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Adoption of Fertilizer Use Practices Among Farmers in Telangana

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ABSTRACT

The present study was conducted in Telangana. A descriptive research design was adopted. Six major field crops were purposively selected. A total of 360 farmers were selected through multistage random sampling. Data were collected using a structured interview schedule covering ten fertilizer use practice domains and analyzed using descriptive statistics and the Kruskal–Wallis test. The results revealed that 28.89 per cent of the farmers had low adoption of fertilizer use practices, followed by medium (23.61%), very low (17.50%), high (17.50%) and very high (12.50%) adoption levels. Adoption was relatively higher for recommended application of major fertilizers. whereas lower adoption was observed for manure application, specialty fertilizer use, nutrient deficiency management and safe fertilizer transport, storage, handling and disposal practices. Significant differences in adoption were observed among the six farmer groups. The study indicates the need for crop-specific extension interventions to promote balanced fertilizer use and improve the adoption of recommended fertilizer use practices for sustainable agricultural production in Telangana.

INTRODUCTION

Balanced fertilizer use is important for enhancing crop productivity, maintaining soil fertility and protecting the environment. Indian soils are widely deficient in organic carbon and several macro and micronutrients indicating the need for balanced and integrated nutrient management (Khurana and Kumar, 2022). Telangana is one of the states with the highest macronutrient fertilizer consumption (Srinivasarao, 2021). However, nutrient use in many districts remains imbalanceded (Chand and Pavithra, 2015) because of excessive nitrogen and phosphorus application and inadequate potassium use (Bora, 2022). Limited production and use of biofertilizers (Khurana and Kumar, 2022) low farmyard manure application further leads to nutrient imbalance and deterioration of soil health (Bora, 2022). Several studies have reported that farmers do not fully adopt the recommended fertilizer use practices. The major reasons include lack of awareness, non-availability of organic manures, inadequate livestock, delayed economic benefits from organic inputs and poor marketing support (Manohari and Vootla, 2021). Farmers generally have low perception regarding the adverse effects of excessive fertilizer use on soil health and the environment (Hussain et al., 2017; Musa et al., 2022). Fertilizer application decisions are often based on personal experience, fertilizer dealers or fellow farmers rather than soil testing and extension recommendations (Yang and Fang, 2015). Long-term indiscriminate fertilizer use has been associated with declining soil pH, phosphorus accumulation, potassium mining and increasing greenhouse gas emissions (Shukla et al., 2022). Promotion of balanced fertilizer use is limited by inadequate soil testing facilities, poor awareness on balanced nutrient management, excessive dependence on urea, weak linkage among research-extension-farmers, and limited adoption of secondary and micronutrient fertilizers (Usama and Khalid, 2018; Shukla et al., 2022). Previous studies have also shown that both excessive and inadequate fertilizer application reduce nutrient use efficiency, farm profitability and long-term soil productivity (Islam et al., 2022).

Most of the previous studies have focused on fertilizer consumption, nutrient balance, farmers' perception or fertilizer recommendations. However, limited information is available on the adoption of recommended fertilizer use practices covering the entire fertilizer use cycle, including manure application, fertilizer application, nutrient deficiency management, transport, storage, handling and disposal. Such information is essential for identifying specific gaps in farmers' practices and planning appropriate extension interventions. Therefore, the present study was undertaken with the objectives, to assess the adoption of recommended fertilizer use practices among farmers in Telangana and to compare the adoption levels among different farmer groups.

