Analysis of Key Determinants Influencing Fertilizer Management in Major Field Crops of Telangana

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ABSTRACT

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| Balanced and efficient fertilizer application plays a vital role in achieving sustainable crop production and maintaining long-term soil health. The present study was conducted in 2024 with two primary objectives: (i) to assess the determinants of fertilizer management in major field crops, and (ii) to analyze the relationship between these determinants and the fertilizer management practices adopted by farmers. A combination of ex-post facto and exploratory research designs was employed. Telangana state was purposively selected due to its consistently high ranking in nutrient consumption among Indian states. Six field crops with the highest area under cultivation over a five-year period were identified. For each crop, one cultivating district was randomly selected. From each district, two mandals were chosen, and within each mandal, three villages were randomly selected, resulting in a total of 36 villages. Ten farmers were randomly selected from each village, yielding a final sample of 360 farmers. The study examined 25 independent variables and three dependent variables representing knowledge and attitude towards fertilizer best management practices (FBMPs), as well as actual fertilizer management. Data were collected using a structured interview schedule and analyzed using appropriate statistical tools, including the Multivariate General Linear Model (MGLM), correlation coefficient and Kruskal-Wallis test. Findings indicated that most farmers had elementary education, low experience in crop cultivation, low social participation, and medium levels of extension contact, information access, scientific orientation, economic motivation, institutional access, capital availability, and input availability. Sustainability orientation was generally low, and farmers largely followed a crop-based farming system. The Kruskal-Wallis test revealed significant differences across farmer groups for key determinants such as education, experience, extension contact, information sources, scientific orientation, economic motivation, institutional and capital access, input availability, and farming system. Correlation coefficient revealed that, these factors were also found to be positively and significantly associated with fertilizer management. |

*Keywords: Determinants, Factors, Profile Characteristics, Correlation, Relationship, Association, Nutrient Management, Socio Economic Characteristics*

1. INTRODUCTION

Efficient and balanced fertilizer use is critical to ensuring sustainable agricultural productivity and maintaining soil health. However, trends in nutrient consumption across Indian states reveal significant disparities and imbalances. Telangana ranked first in the consumption of plant nutrients (NPK per hectare) among Indian states in 2019, followed by Bihar, Haryana, Punjab, and Andhra Pradesh (Srinivasarao, 2021). While such high input use may reflect the region's intensive agricultural practices, it also signals a potential risk of nutrient misuse, leading to long-term soil degradation and environmental concerns. During 2009–2011, in earliest Andhra Pradesh, nitrogen and phosphorus use exceeded recommended levels by 65.52% and 44.83%, respectively, whereas potassium use showed a deficit of 8.73% (Chand and Pavithra, 2015). Such disproportionate nutrient application patterns suggest a skewed understanding of crop-specific and soil-specific nutrient needs among farmers. In more recent years, Telangana’s position in overall macronutrient consumption declined, ranking ninth in 2020–21. Still, the nutrient usage per hectare remained substantial, with 129.06 kg of nitrogen, 52.36 kg of phosphorus, and 19.11 kg of potassium, culminating in a total macronutrient consumption of 200.53 kg/ha (Department of Agriculture, Govt. of Telangana, 2021–22). Despite this high input use, reports indicate that nitrogen deficiency (<44%) is prevalent in districts such as Nizamabad, Warangal, and Nalgonda, while phosphorus deficiency (<55%) is widespread in areas like Adilabad, Medak, Mahbubnagar, and Nizamabad. In addition to chemical fertilizer imbalances, the use of organic and biological inputs remains limited. No district in Telangana reported farmyard manure (FYM) use covering more than 75% of the cultivated area (Bora, 2022). Likewise, the state ranked low in biofertilizer production, placing 13th in solid biofertilizers and 12th in liquid biofertilizers among all Indian states and union territories in 2020–21, with output volumes remaining below 5,000 tonnes (Khurana and Kumar, 2022). These trends highlight not only the imbalance in nutrient application but also the underutilization of alternative, sustainable fertilization methods. Given these concerns, it becomes essential to understand the factors influencing fertilizer management at the farm level. Farmer behaviour regarding fertilizer use is shaped by a variety of determinants, ranging from socio-economic to institutional and psychological factors. Despite the importance of such analysis, limited empirical studies have comprehensively examined these determinants in the context of Telangana, especially across its major field crops. To address this gap, the present study aims to explore the underlying factors that govern fertilizer management practices among farmers cultivating major crops in Telangana. To direct the investigation, the following null hypotheses were formulated: (1) There is no significant difference in the identified determinants of fertilizer management across different farmer groups and (2) The determinants do not significantly influence fertilizer management practices in major field crops. Accordingly, the specific objectives of the study were: (1) To assess the determinants of fertilizer management in major field crops and (2) To analyze the relationship between these determinants and the fertilizer management practices adopted by farmers.

