: https://doi.org/10.9734/ijpss/2026/v38i46028

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://pr.sdiarticle5.com/review-history/153844

Original Research Article

Received: 21/01/2026
Accepted: 13/03/2026
Published: 03/04/2026

Abstract

Soil testing and soil health card (SHC)-based nutrient management are pivotal components of sustainable agriculture. This study evaluated the knowledge level of 120 farmers in Karimnagar district, Telangana State, India, concerning soil sampling procedures and soil test-based fertilizer recommendations. Employing an ex-

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Cite as: *Reddy, K. M. M., Archana, P., Reddy, C. V., Reddy, M. J. M., Padmaveni, C., & Sudharani, V. (2026). Assessment of Farmers' Knowledge on Soil Sampling Procedures and Soil Test Based Nutrient Management in Karimnagar District of Telangana, India. International Journal of Plant & Soil Science, 38(4), 41–50. https://doi.org/10.9734/ijpss/2026/v38i46028*

post facto research design with a pre-tested structured interview schedule, data were collected and analysed using descriptive statistics and Pearson's correlation coefficient. The findings reveal that a majority of respondents (60%) possessed a medium level of knowledge, while 24.17% demonstrated high knowledge and 15.83% showed low knowledge. The highest awareness was recorded for the availability of soil testing services (88.33%), the need to apply nitrogen in three split doses in paddy (87.50%), and the role of balanced fertilization in maintaining soil health (85.83%). Conversely, knowledge gaps were most pronounced concerning the recommended zinc sulphate dose for correcting zinc deficiency in paddy (56.67%), the prescribed quantity of muriate of potash for paddy (58.33%), and the variation of fertilizer dose for paddy with soil test values (57.50%). Correlation analysis identified education ($r = 0.462^{**}$), training undergone ($r = 0.518^{**}$), extension contact ($r = 0.487^{**}$), scientific orientation ($r = 0.436^{**}$), and innovativeness ($r = 0.401^{**}$) as highly significant predictors of knowledge at the 1% level. Farm size ($r = 0.298^{*}$), economic motivation ($r = 0.321^{*}$), and achievement motivation ($r = 0.354^{*}$) were significant at the 5% level. Age and farming experience did not exhibit significant relationships with knowledge. These results underline the critical need for targeted extension training, field demonstrations, and digital outreach to bridge knowledge gaps and enhance adoption of soil test-based nutrient management among farming communities.

Keywords: Soil health card; soil sampling; nutrient management; farmers' knowledge; extension contact.

1. Introduction

Soil health is the cornerstone of agricultural productivity and long-term environmental sustainability. In a country like India, where smallholder farmers constitute over 85% of the agricultural workforce, soil degradation due to imbalanced and indiscriminate use of chemical fertilizers has emerged as a critical challenge (Srivastava et al., 2016). Soil testing, a scientifically validated diagnostic tool, provides crop-specific and site-specific fertilizer recommendations that optimize input use efficiency, minimize economic costs, and protect ecosystem services (Bhatt et al., 2021).

The Government of India launched the Soil Health Card (SHC) Scheme in February 2015 to extend soil testing services to every farmer in the country. The scheme envisages testing of 12 nutrient parameters – comprising three macro-nutrients (N, P, K), two secondary nutrients (S, Ca, Mg) and five micronutrients (Zn, Fe, Mn, Cu, B) – along with physical parameters such as soil pH and electrical conductivity (EC) – and issuing farmers a card-carrying crop-wise fertilizer recommendation (Ministry of Agriculture & Farmers Welfare [MoAFW], 2022). By March 2022, more than 230 million SHCs had been distributed nationwide, yet studies consistently report a divergence between card receipt and actual adoption of recommendations (Mukhopadhyay et al., 2021).