MATERIALS AND METHODS

The study was conducted in Telangana during 2023-2025. Descriptive research design was adopted for the study. Telangana was purposively selected as it was among the top states in consumption of macronutrients (Directorate of Economics and Statistics, 2022). Six major field crops, namely paddy, cotton, maize, red gram, soybean and Bengal gram, were purposively selected based on maximum area under cultivation during 2017-2021. For each crop, one district was randomly selected among the cultivating districts of particular crop. For each district, two mandals were randomly selected. From each mandal, three villages were randomly selected. From each village, ten farmers were randomly selected. Thus, a total of six crops, six districts, thirty-six mandals and three hundred and sixty farmers were selected. A structured interview schedule was developed to collect information on the adoption of recommended fertilizer use practices. The schedule comprised ten practice domains, namely manure application, nitrogen fertilizer application, phosphatic fertilizer application, potassic fertilizer application, specialty fertilizer application, nutrient deficiency and adverse condition management, fertilizer transport, fertilizer storage, fertilizer handling and fertilizer disposal. Data were collected through personal interviews with the selected farmers. The data were analysed using descriptive statistics to determine the extent of adoption of recommended fertilizer use practices. The Kruskal–Wallis test was employed to assess the significance of differences in adoption levels among the six farmer groups.

RESULTS AND DISCUSSION

Adoption of fertilizer use practices among farmers

The results presented in Table 1 revealed that the adoption of fertilizer use practices among farmers was predominantly at low to medium levels. Overall, 28.89% of the respondents belonged to the low adoption category, followed by 23.61% in the medium category. Equal proportions (17.50%) of the respondents exhibited very low and high adoption levels, whereas only 12.50% had very high adoption. Among the farmer groups, maize farmers recorded the highest proportion of very high adoption (30.00%), followed by red gram farmers (23.33%). In contrast, very low adoption was more common among soybean (41.67%) and Bengal gram (36.67%) farmers. Kruskal-Wallis test revealed a significant difference in adoption of fertilizer use practices among farmer groups at the 0.01 level of probability ($\chi^2 = 84.882$, $df = 5$).

The predominance of low to medium adoption indicates that although farmers have adopted some recommended fertilizer use practices, comprehensive adoption remains limited. This may be attributed to inadequate awareness of recommended practices, resource constraints and reliance on conventional fertilizer use practices rather than scientific recommendations, resulting in considerable variation in adoption among the selected farmer groups.

Table 1: Extent of adoption of fertilizer use practices (*n*=360)

Category	Farmer groups						
	Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)

Very low	5 (8.33)	9 (15.00)	0 (0.00)	0 (0.00)	25 (41.67)	22 (36.67)	63 (17.50)
Low	20 (33.33)	15 (25.00)	10 (16.67)	14 (23.33)	19 (31.67)	19 (31.67)	104 (28.89)
Medium	13 (21.67)	13 (21.67)	19 (31.67)	19 (31.67)	13 (21.67)	14 (23.33)	85 (23.61)
High	14 (23.33)	16 (26.67)	13 (21.67)	12 (20.00)	3 (5.00)	4 (6.67)	63 (17.50)
Very high	8 (13.33)	7 (11.67)	18 (30.00)	14 (23.33)	0 (0.00)	1 (1.67)	45 (12.50)
Total	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)

Differences among farmer groups were tested using the Kruskal–Wallis test
$\chi2$ (5) = 84.882, $p < 0.01$
a. f = frequency

Adoption of manure application practices

Manure application was adopted by only 28.89 per cent of the farmers, while the remaining 71.11 per cent did not apply manure (Table 2). Among the adopters, the recommended quantity of manure was practiced by only 16.11 per cent of the respondents, whereas 12.50 per cent of farmers practiced deficit application. Similarly, 18.33 per cent applied manure at the recommended time. The recommended method of manure application was followed by all manure adopters, and a similar proportion reported using machinery for manure application. Adoption was comparatively higher among cotton and red gram farmers compared to soybean and Bengal gram farmers. Kruskal-Wallis test revealed a significant difference in adoption of manure application among farmer groups at the 0.01 level of probability ($\chi^2 = 44.755$, $df = 5$).

The low adoption of manure application could be because of the limited availability of farmyard manure, as less than one-third of the respondents owned livestock (Akomdo *et al.,* 2023). Farmers without sufficient manure had either avoided its application or used it only in cotton which was expected to provide higher economic returns. In addition, high cost and limited local availability has resulted in limited usage of manure (Dessie *et al.*, 2023). Farmers who adopted manure generally followed the recommended method and time of application indicating that the major constraint was resource availability rather than knowledge (Tovihoudji *et al.*, 2023).