2. methodology

The study was undertaken in the year 2024, by adopting an ex-post facto and exploratory research designs to investigate the research objectives. Telangana state was purposively chosen as the study area, considering its prominent role in fertilizer consumption across India. In terms of macronutrient consumption per hectare, Telangana held the second position in 2018–19, trailing only Punjab, and maintained a high ranking in subsequent years *i.e* seventh in 2019–20 and sixth in 2020–21 (Directorate of Economics and Statistics, Government of India, 2022). The researcher's contextual knowledge of the region and the absence of similar comprehensive studies in Telangana further supported its selection. To determine the most relevant crops, data spanning five agricultural years (2017–18 to 2021–22) were examined, focusing on area coverage during kharif and rabi seasons. Six field crops with the largest acreage were purposively identified. Following this, district-level cultivation data for these crops were obtained, and one district per crop was randomly selected from the group of major cultivating districts. To ensure representation across ecological diversity, two districts from each of Telangana’s agro-climatic zones were included. The final set of districts and corresponding crops were: Paddy from Nizamabad (North Telangana Zone), Cotton from Nalgonda (South Telangana Zone), Maize from Warangal (Central Telangana Zone), Red gram from Vikarabad (South Telangana Zone), Soybean from Sangareddy (Central Telangana Zone) and Bengal gram from Adilabad (North Telangana Zone). Within each selected district, two mandals growing the identified crop were randomly selected, totalling 12 mandals. From each mandal, three villages were randomly chosen, giving 36 villages in all. In each village, ten farmers engaged in cultivating the respective crop were selected through simple random sampling. This process resulted in a total sample size of 360 farmers. The study initially involved twenty five independent variables and one dependent variable, for which an interview schedule was meticulously developed. Primary data collection was carried out through personal interviews, and responses were translated into quantitative scores using standardized scoring methods. The collected data were then processed and analyzed using suitable statistical techniques, including frequencies, percentages, mean, standard deviation, rank analysis, correlation coefficients, Multivariate General Linear Model, the Kruskal-Wallis H test, and Dunn’s post-hoc test for multiple comparisons. After running the multivariate general linear model, those twelve determinants which affected fertilizer management significantly were presented in the study.

3. results and discussion

**3.1 Analysis of Key Determinants Influencing Fertilizer Management in Major Field Crops**

The distribution of key determinants of fertilizer management in major field crops is presented in Table 1. Pairwise comparison of farmer groups on key determinants based on mean rank as per Kruskal-Wallis test is presented in Table 2.

**3.1.1 Education**

Overall, less than one fourth (24.17%) of the farmers had an education level up to primary school, followed by middle school (21.94%), high school (17.50%), illiterate (20.00%), intermediate (10.83%), those who could read and write (3.89%), and graduation (1.11%). Education levels varied significantly among the different farmer groups (Chi-square = 81.018, df = 5, *P* =.000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in education between paddy (*P* = .000) and maize (*P* = .000) farmers compared to cotton, red gram, soybean, and Bengal gram farmers.Less than half of the farmers were either illiterate or had completed only primary education. The reasons for this might include a lack of interest in education or the unavailability of schools in their locality. Similarly, less than half of the farmers had completed primary and secondary education. This might be due to limited educational facilities during their school-going years. Many families relied on farming as their primary source of income; hence, children often had to join agricultural work at an early age. In the past, the importance of education was rarely understood in rural areas, and other professions were not considered prestigious, which may have hindered educational attainment. However, families with a higher socioeconomic status recognized the value of education and supported their children’s schooling wherever institutional facilities were available. These individuals attained education up to high school or intermediate levels. They might not have found better job opportunities or may have chosen farming over other jobs, as it was considered a prestigious occupation a few decades ago. The presence of young farmers and greater land availability might have further motivated them to continue farming, as it was more profitable than other employment options (Abdollahzadeh *et al.,* 2015), (Ben Khadda *et al.,* 2021), (Swamy, 2023) and (Kemekar and Salunkhe, 2024a)