A persistent bottleneck is inadequate farmer knowledge of soil sampling procedures and the scientific rationale underlying SHC recommendations. Farmers who do not understand when, where, and how to collect representative soil samples may generate erroneous test results that translate into suboptimal management decisions (Das et al., 2020). Several studies conducted across diverse agro-climatic regions of India have reported considerable variation in farmers' knowledge levels regarding soil health management and Soil Health Card-based recommendations, with most farmers exhibiting moderate awareness but significant gaps in technical and micronutrient-related aspects (Chundru et al., 2024; Gowda & Shivaramu, 2025). However, region-specific studies are essential because soil type, cropping system, and the socio-economic fabric of farming communities differ substantially across districts.

Telangana, established as India's 29th state in 2014, has placed considerable emphasis on soil health management through the expansion of soil testing infrastructure and strengthening of extension systems, including Krishi Vigyan Kendras (KVKs). Karimnagar district, located in the northern region of the state, is characterized by Alfisols and Vertisols with considerable spatial variability in soil fertility and micronutrient status, particularly zinc and iron deficiencies, as reported in recent soil assessment studies in semi-arid regions of India (Fausak et al., 2024; Sharma et al., 2024). The district is a major producer of rice, maize, and cotton, where soil test-based nutrient management practices have been shown to significantly improve crop productivity, resource-use efficiency, and economic returns (Bhatt et al., 2021). Despite these favorable institutional and agronomic conditions, there remains a lack of comprehensive, location-specific studies assessing farmers’ knowledge of soil sampling procedures and Soil Health Card (SHC)-based nutrient management in Karimnagar district.

Against this backdrop, the present investigation was undertaken with the following objectives:

1. To assess the personal, socio-economic and psychological profile of respondent farmers.
2. To evaluate their knowledge level on soil sampling procedures and soil health card-based nutrient Management.
3. To examine the relationship between farmers' profile characteristics and their knowledge level.

2. Materials and Methods

2.1 Study Area and Research Design

The study was conducted in erstwhile Karimnagar district of Telangana State in South India. An ex-post facto research design was adopted since the study aimed to investigate an existing phenomenon, farmers' knowledge of soil health management, without any experimental intervention (Kerlinger, 1986). The district was purposively selected owing to its agronomic significance, varied soil types and the active presence of soil testing infrastructure.

2.2 Sample Size and Sampling Procedure

A multi-stage random sampling technique was employed for the selection of respondents. In the first stage, six mandals were randomly selected from erstwhile Karimnagar district. In the second stage, four villages were randomly chosen from each selected mandal, resulting in a total of 24 villages. In the final stage, from each village, 05 farmers who had received Soil Health Cards were randomly selected, making a total sample size of 120 respondents. The sample size satisfies the minimum requirement for reliable Pearson correlation analysis at the 5% significance level (Cochran, 1977).

2.3 Data Collection

Primary data were collected through personal interviews using a pre-tested, structured interview schedule. The schedule was developed in consultation with subject matter specialists in soil science and agricultural extension, translated into Telugu for ease of administration and pre-tested on 15 farmers outside the study villages to assess clarity and reliability. The schedule comprised two sections: (a) personal, socio-economic and psychological profile variables (age, education, farm size, farming experience, training undergone, extension contact, scientific orientation, economic motivation, achievement motivation, and innovativeness) and (b) a knowledge assessment component consisting of 26 fill in the blank, multiple choice and true/false statements on soil sampling procedures and SHC-based nutrient management. Each correct response was awarded one mark and each incorrect or 'don't know' response was awarded zero, yielding a maximum possible knowledge score of 26.

2.4 Measurement of Variables

Profile variables were measured using standardized and validated scales commonly employed in social science and agricultural extension research (Kerlinger, 1986; Kothari, 2004). Knowledge scores were categorized into three levels, viz., low (up to 8), medium (9–17), and high (18–26), based on the mean and standard deviation of the obtained scores. Pearson’s product–moment correlation coefficient (r) was computed to examine the relationship between each profile variable and the knowledge score, with statistical significance tested at the 1% and 5% probability levels (Field, 2018; Cohen et al., 2003).

2.5 Statistical Analysis

Data were compiled, coded and analysed using IBM SPSS Statistics. Frequency distribution and percentage analyses were used for the profile characteristics and individual knowledge items. Correlation analysis was performed to identify predictors of farmer knowledge.