Table 2: Extent of adoption of manure application practices (n=360)

Manure application practices	Extent of adoption	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Not Adopted		43 (71.67)	29 (48.33)	39 (65.00)	35 (58.33)	55 (91.67)	55 (91.67)	256 (71.11)
Adopted		17 (28.33)	31 (51.67)	21 (35.00)	25 (41.67)	5 (8.33)	5 (8.33)	104 (28.89)
Quantity of Application	Highly Deficit (-51% to - 99%)	0 (0.00)	1 (1.67)	21 (35.00)	7 (11.67)	0 (0.00)	0 (0.00)	29 (8.06)
	Deficit (-26% to -50%)	0 (0.00)	12 (20.00)	0 (0.00)	4 (6.67)	0 (0.00)	0 (0.00)	16 (4.44)
	Optimum (-25% to 25%)	16 (26.67)	18 (30.00)	0 (0.00)	14 (23.33)	5 (8.33)	5 (8.33)	58 (16.11)
Average quantity used Kg/acre Recommended quantity Kg/ acre*		2176 2000*	2919 4000*	2452 10000*	1316 2000*	1964 2000*	1970 2000*	-

Time of application	Improper	0 (0.00)	8 (13.33)	2 (3.33)	3 (5.00)	1 (1.67)	1 (1.67)	15 (4.17)
	Partially Appropriate	0 (0.00)	5 (8.33)	6 (10.00)	7 (11.67)	4 (6.67)	1 (1.67)	23 (6.39)
	As recommended	17 (28.33)	18 (30.00)	13 (21.67)	15 (25.00)	0 (0.00)	3 (5.00)	66 (18.33)
Method of application	As recommended	17 (28.33)	31 (51.67)	21 (35.00)	25 (41.67)	5 (8.33)	5 (8.33)	104 (28.89)
Machinery	Not at all	17 (28.33)	31 (51.67)	21 (35.00)	25 (41.67)	5 (8.33)	5 (8.33)	104 (28.89)
Kruskal–Wallis test $\chi 2$ (5) = 44.755, $p < 0.01$								

Adoption of nitrogen fertilizer application practices

Table 3 indicates that 46.39 per cent of the respondents had applied nitrogenous fertilizers in the recommended quantity, whereas 24.17 per cent applied it in highly excessive quantities. Two-fifths (44.17%) of the farmerss practiced the recommended time of application, whereas majority (69.17%) adopted the recommended method. Excess application was particularly evident among paddy and red gram farmers, while optimum application was more common among maize and Bengal gram farmers. Use of machinery for nitrogen fertilizer application was limited and observed only among a small proportion of farmers. Kruskal-Wallis test revealed a significant difference in adoption of nitrogenous fertilizer application among farmer groups at the 0.01 level of probability (χ^2 = 137.618, df = 5).

Table 3: Extent of adoption of nitrogenous fertilizer application practices (*n*=360)