**Table 1. Distribution of key determinants of fertilizer management in major field crops (n=360)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Categories** | **Farmer groups** | | | | | | |
| **Paddy**  **(n1=60)** | **Cotton**  **(n2=60)** | **Maize**  **(n3=60)** | **Red gram**  **(n4=60)** | **Soybean**  **(n5=60)** | **Bengal gram**  **(n6=60)** | **Overall**  **(n=360)** |
| **F**  **(%)** | **F**  **(%)** | **F**  **(%)** | **F**  **(%)** | **F**  **(%)** | **F**  **(%)** | **F**  **(%)** |
| **Education** | Illiterate | 3 (5.00) | 23 (38.33) | 3 (5.00) | 20 (33.33) | 14 (23.33) | 9 (15.00) | 72 (20.00) |
| Can read only | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 2 (3.33) | 2 (0.56) |
| Can read and write | 3 (5.00) | 0 (0.00) | 0 (0.00) | 4 (6.67) | 0 (0.00) | 7 (11.67) | 14 (3.89) |
| Primary school | 7 (11.67) | 18 (30.00) | 9 (15.00) | 20 (33.33) | 15 (25.00) | 18 (30.00) | 87 (24.17) |
| Middle school | 10 (16.67) | 13 (21.67) | 16 (26.67) | 10 (16.67) | 20 (33.33) | 10 (16.67) | 79 (21.94) |
| High school | 19 (31.67) | 6 (10.00) | 22 (36.67) | 4 (6.67) | 5 (8.33) | 7 (11.67) | 63 (17.50) |
| Intermediate | 18 (30.00) | 0 (0.00) | 8 (13.33) | 2 (3.33) | 6 (10.00) | 5 (8.33) | 39 (10.83) |
| Graduation | 0 (0.00) | 0 (0.00) | 2 (3.33) | 0 (0.00) | 0 (0.00) | 2 (3.33) | 4 (1.11) |
| **Mean ()**  **Rank** | 5.50 (I) | 3.27 (VI) | 5.38 (II) | 3.33 (V) | 4.10 (IV) | 4.15 (III) | 4.29 |
| **SD ()** | 1.56 | 1.89 | 1.43 | 1.85 | 1.93 | 1.89 | 1.97 |
| **Experience in** **selected crop cultivation** | Low  (1.00 - 13.33) | 29 (48.33) | 30 (50.00) | 16 (26.67) | 19 (31.67) | 60 (100) | 38 (63.33) | 192 (53.33) |
| Medium  (13.33 - 25.67) | 24 (40.00) | 30 (50.00) | 31 (51.67) | 24 (40.00) | 0 (0.00) | 22 (36.67) | 131 (36.39) |
| High  (25.67 - 38.00) | 7 (11.67) | 0 (0.00) | 13 (21.67) | 17 (28.33) | 0 (0.00) | 0 (0.00) | 37 (10.28) |
| **Mean ()**  **Rank** | 15.45 (III) | 12.43 (IV) | 18.45 (II) | 19.93 (I) | 4.02 (VI) | 11.10 (V) | 13.56 |
| **SD ()** | 7.39 | 6.02 | 9.15 | 10.63 | 1.35 | 6.04 | 9.02 |
| **Social participation** | Low  (1.00 - 1.67) | 33 (55.00) | 28 (46.67) | 31 (51.67) | 38 (63.33) | 33 (55.00) | 24 (40.00) | 187 (51.94) |
| Medium  (1.67 - 2.33) | 21 (35.00) | 26 (43.33) | 24 (40.00) | 20 (33.33) | 23 (38.33) | 30 (50.00) | 144 (40.00) |
| High  (2.33 - 3.00) | 6 (10.00) | 6 (10.00) | 5 (8.33) | 2 (3.33) | 4 (6.67) | 6 (10.00) | 29 (8.06) |
| **Mean ()**  **Rank** | 1.58 (III) | 1.63 (II) | 1.57 (IV) | 1.40 (VI) | 1.52 (V) | 1.70 (I) | 1.56 |
| **SD ()** | 0.70 | 0.66 | 0.65 | 0.56 | 0.62 | 0.65 | 0.64 |
| **Extension contact** | Low  (19.00 - 24.33) | 9 (15.00) | 11 (18.33) | 7 (11.67) | 29 (48.33) | 19 (31.67) | 17 (28.33) | 92 (25.56) |
| Medium  (24.33 - 29.67) | 27 (45.00) | 30 (50.00) | 24 (40.00) | 22 (36.67) | 25 (41.67) | 25 (41.67) | 153 (42.50) |
| High  (29.67 - 35.00) | 24 (40.00) | 19 (31.67) | 29 (48.33) | 9 (15.00) | 16 (26.67) | 18 (30.00) | 115 (31.94) |
| **Mean ()**  **Rank** | 28.42 (I) | 27.60 (III) | 28.25 (II) | 24.15 (VI) | 26.12 (V) | 26.45 (IV) | 26.82 |
| **SD ()** | 4.44 | 4.11 | 3.44 | 4.04 | 4.44 | 4.80 | 4.44 |
| **Source of information on fertilizers** | Low  (22.00 - 27.67) | 16 (26.67) | 20 (33.33) | 16 (26.67) | 27 (45.00) | 21 (35.00) | 20 (33.33) | 120 (33.33) |
| Medium (27.67 - 33.33) | 28 (46.67) | 28 (46.67) | 25 (41.67) | 27 (45.00) | 29 (48.33) | 28 (46.67) | 165 (45.83) |
| High  (33.33 - 39.00) | 16 (26.67) | 12 (20.00) | 19 (31.67) | 6 (10.00) | 10 (16.67) | 12 (20.00) | 75 (20.83) |
| **Mean ()**  **Rank** | 30.20 (I) | 28.58 (V) | 29.73 (II) | 27.42 (VI) | 28.60 (IV) | 29.17 (III) | 28.93 |
| **SD ()** | 4.32 | 3.73 | 4.06 | 3.71 | 3.69 | 4.51 | 4.12 |
| **Scientific orientation** | Low  (9.00 -16.00) | 13 (21.67) | 18 (30.00) | 7 (11.67) | 28 (46.67) | 22 (36.67) | 19 (31.67) | 107 (29.72) |
| Medium  (16.00 - 23.00) | 25 (41.67) | 27 (45.00) | 28 (46.67) | 22 (36.67) | 23 (38.33) | 27 (45.00) | 152 (42.22) |
| High  (23.00 - 30.00) | 22 (36.67) | 15 (25.00) | 25 (41.67) | 10 (16.67) | 15 (25.00) | 14 (23.33) | 101 (28.06) |
| **Mean ()**  **Rank** | 20.42 (II) | 19.42 (III) | 22.43 (I) | 16.78 (VI) | 18.95 (V) | 19.25 (IV) | 19.51 |
| **SD ()** | 5.13 | 5.10 | 4.82 | 4.82 | 5.02 | 5.19 | 5.25 |
| **Economic motivation** | Low  (12.00 - 18.00) | 8 (13.33) | 21 (35.00) | 6 (10.00) | 26 (43.33) | 19 (31.67) | 14 (23.33) | 93 (25.83) |
| Medium  (18.00 - 24.00) | 21 (35.00) | 23 (38.33) | 25 (41.67) | 23 (38.33) | 23 (38.33) | 23 (38.33) | 138 (38.33) |
| High  (24.00 - 30.00) | 31 (51.67) | 16 (26.67) | 29 (48.33) | 11 (18.33) | 18 (30.00) | 23 (38.33) | 129 (35.83) |
| **Mean ()**  **Rank** | 22.58 (I) | 21.13 (IV) | 22.08 (II) | 18.43 (VI) | 20.70 (V) | 21.90 (III) | 21.13 |
| **SD ()** | 3.76 | 5.69 | 4.07 | 4.18 | 4.36 | 5.12 | 4.75 |
| **Sustainability orientation** | Low  (18.00 - 21.99) | 27 (45.00) | 22 (36.67) | 27 (45.00) | 29 (48.33) | 28 (46.67) | 20 (33.33) | 151 (41.94) |
| Medium  (22.00 - 25.99) | 19 (31.67) | 20 (33.33) | 20 (33.33) | 17 (28.33) | 19 (31.67) | 19 (31.67) | 111 (30.83) |
| High  (26.00 - 30.00) | 14 (23.33) | 18 (30.00) | 13 (21.67) | 14 (23.33) | 13 (21.67) | 21 (35.00) | 98 (27.22) |
| **Mean ()**  **Rank** | 23.43 (I) | 23.08 (III) | 23.13 (II) | 22.82 (VI) | 22.97 (V) | 23.02 (IV) | 23.08 |
| **SD ()** | 3.64 | 3.66 | 3.41 | 3.52 | 3.73 | 3.45 | 3.55 |
| **Institutional access** | Low  (52.00 - 57.33) | 12 (20.00) | 19 (31.67) | 17 (28.33) | 29 (48.33) | 25 (41.67) | 17 (28.33) | 119 (33.05) |
| Medium  (57.33 - 62.67) | 19 (31.67) | 26 (43.33) | 22 (36.67) | 21 (35.00) | 22 (36.67) | 20 (33.33) | 130 (36.11) |
| High  (62.67 - 68.00) | 29 (48.33) | 15 (25.00) | 21 (35.00) | 10 (16.67) | 13 (21.67) | 23 (38.33) | 111 (30.83) |
| **Mean ()**  **Rank** | 61.00 (I) | 59.17 (IV) | 60.03 (III) | 57.90 (VI) | 58.77 (V) | 60.12 (II) | 59.50 |
| **SD ()** | 4.14 | 4.37 | 4.73 | 3.83 | 3.83 | 3.85 | 4.23 |
| **Capital availability** | Low  (54.00 - 63.00) | 7 (11.67) | 9 (15.00) | 7 (11.67) | 18 (30.00) | 15 (25.00) | 10 (16.67) | 66 (18.33) |
| Medium  (63.00 - 72.00) | 30 (50.00) | 42 (70.00) | 37 (61.67) | 37 (61.67) | 33 (55.00) | 36 (60.00) | 215 (59.72) |
| High  (72.00 - 81.00) | 23 (38.33) | 9 (15.00) | 16 (26.67) | 5 (8.33) | 12 (20.00) | 14 (23.33) | 79 (21.94) |
| **Mean ()**  **Rank** | 69.10 (I) | 65.80 (V) | 67.23 (II) | 63.45 (VI) | 66.20 (IV) | 66.40 (III) | 66.36 |
| **SD ()** | 5.99 | 4.65 | 5.04 | 5.20 | 5.92 | 5.94 | 5.70 |
| **Manures and fertilizers availability** | Low  (183 - 197) | 16 (26.67) | 21 (35.00) | 16 (26.67) | 28 (46.67) | 26 (43.33) | 14 (23.33) | 121 (33.61) |
| Medium  (197 - 211) | 17 (28.33) | 39 (65.00) | 22 (36.67) | 32 (53.33) | 34 (56.67) | 15 (25.00) | 159 (44.16) |
| High  (211 - 225) | 27 (45.00) | 0 (0.00) | 22 (36.67) | 0 (0.00) | 0 (0.00) | 31 (51.67) | 80 (22.22) |
| **Mean ()**  **Rank** | 204.52 (II) | 197.52 (IV) | 203.92 (III) | 195.68 (VI) | 196.57 (V) | 208.17 (I) | 201.06 |
| **SD ()** | 11.25 | 2.45 | 9.19 | 6.04 | 5.59 | 12.14 | 9.65 |
| **Farming system** | Crop | 43 (71.67) | 24 (40.00) | 42 (70.00) | 47 (78.33) | 45 (75.00) | 54 (90.00) | 255 (70.83) |
| Crop + Dairy | 10 (16.67) | 24 (40.00) | 15 (25.00) | 6 (10.00) | 8 (13.33) | 4 (6.67) | 67 (18.61) |
| Crop + Sheep farming | 5 (8.33) | 3 (5.00) | 0 (0.00) | 4 (6.67) | 0 (0.00) | 0 (0.00) | 12 (3.33) |
| Crop + Goatery | 2 (3.33) | 3 (5.00) | 3 (5.00) | 3 (5.00) | 7 (11.67) | 2 (3.33) | 20 (5.56) |
| Crop + Poultry | 0 (0.00) | 6 (10.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 6 (1.67) |
| **Mean ()**  **Rank** | 1.28 (III) | 1.60 (I) | 1.30 (II) | 1.22 (V) | 1.25 (IV) | 1.10 (VI) | 1.29 |
| **SD ()** | 0.45 | 0.49 | 0.46 | 0.42 | 0.44 | 0.30 | 0.45 |