3. Results and Discussion

3.1 Profile Characteristics of Respondent Farmers

Table 1 presents the distribution of respondents based on their personal, socio-economic, and psychological attributes.

Table 1. Distribution of respondents based on their personal, socio-economic and psychological attributes of the farmers under the study

n=120

S. No.	Variable	Category	Respondents	
			Frequency	Percentage (%)
1	Age			
		Young age (up to 35 years)	28	23.33
		Middle age (35 to 50 years)	62	51.67
		Old age (above 55 years)	30	25.00
2	Education			
		Illiterate	02	01.67
		Primary school	24	20.00
		High school	42	35.00
		Intermediate	32	26.67
		Under graduation	16	13.33
		Post graduation and above	04	03.33
3	Farm size			
		Marginal (0.1- 1.0 ha)	24	20.00
		Small (1.1-2.0 ha)	44	36.67
		Semi- medium (2.1-4.0 ha)	32	26.67
		Medium (4.1-10.00 ha)	18	15.00
		Large (above 10.00 ha)	02	01.66
4.	Farming Experience			
		Low farming experience	28	23.34
		Medium farming experience	56	46.66
		High farming experience	36	30.00
5.	Training undergone			
		Low	33	27.50
		Medium	58	48.34
		High	29	24.16
6.	Extension Contact			
		Low	25	20.83
		Medium	63	52.50
		High	32	26.67
7.	Scientific Orientation			
		Low	38	31.67
		Medium	54	45.00
		High	28	23.33
8.	Economic Motivation			
		Low	32	26.67
		Medium	52	43.33
		High	36	30.00
9.	Achievement Motivation			
		Low	30	25.00
		Medium	53	44.17
		High	37	30.83
10.	Innovativeness			
		Low	34	28.33
		Medium	58	48.33
		High	28	23.34

With respect to age, more than half of the respondents (51.67%) were in the middle-age group (35–50 years), followed by the old-age group (25.00%) and the young-age group (23.33%). The predominance of middle-aged farmers in agricultural activities is consistent with recent studies, which attribute this pattern to the increasing migration of rural youth toward non-farm employment opportunities and urban sectors (Chand et al., 2017). Regarding educational status, the majority of respondents had studied up to high school level (35.00%), followed by intermediate level (26.67%), indicating gradual improvements in rural literacy and educational attainment in India over recent years (Ministry of Statistics and Programme Implementation, 2022; World Bank, 2023).

Farm size distribution revealed that small farmers (1.1–2.0 ha) constituted the largest category (36.67%), which is in line with recent national trends indicating a continued decline in average landholding size and the dominance of small and marginal farmers in Indian agriculture (Agricultural Census Division, 2019; Chand et al., 2017). The prevalence of small and marginal landholdings (56.67% combined) underscores the importance of adopting cost-effective and precision-based nutrient management approaches, such as soil test-based fertilization, to enhance productivity and resource-use efficiency. Regarding farming experience, a plurality of respondents (46.66%) had medium-level experience, suggesting the presence of an active and economically productive farming population within the working-age group.

Concerning the training undergone, about 48.34% of the respondents had medium-level exposure to agricultural training, indicating moderate penetration of extension capacity-building programs. Extension contact was also at a medium level for 52.50% of respondents, which is consistent with recent empirical evidence showing that access to and effectiveness of agricultural extension services in India remain uneven across regions and farmer groups (Biradar et al., 2025). Psychological attributes, including scientific orientation, economic motivation, achievement motivation, and innovativeness, were predominantly observed at medium levels (45.00%, 43.33%, 44.17%, and 48.33%, respectively), indicating considerable scope for improvement through targeted extension interventions and behaviorally informed advisory approaches (Jha et al., 2024; Barman et al., 2025).

3.2 Knowledge of Farmers on Soil Sampling Procedures and SHC-Based Nutrient Management

Table 2 presents the item-wise distribution of respondents' knowledge on soil sampling procedures and SHC-based recommendations.