Nitrogenous fertilizer application practices	Extent of adoption	Farmer groups						
		Paddy (n_1=60)	**Cotton (n_2=60)**	**Maize (n_3=60)**	**Red gram (n_4=60)**	**Soybean (n_5=60)**	**Bengal gram (n_6=60)**	**Overall (n=360)**
		f (%)	**f (%)**	**f (%)**	**f (%)**	**f (%)**	**f (%)**	**f (%)**
Quantity of Application	Highly Deficit (-51% to - 99%)	**0 (0.00)**	**5 (8.33)**	**0 (0.00)**	**0 (0.00)**	**35 (58.33)**	**0 (0.00)**	**40 (11.11)**
	Deficit (-26% to -50%)	**0 (0.00)**	**10 (16.67)**	**17 (28.33)**	**0 (0.00)**	**1 (1.67)**	**7 (11.67)**	**35 (9.72)**
	Optimum (-25% to 25%)	**24 (40.00)**	**33 (55.00)**	**43 (71.67)**	**0 (0.00)**	**18 (30.00)**	**49 (81.67)**	**167 (46.39)**
	Excess (25% to 50%)	**22 (36.67)**	**3 (5.00)**	**0 (0.00)**	**0 (0.00)**	**6 (10.00)**	**0 (0.00)**	**31 (8.61)**
	Highly Excess (>51%)	**14 (23.33)**	**9 (15.00)**	**0 (0.00)**	**60 (100)**	**0 (0.00)**	**4 (6.67)**	**87 (24.17)**
Average quantity used Kg/acre Recommended quantity Kg/acre*		**65 48***	**50 48***	**68 80***	**30 8***	**15 24***	**9 8***	-
Time of application	Improper	**25 (41.67)**	**33 (55.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**58 (16.11)**
	Partially Appropriate	**29 (48.33)**	**9 (15.00)**	**45 (75.00)**	**9 (15.00)**	**25 (41.67)**	**26 (43.33)**	**143 (39.72)**
	As recommended	**6 (10.00)**	**18 (30.00)**	**15 (25.00)**	**51 (85.00)**	**35 (58.33)**	**34 (56.67)**	**159 (44.17)**

Method of application	Improper	**0 (0.00)**	**34 (56.67)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**34 (9.44)**
	Partially Appropriate	**7 (11.67)**	**7 (11.67)**	**14 (23.33)**	**9 (15.00)**	**25 (41.67)**	**15 (25.00)**	**77 (21.39)**
	As recommended	**53 (88.33)**	**19 (31.67)**	**46 (76.67)**	**51 (85.00)**	**35 (58.33)**	**45 (75.00)**	**249 (69.17)**
Machinery	Some	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**26 (43.33)**	**1 (1.67)**	**27 (7.50)**
	Little	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**5 (8.33)**	**3 (5.00)**	**8 (2.22)**
	Large	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**0 (0.00)**	**7 (11.67)**	**7 (11.67)**	**14 (3.89)**
Kruskal–Wallis test $\chi 2$ (5) = 137.618, p < 0.01								

The variation in nitrogenous fertilizer application among farmers may be attributed to inadequate knowledge regarding the recommended quantity, timing and split application of nitrogen fertilizers (Dwivedi *et al.,* 2020). Many farmers applied fertilizers based on their own experience rather than scientific recommendations, because of fear of low yield (Dwivedi *et al.,* 2021). The use of complex fertilizers at different crop stages also contributed to deviations from the recommended schedule, resulting in excessive or inadequate nitrogen application in several crops (Akomdo *et al.,* 2023).

Adoption of phosphatic fertilizer application practices

The data presented in Table 4 indicate that majority (59.44%) of the respondents applied phosphatic fertilizers at the recommended quantity, while 24.17 per cent applied it in either deficit quantity or excess quantity. Half of the farmers (50.56%) followed the recommended time of application and a majority (83.89%) adopted the recommended method of application. Optimum application was more evident among red gram, soybean and Bengal gram farmers, whereas excessive application was observed mainly among paddy and maize farmers. Kruskal-Wallis test revealed a significant difference in adoption of phosphatic fertilizer application among farmer groups at the 0.01 level of probability ($\chi^2 = 202.431$, $df = 5$).

Table 4: Extent of adoption of phosphatic fertilizer application practices (*n*=360)

Phosphatic fertilizer application practices	Extent of adoption	**Farmer groups**						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Quantity of Application	Highly Deficit (-51% to - 99%)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (6.67)	0 (0.00)	4 (1.11)
	Deficit (-26% to -50%)	0 (0.00)	4 (6.67)	26 (43.33)	0 (0.00)	0 (0.00)	25 (41.67)	55 (15.28)
	Optimum (-25% to 25%)	24 (40.00)	34 (56.67)	5 (8.33)	60 (100)	56 (93.33)	35 (58.33)	214 (59.44)
	Excess (25% to 50%)	22 (36.67)	0 (0.00)	29 (48.33)	0 (0.00)	0 (0.00)	0 (0.00)	51 (14.17)
	Highly Excess (>51%)	14 (23.33)	22 (36.67)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	36 (10.00)
Average quantity used Kg/ acre Recommended quantity Kg/acre*		41 24*	31 24*	35 32*	23 20*	22 24*	17 20*	-