**3.1.2 Experience in selected crop cultivation**

More than half (53.33%) of the farmers had a low level of experience in selected crop cultivation, followed by medium (36.39%) and high (10.28%) levels of experience. Experience in selected crop cultivation varied significantly among the different farmer groups (Chi-square = 90.499, df = 5, *P* = .000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in experience in selected crop cultivation between soybean farmers (*P* =.000) compared to all other farmer groups and Bengal gram (*P* =.007), as well as between Bengal gram (*P* =.000) and cotton farmers compared to maize (*P* =.02) and red gram (*P* =.03) farmers. Most of the paddy and cotton farmers fall into the low and medium experience categories. The reason for this among paddy farmers might be the shift from sugarcane cultivation to paddy cultivation a decade ago or the cultivation of turmeric in some alternate years. Since half of the cotton farmers had irrigation facilities, they might have cultivated paddy instead of cotton, which lowered their number of years in cotton cultivation. In the case of maize and red gram, the majority of farmers fall into the medium and high experience categories. This might be because they have been cultivating similar crops year after year and due to the presence of older farmers. All the soybean farmers had low experience, because they started cultivating soybean only in the past five years. A similar situation is seen in the case of Bengal gram, where the majority have started cultivating it recently, while a few farmers have been cultivating it for the last fifteen years, resulting in low and medium experience categories (Choudhary, 2010) and (Ibeagwa *et al.,* 2022).