Table 2. Distribution of respondents according to their level of knowledge on soil sampling procedures and soil health card-based recommendations

n=120

S. No.		Frequency (n)	Percentage (%)
1.	Acid soils can be reclaimed by the application of lime.	79	65.83
2.	The recommended quantity of muriate of potash for paddy cultivation is 16 kg per acre.	70	58.33
3.	Vermicompost is manure produced by using earthworms.	94	78.33
4.	Nitrogenous fertilizers in hybrid cotton should be applied in three split doses.	77	64.17
5.	Zinc deficiency in paddy can be corrected by spraying 5 grams of zinc sulphate per litre of water.	68	56.67
6.	Soil testing services are provided by Soil Testing Laboratories, KVKs/Research Stations and private agencies.	106	88.33
7.	Zinc is not a macro nutrient.	88	73.33
8.	Gypsum is used as a soil amendment for reclaiming sodic (alkali) soils.	78	65.00
9.	Soil samples should not be collected from abnormal areas such as bunds, manure heaps, irrigation channels or wet spots.	96	80.00
10.	Soil samples should be collected in a zigzag manner from the field to obtain a representative sample.	76	63.33
11.	Soil samples should be collected after harvest or before sowing of the crop.	72	60.00

S. No.		Frequency (n)	Percentage (%)
12.	About 8–10 soil cores should be collected from one acre to prepare a composite soil sample.	95	79.17
13.	The Soil Health Card Scheme was started in the year 2015.	86	71.67
14.	The major (macro) nutrients tested in soil are Nitrogen, Phosphorus and Potassium.	92	76.67
15.	The secondary nutrients tested in soil include Sulphur, Calcium and Magnesium.	73	60.83
16.	The micronutrients tested in soil include Zinc, Iron, Manganese, Copper and Boron.	87	72.50
17.	The physical parameters reported in the Soil Health Card include soil pH and Electrical Conductivity (EC).	102	85.00
18.	The recommended fertilizer dose for paddy varies according to soil test values.	69	57.50
19.	The recommended fertilizer dose for maize varies depending on soil fertility status.	84	70.00
20.	Azolla is a suitable biofertilizer for rice cultivation.	74	61.67
21.	In paddy, nitrogenous fertilizers should be applied in three split doses at basal, tillering and panicle initiation stages.	105	87.50
22.	Phosphorus solubilizing bacteria enhance the availability of phosphorus in soil.	94	78.33
23.	Phosphorus fertilizers in paddy should be applied as basal dose.	101	84.17
24.	The commonly used nitrogenous fertilizer is urea.	86	71.67
25.	The Soil Health Card provides crop-wise fertilizer recommendations based on soil test results.	81	67.50
26.	Balanced fertilization helps in maintaining soil health and improving crop productivity.	103	85.83

Among the 26 knowledge items assessed, the highest level of awareness was recorded for the availability of soil testing services at Soil Testing Laboratories, KVKs/Research Stations and private agencies (88.33%), followed by the application of nitrogenous fertilizers in paddy in three split doses (87.50%), the role of balanced fertilization in maintaining soil health and improving crop productivity (85.83%) and the physical parameters reported in Soil Health Cards (SHCs), i.e., soil pH and electrical conductivity (EC) (85.00%). These high awareness levels regarding infrastructure-related services and widely promoted agronomic practices may be attributed to sustained extension efforts, including mass media campaigns, farmer training programs, and field demonstrations, which have been shown to significantly enhance farmers' knowledge and adoption of improved agricultural practices (Davis & Sulaiman, 2014).

Relatively high knowledge was also observed for the need to avoid abnormal areas during soil sampling (80.00%), collection of 8–10 soil cores per acre for composite samples (79.17%), the definition of vermicompost and the role of phosphorus-solubilizing bacteria (78.33% each) and the classification of zinc as a micronutrient (73.33%). These findings suggest that demonstration-oriented extension activities and exposure to organic farming training have adequately addressed certain technical concepts.