Time of application	Improper	28 (46.67)	0 (0.00)	9 (15.00)	0 (0.00)	0 (0.00)	0 (0.00)	37 (10.28)
	Partially Appropriate	14 (23.33)	40 (66.67)	36 (60.00)	0 (0.00)	29 (48.33)	22 (36.67)	141 (39.17)
	As recommended	18 (30.00)	20 (33.33)	15 (25.00)	60 (100)	31 (51.67)	38 (63.33)	182 (50.56)
Method of application	Improper	20 (33.33)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	20 (5.56)
	Partially Appropriate	0 (0.00)	20 (33.33)	7 (11.67)	0 (0.00)	0 (0.00)	11 (18.33)	38 (10.56)
	As recommended	40 (66.67)	40 (66.67)	53 (88.33)	60 (100)	60 (100)	49 (81.67)	302 (83.89)
Machinery	Large	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	25 (41.67)	10 (16.67)	35 (9.72)
Kruskal–Wallis test $\chi2$ (5) = 202.431, $p < 0.01$								

The relatively better adoption of phosphatic fertilizer management in pulse crops could be due to greater adherence to the recommended single basal application (Akomdo *et al.*, 2023). Whereas variations observed in cereals and cotton were mainly because of the use of complex fertilizers at different crop stages (Dwivedi *et al.*, 2020). This has resulted in variations in the recommended timing and method of application. Farmers' dependence on experience-based fertilizer application instead of scientific recommendations might have further contributed to these variations (Dwivedi *et al.*, 2021).

***Adoption of potassic fertilizer application** practices*

Table 5: Extent of adoption of potassic fertilizer application practices (*n*=360)

Potassic fertilizer application practices	Extent of adoption	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Not Adopted		0 (0.00)	29 (48.33)	0 (0.00)	42 (70.00)	60 (100)	58 (96.67)	189 (52.50)
Adopted		60 (100)	31 (51.67)	60 (100)	18 (30.00)	0 (0.00)	2 (3.33)	171 (47.50)
Quantity	**Optimum (-25% to 25%)**	41 (68.33)	31 (51.67)	46 (76.67)	9 (15.00)	0 (0.00)	0 (0.00)	127 (35.28)
	Highly Excess (>51%)	18 (30.00)	0 (0.00)	11 (18.33)	9 (15.00)	0 (0.00)	2 (3.33)	40 (11.11)
Average quantity used Kg/acre Recommended quantity Kg/acre*		21 16*	30 24*	36 32*	23 15*	0 16*	13 8*	-
Time of application	**Improper**	49 (81.67)	31 (51.67)	0 (0.00)	18 (30.00)	0 (0.00)	0 (0.00)	98 (27.22)
	Partially Appropriate	8 (13.33)	0 (0.00)	39 (65.00)	0 (0.00)	0 (0.00)	1 (1.67)	48 (13.33)
	As recommended	3 (5.00)	0 (0.00)	21 (35.00)	0 (0.00)	0 (0.00)	1 (1.67)	25 (6.94)
Method of application	**Improper**	28 (46.67)	31 (51.67)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	59 (16.39)
	Partially Appropriate	2 (3.33)	0 (0.00)	39 (65.00)	0 (0.00)	0 (0.00)	0 (0.00)	41 (11.39)
	As recommended	30 (50.00)	0 (0.00)	21 (35.00)	18 (30.00)	0 (0.00)	2 (3.33)	71 (19.72)

Kruskal–Wallis test $\chi 2\,(5) = 300.482$, $p < 0.01$

Adoption of potassic fertilizer application varied considerably across the selected crops (Table 5). Overall, less than half (47.50%) of the farmers applied potassic fertilizers, while 52.50 per cent did not use them. Among the adopters, only 35.28 per cent applied the recommended quantity. However, only 6.94 per cent followed the recommended time of application. Only few (19.72%) adopted the recommended method indicating comparatively poor adherence to the recommended potassic fertilizer practices. Kruskal-Wallis test revealed a significant difference in adoption of potassic fertilizer application among farmer groups at the 0.01 level of probability ($\chi^2 = 300.482$, $df = 5$).