**3.1.3 Social participation**

More than half (51.94%) of the farmers had a low level of social participation, followed by medium (40.00%) and high (8.06%) levels of participation. Social participation levels did not significantly vary among the different farmer groups (Chi-square = 7.835, df = 5, *P* = .17), resulting in acceptance of the null hypothesis.Half of the farmers had lower social participation, which might be due to either the unavailability of social institutions in their villages or the lack of participation by the farmers in social groups. The high level of social participation resulted from the involvement of young farmers in youth clubs and middle-aged farmers in community groups, religious groups, Primary Agricultural Cooperative Societies, and Gram Sabhas. Those who had limited participation in some of these social institutions exhibited a medium level of social participation (Akomdo *et al.,* 2023).

**3.1.4 Extension contact**

More than two fifths (42.50%) of the farmers had a medium level of extension contact, followed by high (31.94%) and low (25.56%) levels of extension contact. Extension contact levels varied significantly among the different farmer groups (Chi-square = 38.180, df = 5, *P* =.000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in extension contact between red gram farmers compared to paddy (*P* = *.*000), cotton (*P* = *.*001) and maize (*P* = *.*000) farmers.Most of the farmers had a medium level of extension contact, which might be due to the limited number of extension workers available to cover larger farming populations or limited outreach efforts. Moreover, extension personnel often use group-based contact methods, through which they reach many farmers at once, but this may not result in deep individual contact. Furthermore, nowadays, most farmer-related needs are addressed through online modes at cyber kiosks, which further reduces contact with extension workers. Some farmers may approach extension workers only when they face a problem or need specific inputs. Most of the farmers were middle-aged and had a moderate level of education, which might have allowed them to be open to seeking help, but they might not have utilized the services to their full extent. Sometimes, farmers may perceive that extension advice is useful but not always applicable, or inconsistent past results might lead to only medium-level extension contact. The high level of extension contact might be due to homophilous communication between the farmers and extension workers, resulting from similarities in education and income levels. Furthermore, a few farmers recognize the value of extension services, regularly participate in extension programmes, and seek advice, which helps build mutual trust and rapport. Farmers with higher incomes or social status may try to maintain contact with extension workers, as it adds prestige to their profile in the village. Farmers with lower education levels or older age might be less inclined to use extension services or less able to engage in extension programmes. This might be due to the farmer’s limited motivation and trust in extension services or their belief that traditional farming methods and their vast experience are sufficient to solve their problems (Hasan *et al.,* 2015), (Islam, 2021) and (Kemekar and Salunkhe, 2024b).

**3.1.5 Source of information on fertilizers**

Less than half (45.83%) of the farmers had a medium level of access to sources of information on fertilizers, followed by low (33.33%) and high (20.83%) levels of access. Access to sources of information on fertilizers varied significantly among the different farmer groups (Chi-square = 17.313, df = 5, *P* =.004), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in sources of information on fertilizers between red gram farmers compared to paddy farmers (*P* =.003) and maize farmers (*P* = .03).Less than half of the farmers had a medium level of sources of information on fertilizers. This might be due to the medium level of extension contact possessed by the farmers. Most of the farmers seek information from input dealers and company representatives regarding new types of fertilizers, etc. Some of the farmers believed that they had enough knowledge about dosage, timing, and methods of fertilizer application; hence, they didn’t feel the need to collect more information on fertilizers. Moreover, those with extension contact had sought information related to pests, diseases, and other problems, but not about fertilizers. Hence, they fell under the low category. Those who had trust in the sources and believed that the information would help them make improvements in their fertilizer application continuously sought information on fertilizers, which led them to fall under the high category (Mahantesh, 2008), (Parihar, 2017) and (Dave and Snehal, 2018).

**3.1.6 Scientific orientation**

More than two fifths (42.22%) of the farmers had a medium level of scientific orientation, followed by low (29.72%) and high (28.06%) levels of scientific orientation. Scientific orientation levels varied significantly among the different farmer groups (Chi-square = 35.211, df = 5, *P* = .000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in scientific orientation between maize farmers compared to red gram (*P* =.000), soybean (*P* =.004), cotton (*P* =.03) and Bengal gram (*P* =.02) farmers, as well as between paddy and red gram farmers (*P* =.005). Two-fourths of the farmers had medium scientific orientation, followed by an equal number of farmers having low and high scientific orientation. It might be due to moderate exposure to extension services and information sources, which increases basic awareness but not deep understanding. Most farmers had primary to middle school education, which leads to a limited understanding of scientific concepts. Traditional beliefs, a risk-averse mindset, and financial constraints also play a role, as many small and marginal farmers are cautious about trying new methods without guaranteed returns. Limited social participation further affects scientific orientation. Paddy and maize farmers had a medium to high level of scientific orientation because of higher education and income levels and greater contact with extension personnel. A higher proportion of farmers with low scientific orientation can be seen among red gram and soybean farmers, which might be because of lower education and income levels and lesser extension contact (Rajkhowa, 2019) and (Verma, 2019).