Conversely, significant knowledge gaps existed in areas directly linked to precision nutrient management. The correct dose of zinc sulphate for correcting zinc deficiency in paddy (56.67%), the recommended dose of muriate of potash for paddy (58.33%), and the variation of fertiliser dose for paddy with soil test values (57.50%) recorded the lowest percentages. Similar deficiencies in farmers' knowledge regarding micronutrient application and precise fertilizer dosage have been highlighted in recent studies across India, which report that while farmers are generally aware of soil health concepts, their understanding of crop-specific and quantitative nutrient recommendations remains limited (Chundru et al., 2024; Jha et al., 2024; Barman et al., 2025). These findings suggest that although general awareness exists, the technical details embedded in Soil Health Card (SHC) recommendations are not adequately internalized by farmers.

Furthermore, only 60.00% of respondents correctly identified the appropriate timing of soil sampling (after harvest or before sowing) and 63.33% understood the zigzag transect method for collecting representative samples. These gaps are particularly consequential because incorrect sampling undermines the reliability of soil test results and the ensuing recommendations (Das et al., 2020). Encouraging results were noted for the paddy-specific basal application of phosphorus (84.17%) and awareness of the SHC scheme launch year (71.67%), suggesting good uptake of broadly communicated information.

3.3 Overall Knowledge Level

Table 3 presents the categorization of respondents by overall knowledge level.

The majority of respondents (60.00%) fell in the medium knowledge category (score range: 9–17), followed by high knowledge (24.17%; score range: 18–26) and low knowledge (15.83%; score range: up to 8). The predominance of medium-level knowledge is consistent with recent empirical studies on Soil Health Card utilization and soil health management practices across different regions of India, which report that farmers generally possess moderate awareness with gaps in technical aspects (Chundru et al., 2024; Gowda & Shivaramu, 2025). The relatively smaller proportion of farmers with high knowledge highlights the need for intensive capacity-building efforts, particularly in areas such as quantitative fertilizer recommendations, micronutrient management, and scientific soil sampling procedures.

Table 3. Distribution of respondents according to their knowledge level on soil sampling procedures and SHC based recommendations

n=120

S. No.	Category	Score Range	Frequency (n)	Percentage (%)
01.	Low knowledge	Up to 8	19	15.83
02.	Medium knowledge	9 – 17	72	60.00
03.	High knowledge	18 – 26	29	24.17
	Total:		120	100.00

3.4 Correlation between Profile Characteristics and Knowledge Level

Table 4 summarises the Pearson correlation coefficients between farmer profile variables and knowledge level.

Table 4. Correlation between profile characteristics of the farmers and their level of knowledge on soil sampling procedures and SHC based recommendations

n = 120

S. No.	Independent Variables	Correlation Coefficient (r)	Significance
1	Age	-0.112	NS
2	Education	0.462**	Significant
3	Farm size	0.298*	Significant
4	Farming experience	0.145	NS
5	Training undergone	0.518**	Significant
6	Extension contact	0.487**	Significant
7	Scientific orientation	0.436**	Significant
8	Economic motivation	0.321*	Significant
9	Achievement motivation	0.354*	Significant
10	Innovativeness	0.401**	Significant

** Significant at 5% level; ** Significant at 1% level; NS - Non-significant*

Training undergone exhibited the strongest positive correlation with knowledge (r = 0.518**), confirming that structured learning experiences substantially enhance farmers' understanding of soil health management. This finding is consistent with recent studies demonstrating a significant positive relationship between participation in agricultural training programs and farmers’ knowledge as well as adoption of improved practices (Jha et al., 2024). Exposure to training programs facilitates both declarative knowledge (understanding concepts) and procedural knowledge (application skills), which are essential for accurate soil sampling and efficient fertilizer use.

Extension contact was the second strongest predictor (r = 0.487**), affirming the indispensable role of extension systems—including public extension agents, Krishi Vigyan Kendra (KVK) scientists, and input dealers—in knowledge dissemination. This finding is supported by recent empirical evidence demonstrating that access to extension services significantly improves farmers' knowledge, adoption of improved practices, and overall productivity (Biradar et al., 2025). Furthermore, emerging research highlights that modern extension approaches, including digital advisory tools and video-based learning platforms, are enhancing the effectiveness and reach of extension systems in disseminating agricultural knowledge (Coggins et al., 2025). The increasing use of digital extension modalities by state agricultural universities and extension agencies is therefore expected to further strengthen knowledge dissemination among farmers in the coming years.