The low adoption of recommended potassic fertilizer practices was primarily associated with the complete or partial omission of potassic fertilizers in several crops (Dwivedi *et al.,* 2020). Many farmers considered potassic fertilizer unnecessary in certain crops and relied solely on complex fertilizers without considering the recommended dose and schedule (Dwivedi *et al.,* 2021). Lack of soil testing and limited awareness regarding crop-specific potassium requirements may also have contributed to poor adoption (Akomdo *et al.,* 2023).

Adoption of specialty fertilizers application practices

The adoption of specialty fertilizers was generally poor among the respondents (Table 6). Most farmers did not apply zinc, sulphur, micronutrients, biofertilizers or nano urea as recommended. In contrast, neem-coated urea was universally adopted by all respondents. Adoption of plant growth regulators was observed only among Bengal gram farmers, reflecting crop-specific recommendations. Overall, the findings indicate limited use of specialty fertilizers despite their importance in balanced nutrient management.

The poor adoption of specialty fertilizers could be due to limited awareness regarding its benefits, inadequate technical guidance and additional cost involved. Farmers generally preferred conventional fertilizers. Speciality fertilizers such as micronutrients, biofertilizers and nano fertilizers were adopted only to a limited extent. However, the universal adoption of neem-coated urea reflects its easy availability and widespread promotion through government initiatives.

Table 6: Extent of adoption of specialty fertilizers application practices (*n*=360)

Specialty fertilizer application practices (recommended*)	Categories	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Zinc (Soil) (all crops*)	Not adopted	53 (88.33)	55 (91.66)	55 (91.66)	60 (100)	60 (100)	60 (100)	343 (95.27)
	Fully adopted	7 (11.66)	5 (8.33)	5 (8.33)	0 (0.00)	0 (0.00)	0 (0.00)	17 (4.72)
Sulphur (Bengal gram*)	Not adopted	41 (68.33)	60 (100)	51 (85.00)	60 (100)	60 (100)	44 (73.33)	316 (87.78)
	Partially adopted	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	16 (26.66)	16 (4.44)
	Fully adopted	19 (31.66)	0 (0.00)	9 (15.00)	0 (0.00)	0 (0.00)	0 (0.00)	28 (7.78)
Multi micro nutrients (All crops*)	Not adopted	45 (75.00)	47 (78.33)	50 (83.33)	60 (100)	60 (100)	60 (100)	322 (89.44)
	Fully adopted	15 (25.00)	13 (21.66)	10 (16.66)	0 (0.00)	0 (0.00)	0 (0.00)	38 (10.56)
Biofertilizers (All crops*)	Not adopted	48 (80.00)	54 (90.00)	60 (100)	60 (100)	60 (100)	60 (100)	342 (95.00)
	Fully adopted	12 (20.00)	6 (10.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	18 (5.00)
PGRs	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	0 (0.00)	300 (83.33)
	Fully adopted	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	60 (100)	60 (16.66)

Nano urea	Not adopted	54 (90.00)	57 (95.00)	54 (90.00)	60 (100)	60 (100)	60 (100)	345 (95.83)
	Fully adopted	6 (10.00)	3 (5.00)	6 (10.00)	0 (0.00)	0 (0.00)	0 (0.00)	15 (4.17)
Neem Coated Urea	Fully adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)

Adoption of nutrient deficiency and adverse condition management practices

Table 7 shows that adoption of nutrient deficiency and adverse condition management practices was generally low. Majority (64.72%) of the respondents partially monitored their crops for nutrient deficiencies, while few (35.28%) fully adopted this practice. More than half of the respondents did not adopt nutrient deficiency detection, nutrient deficiency management or nutrient management under waterlogged and drought conditions. These findings suggest inadequate adoption of corrective nutrient management practices among the farmers. Kruskal-Wallis test revealed a significant difference in adoption of nutrient deficiency and adverse condition management among farmer groups at the 0.01 level of probability ($\chi^2 = 35.723$, $df = 5$).