**3.1.7 Economic motivation**

More than one third (38.33%) of the farmers had a medium level of economic motivation, followed by high (35.83%) and low (25.83%) levels of economic motivation. Economic motivation levels varied significantly among the different farmer groups (Chi-square = 29.664, df = 5, *P* =.000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in economic motivation between red gram farmers compared to paddy (*P* =.000), maize (*P* =.000), and Bengal gram (*P* =.002) farmers.Most of the farmers had a medium to high level of economic motivation. This might be due to higher annual income, higher education, scientific orientation, and other situational factors such as irrigation availability and farm size. On the other hand, lower economic motivation was observed among red gram, soybean, and cotton farmers due to lower annual incomes, limited farm sizes, lower education levels, limited irrigation facilities, and limited extension contact to a certain extent. Furthermore, the lack of credit facilities, higher input prices, lower market prices, and complex technologies also limit economic motivation (Sharma *et al.,* 2014) and (Bagri, 2020).

**Table 2.** **Pairwise comparison of farmer groups on key determinants based on mean rank as per Kruskal-Wallis test**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Determinants** | **Farmer groups** | **Mean rank** | **P** | **C** | **M** | **R** | **S** | **B** |
| **Education**  χ2 (5) = 81.018  *P* =.000 | Paddy | 248.80 |  |  |  |  |  |  |
| Cotton | 128.78 | \*\* |  | \*\* |  |  |  |
| Maize | 240.71 |  |  |  |  |  |  |
| Red gram | 127.73 | \*\* |  | \*\* |  |  |  |
| Soybean | 170.72 | \*\* |  | \*\* |  |  |  |
| Bengal gram | 166.27 | \*\* |  | \*\* |  |  |  |
| **Experience in selected crop cultivation**  *χ2 (5) = 90.499, P* = .000 | Paddy | 189.74 |  |  |  |  |  |  |
| Cotton | 177.25 |  |  | \* | \* |  |  |
| Maize | 233.13 |  |  |  |  |  |  |
| Red gram | 230.66 |  |  |  |  |  |  |
| Soybean | 96.50 | \*\* | \*\* | \*\* | \*\* |  | \*\* |
| Bengal gram | 155.72 |  |  | \*\* | \*\* |  |  |
| **Social participation χ**2 (5) = 7.835, *P* = .17 | | | | | | | | |
| **Extension contact**  *χ2 (5) = 38.180, P* = .000 | Paddy | 214.03 |  |  |  |  |  |  |
| Cotton | 197.28 |  |  |  |  |  |  |
| Maize | 216.97 |  |  |  |  |  |  |
| Red gram | 119.08 | \*\* | \*\* | \*\* |  |  |  |
| Soybean | 165.53 |  |  |  |  |  |  |
| Bengal gram | 170.11 |  |  |  |  |  |  |
| **Source of information on fertilizers**  *χ2 (5) = 17.313, P* = .004 | Paddy | 210.71 |  |  |  |  |  |  |
| Cotton | 169.71 |  |  |  |  |  |  |
| Maize | 199.89 |  |  |  |  |  |  |
| Red gram | 140.95 | \*\* |  | \* |  |  |  |
| Soybean | 172.83 |  |  |  |  |  |  |
| Bengal gram | 188.91 |  |  |  |  |  |  |
| **Scientific orientation**  *χ2 (5) = 35.211, P* = .000 | Paddy | 197.03 |  |  |  |  |  |  |
| Cotton | 177.15 |  |  | \* |  |  |  |
| Maize | 237.02 |  |  |  |  |  |  |
| Red gram | 128.96 | \*\* |  | \*\* |  |  |  |
| Soybean | 167.55 |  |  | \*\* |  |  |  |
| Bengal gram | 175.30 |  |  | \* |  |  |  |
| **Economic motivation**  *χ2 (5) = 29.664, P* = .000 | Paddy | 214.02 |  |  |  |  |  |  |
| Cotton | 175.29 |  |  |  |  |  |  |
| Maize | 204.34 |  |  |  |  |  |  |
| Red gram | 122.68 | \*\* |  | \*\* |  |  | \*\* |
| Soybean | 172.14 |  |  |  |  |  |  |
| Bengal gram | 194.53 |  |  |  |  |  |  |
| **Sustainability orientation** *χ2 (5) = 1.181, P* = .95 | | | | | | | | |
| **Institutional access**  *χ2 (5) = 19.304, P* = .002 | Paddy | 215.33 |  |  |  |  |  |  |
| Cotton | 174.93 |  |  |  |  |  |  |
| Maize | 191.68 |  |  |  |  |  |  |
| Red gram | 140.32 | \*\* |  |  |  |  |  |
| Soybean | 164.95 |  |  |  |  |  |  |
| Bengal gram | 195.80 |  |  |  |  |  |  |
| **Capital availability**  *χ2 (5) = 27.693, P* = .000 | Paddy | 227.19 |  |  |  |  |  |  |
| Cotton | 169.90 | \* |  |  |  |  |  |
| Maize | 199.48 |  |  |  |  |  |  |
| Red gram | 133.11 | \*\* |  | \*\* |  |  |  |
| Soybean | 171.75 |  |  |  |  |  |  |
| Bengal gram | 181.58 |  |  |  |  |  |  |
| **Manures and fertilizers availability**  *χ2 (5) = 58.694, P* = .000 | Paddy | 218.45 |  |  |  |  |  |  |
| Cotton | 145.23 | \*\* | \* |  |  |  | \*\* |
| Maize | 206.06 |  |  |  |  |  |  |
| Red gram | 131.32 | \*\* | \*\* |  |  |  | \*\* |
| Soybean | 143.13 | \*\* | \* |  |  |  | \*\* |
| Bengal gram | 238.83 |  |  |  |  |  |  |
| **Farming system**  *χ2 (5) = 40.345, P* = .000 | Paddy | 179.00 |  |  | \*\* |  |  |  |
| Cotton | 236.00 |  |  |  |  |  |  |
| Maize | 182.00 |  |  | \*\* |  |  |  |
| Red gram | 167.00 |  |  | \*\* |  |  |  |
| Soybean | 173.00 |  |  | \*\* |  |  |  |
| Bengal gram | 146.00 |  |  | \*\* |  |  |  |
| *\*\*Significance at 0.05 level of probability, \*Significance at 0.01 level of probability*  P = Paddy, C = Cotton, M = Maize, R = Red gram S = Soybean, B= Bengal gram | | | | | | | | |