Education (r = 0.462**) was positively and highly significantly correlated with knowledge, which is consistent with recent empirical studies indicating that higher educational attainment enhances farmers' ability to understand, interpret, and adopt scientific agricultural recommendations (Jha et al., 2024; Barman et al., 2025). Better-educated farmers are more capable of decoding Soil Health Card (SHC) recommendations, interpreting technical information, and making informed decisions regarding nutrient management. Innovativeness (r = 0.401**) also showed a significant relationship, suggesting that farmers with a greater propensity to adopt new ideas and technologies are more likely to acquire and retain knowledge related to soil health management, a finding supported by recent studies on technology adoption behavior in agriculture (Barman et al., 2025).

Scientific orientation (r = 0.436**) was significantly associated with knowledge, indicating that farmers who approach agricultural problems analytically are better equipped to understand the scientific basis of soil testing and balanced fertilization. This finding is supported by recent studies demonstrating that cognitive and behavioral traits significantly influence farmers' knowledge and adoption of improved agricultural practices (Jha et al., 2024; Barman et al., 2025). Achievement motivation (r = 0.354*) and economic motivation (r = 0.321*) were significant at the 5% level, suggesting that goal-oriented farmers who perceive agriculture as a commercial enterprise are more likely to acquire knowledge that enhances productivity and profitability.

Farm size showed a weak but significant positive correlation (r = 0.298*), supporting the view that farmers with larger landholdings tend to have greater exposure to diverse soil conditions, improved access to extension services, and higher economic incentives to adopt precision nutrient management practices (Jha et al., 2024). However, the relatively low magnitude of correlation indicates that farm size alone is not a strong determinant, and targeted interventions for small and marginal farmers remain essential. Neither age (r = -0.112, NS) nor farming experience (r = 0.145, NS) exhibited significant relationships with knowledge, suggesting that mere years of farming do not necessarily translate into a scientifically accurate understanding of soil management practices. Similar observations have been reported in recent studies, which highlight that reliance on traditional practices and experiential knowledge may limit the adoption of scientifically recommended practices among farmers (Barman et al., 2025).

4. Conclusions and Recommendations

The study reveals that the majority of farmers in Karimnagar district possess a medium level of knowledge regarding soil sampling procedures and SHC-based nutrient management. While general awareness about soil testing infrastructure, the SHC scheme, and broad fertiliser management principles is reasonably satisfactory, critical gaps persist in the domain of quantitative, crop-specific recommendations – particularly the recommended doses for micronutrients like zinc sulphate, secondary nutrients, and potash – and in the technical details of representative soil sampling. These gaps, if unaddressed, can compromise the scientific integrity of soil test results and the accuracy of crop-specific fertilizer recommendations derived from the SHC.

Training undergone, extension contact, education, scientific orientation, and innovativeness emerged as the most significant positive predictors of knowledge, collectively pointing toward a multi-pronged extension strategy. The following recommendations are advanced: (1) intensive soil sampling demonstrations and field visits should be organized at critical crop-stage periods to impart hands-on procedural knowledge; (2) SHC-based training modules should explicitly address micronutrient management and dose-specific recommendations using local crop case studies; (3) digital extension tools such as farmer-facing mobile applications, interactive voice response systems, and social media campaigns should be deployed to improve extension contact frequency and reach; (4) functionally literate farmers and innovators within villages should be trained as 'soil health champions' or lead farmers to facilitate peer-to-peer knowledge dissemination; and (5) extension programs should systematically target small and marginal farmers who may lack the social and economic capital to independently access information.

Future research should employ longitudinal designs to assess whether enhanced knowledge translates into behavioural change (actual adoption of soil sampling and SHC recommendations) and improved soil health and crop productivity outcomes. Multi-district comparative studies covering the entire Telangana state would generate more generalizable findings to guide state-level extension policy.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/153844