**3.1.8 Sustainability orientation**

More than two fifths (41.94%) of the farmers had a low level of sustainability orientation, followed by medium (30.83%) and high (27.22%) levels of sustainability orientation. Sustainability orientation levels did not significantly vary among the different farmer groups (Chi-square = 1.181, df = 5, p = .95), resulting in acceptance of the null hypothesis.Most of the farmers had a low level of sustainability orientation, followed by medium and high level of sustainability orientation. The reasons for these results might include a lack of awareness among farmers about sustainable farming practices, such as balanced nutrient management, nutrient recycling, and soil and water conservation. Many farmers were unable to recognize the importance of these practices in relation to nutrient conservation. Additionally, they lacked awareness of the long-term impacts of unsustainable practices on their farms and crops. With increased competition for higher yields, farmers were prioritizing profits over sustainability. The only aspect of sustainability that farmers recognized was the use of manures, while other practices were not considered important or harmful (Sadati *et al.,* 2010), (Sunitha, 2019) and (Bagri, 2020).

**3.1.9 Institutional access**

More than one third (36.11%) of the farmers had a medium level of institutional access, followed by low (33.05%) and high (30.83%) levels of institutional access. Institutional access varied significantly among the different farmer groups (Chi-square = 19.304, df = 5, *P* =.002), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in institutional access between red gram farmers (*P* =.001) compared to paddy farmers.Nearly one-third of the farmers had medium, low, and high levels of institutional access, respectively. This might be because most of the farmers had access to inputs such as seeds, fertilizers, and pesticides within their own villages, providing them ease of service access. Some farmers had access to facilities like soil testing labs, KVK, DAATTC, research stations, banks, cooperative societies, agricultural offices, godowns, and market yards in nearby mandals with ease of service access, which placed them in the high category. Those who had some of these facilities in mandals with ease of access but other facilities farther away, or at district level with medium to difficult ease of access, fell under the medium category. Farmers who had most of these facilities far away, at the district level, with difficult ease of access, fell under the low category (Shwetha, 2012), (Argade, 2014) and (Kavitha, 2021).

**3.1.10 Capital availability**

More than half (59.72%) of the farmers had a medium level of capital availability, followed by high (21.94%) and low (18.33%) levels of capital availability. Capital availability varied significantly among the different farmer groups (Chi-square = 27.693, df = 5, *P* =.000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in capital availability between red gram farmers compared to paddy (*P* = .000) and maize (*P* = .007) farmers, as well as between cotton farmers (*P* = .04) compared to paddy farmers. Most of the farmers had a medium level of capital availability. The probable reason for these results might be that most of the farmers had moderately sufficient capital, which included a combination of self-sourced funds and credit, for investment in land, farm buildings, farm machinery and equipment, gardening, irrigation equipment, maintenance of these structures, improvement of land, and livestock and other farm animals. Some of the farmers, who had sufficient capital for these investments either through their own means or in combination with credit, fell under the high category. In contrast, those who did not have sufficient capital for any of these investments fell under the low category. (Rajkhowa, 2019).

**3.1.11 Manures and fertilizers availability**

Less than half (44.16%) of the farmers had a medium level of manures and fertilizers availability, followed by low (33.61%) and high (22.22%) levels of availability. Manures and fertilizers availability varied significantly among the different farmer groups (Chi-square = 58.694, df = 5, *P* = .000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in manures and fertilizers availability between red gram farmers compared to Bengal gram (*P* = .000), paddy (*P* = .000) and maize (*P* = .001) farmers, soybean farmers compared to Bengal gram (*P* = .000), paddy (*P* = .001) and maize (*P* = .01) farmers and cotton farmers compared to Bengal gram (*P* = .000), paddy (*P* = .002) and maize (*P* = .02) farmers.Most of the farmers had a medium level of manure and fertilizer availability. The probable reason for these results might be the availability of FYM, urea, MOP, DAP, 20-20-0-13, 20-20-0, 19-19-19, 18-18-0, 12-32-16, micronutrients, biofertilizers, and nano fertilizers at the mandal level, with moderate to easy access. Some farmers had insufficient availability of manures and fertilizers at the mandal level, with only a moderate level of ease in accessibility, or some of the complex fertilizers, micronutrients, and biofertilizers were not available to them. These farmers might have fallen under the low category. Meanwhile, some farmers had access to manures and fertilizers within their own villages, with ease of availability; hence, they fell under the high category (Issa, 2016) and (Tovihoudji *et al.,* 2023).

**3.1.12 Farming system**

Majority (70.83%) of the farmers followed a cropbased farming system, followed by crop + dairy (18.61%), crop + goatery (5.56%), crop + sheep farming (3.33%), and crop + poultry (1.67%).Farming systems varied significantly among the different farmer groups (Chi-square = 40.345, df = 5, P = .000), resulting in rejection of the null hypothesis. Subsequent pairwise comparisons revealed significant difference in farming system between cotton farmers compared to Bengal gram (*P* = .000), red gram (*P* = .000), soybean (*P* = .000), maize (*P* = .005), and paddy (*P* = .002) farmers. Most of the farmers practiced crop-based farming systems, followed by crop + subsidiary farming systems. The reasons for these results might include the lack of interest among farmers in adopting subsidiary occupations, as they demand daily supervision and care; limited availability of cattle feed in villages due to intensive cultivation and land improvements; the prevalence of nuclear families, which reduces the availability of family members to help; limited labour availability in villages to take care of cattle; and high labour wages, which further reduce the affordability of maintaining a subsidiary enterprise alongside farming (Singh, 2022) and (Rana, 2022).

**3.2 Relationship between key determinants and fertilizer management practices**

Initially, the correlation coefficient between all the variables was calculated. Further these variables were analysed with multivariate general linear model (MGLM). The results revealed that only twelve variables were found significant in MGLM. The correlation of these variables with fertilizer management is furnished in Table 3. The data presented in Table 3 indicated that all the determinants were found positive and highly significant with fertilizer management of farmers.

**Table 3. Correlation analysis of key determinants and fertilizer management of farmers (n=360)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Determinants** | **Paddy**  **(*r*)** | **Cotton**  **(*r*)** | **Maize**  **(*r*)** | **Red gram (*r*)** | **Soybean**  **(*r*)** | **Bengal gram (*r*)** | **Overall**  **(*r*)** |
| Education | 0.4150\*\* | 0.4381\*\* | 0.4762\*\* | 0.5263\*\* | 0.4021\*\* | 0.4383\*\* | 0.4032\*\* |
| Experience in selected crop cultivation | 0.2761\* | 0.4297\*\* | 0.2926\* | 0.0446NS | #DIV/0! | 0.2214NS | 0.3997\*\* |
| Social participation | 0.5142\*\* | 0.4452\*\* | 0.4552\*\* | 0.4450\*\* | 0.2946\* | 0.2896\* | 0.3173\*\* |
| Extension contact | 0.4037\*\* | 0.4433\*\* | 0.4168\*\* | 0.2906\* | 0.2833\* | 0.2409NS | 0.3295\*\* |
| Source of Information on Fertilizers | 0.3482\*\* | 0.3761\*\* | 0.4165\*\* | 0.3471\*\* | 0.2837\* | 0.2781\* | 0.2967\*\* |
| Scientific orientation | 0.4295\*\* | 0.4366\*\* | 0.4261\*\* | 0.4437\*\* | 0.2617\* | 0.3096\* | 0.3611\*\* |
| Economic motivation | 0.3388\*\* | 0.4415\*\* | 0.4236\*\* | 0.4028\*\* | 0.3014\* | 0.2749\* | 0.2947\*\* |
| Sustainability orientation | 0.4871\*\* | 0.4170\*\* | 0.4395\*\* | 0.3540\*\* | 0.3150\* | 0.3864\*\* | 0.3430\*\* |
| Institutional access | 0.3054\* | 0.1925NS | 0.2947\* | 0.2083NS | 0.2901\* | 0.2872\* | 0.2263\*\* |
| Capital availability | 0.4450\*\* | 0.4381\*\* | 0.3932\*\* | 0.3076\* | 0.3033\* | 0.2263NS | 0.2986\*\* |
| Manures and fertilizers availability | 0.4449\*\* | 0.4047\*\* | 0.4112\*\* | 0.4057\*\* | 0.1945NS | 0.3030\* | 0.2215\*\* |
| Farming system | 0.3299\* | 0.3507\*\* | 0.4191\*\* | 0.3577\*\* | 0.0118NS | 0.0556NS | 0.3014\*\* |

*\*\*Significance at 0.05 level of probability, \*Significance at 0.01 level of probability,*

*NS Non significant.*

The determinants such as education (0.4032\*\*), experience in selected crop cultivation (0.3997\*\*), social participation (0.3173\*\*), extension contact (0.3295\*\*), source of information on fertilizers (0.2967\*\*), scientific orientation (0.3611\*\*), economic motivation (0.2947\*\*), sustainability orientation (0.3430\*\*), institutional access (0.2263\*\*), capital availability (0.2986\*\*), manures and fertilizers availability (0.2215\*\*) and farming system (0.3014\*\*) were found positive and highly significant with fertilizer management of farmers (kemekar and Salunkhe, 2023),(Sarada and Suneel Kumar, 2013), (Waghmode *et al.,* 2020), (Akomdo *et al.,* 2023) and (Dessie *et al.,* 2023).

4. Conclusion

It can be concluded that a combination of personal, social, economic, and psychological factors play a significant role in shaping farmers' fertilizer management practices. Although a considerable proportion of farmers had only basic education or were illiterate, several other variables such as practical experience in crop cultivation, involvement in social organizations, interaction with extension services, and access to reliable fertilizer-related information significantly contributed to improved fertilizer management. Moreover, traits like scientific orientation, economic drive, and sustainability mindset were positively linked to better practices. Institutional support, access to capital, and the availability of manures and fertilizers also emerged as critical enablers. These findings indicate that fertilizer management is not influenced by a single factor but rather a network of interrelated characteristics. Therefore, agricultural interventions should adopt a holistic approach, considering these multiple dimensions. Customized support mechanisms focusing on capacity-building, knowledge dissemination, institutional linkage enhancement, and promotion of scientific attitudes among farmers can lead to more efficient and sustainable fertilizer use, ultimately contributing to better productivity and environmental conservation.

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