Table 7: Extent of adoption nutrient deficiency and adverse condition management practices (*n*=360)

Nutrient deficiency and adverse condition management practices	Extent of adoption	Farmer groups: Paddy (n_1=60) f (%)	Cotton (n_2=60) f (%)	Maize (n_3=60) f (%)	Red gram (n_4=60) f (%)	Soybean (n_5=60) f (%)	Bengal gram (n_6=60) f (%)	Overall (n=360) f (%)
Monitoring of crops for identification of nutrient deficiencies	Partially adopted	41 (68.33)	41 (68.33)	45 (75.00)	33 (55.00)	35 (58.33)	38 (63.33)	233 (64.72)
	Fully adopted	19 (31.67)	19 (31.67)	15 (25.00)	27 (45.00)	25 (41.67)	22 (36.67)	127 (35.28)
Nutrient deficiency detection	Not adopted	30 (50.00)	31 (51.67)	35 (58.33)	42 (70.00)	41 (68.33)	31 (51.67)	210 (58.33)
	Partially adopted	20 (33.33)	21 (35.00)	16 (26.67)	18 (30.00)	19 (31.67)	29 (48.33)	123 (34.17)
	Fully adopted	10 (16.67)	8 (13.33)	9 (15.00)	0 (0.00)	0 (0.00)	0 (0.00)	27 (7.50)
Management of nutrient deficiency	Not adopted	30 (50.00)	33 (55.00)	35 (58.33)	46 (76.67)	44 (73.33)	35 (58.33)	223 (61.94)
	Partially adopted	20 (33.33)	19 (31.67)	17 (28.33)	14 (23.33)	16 (26.67)	25 (41.67)	111 (30.83)
	Fully adopted	10 (16.67)	8 (13.33)	8 (13.33)	0 (0.00)	0 (0.00)	0 (0.00)	26 (7.22)
Nutrient management in water logged condition	Not adopted	15 (25.00)	29 (48.33)	30 (50.00)	49 (81.67)	39 (65.00)	35 (58.33)	197 (54.72)
	Partially adopted	45 (75.00)	31 (51.67)	30 (50.00)	11 (18.33)	21 (35.00)	25 (41.67)	163 (45.28)
Nutrient management in drought condition	Not adopted	12 (20.00)	28 (46.67)	32 (53.33)	55 (91.67)	46 (76.67)	35 (58.33)	208 (57.78)
	Partially adopted	48 (80.00)	32 (53.33)	28 (46.67)	5 (8.33)	14 (23.33)	25 (41.67)	152 (42.22)

Kruskal–Wallis test $\chi 2$ (5) = 35.723, $p < 0.01$

The low adoption of nutrient deficiency management practices indicates inadequate diagnostic skills among farmers (Kumaresh and Praveena, 2012). Many farmers monitored their crops, but only a few farmers were able to accurately identify nutrient deficiencies and implement suitable corrective measures (Sarada and Suneel Kumar, 2013). Similarly, nutrient management under waterlogged and drought conditions was largely neglected, possibly because farmers relied on conventional field management practices rather than crop-specific nutrient recommendations. [1] [KP2]

Adoption of fertilizer transport practices

The data presented in Table 8 indicate, moderate adoption of recommended fertilizer transport practices. Most (91.67%) of the farmers partially adopted proper packaging and protection during transport. Safe transportation and careful loading and unloading were fully adopted by 31.39 and 30.56 per cent of the respondents, respectively. However, checking of vehicles before transportation adopted as recommended by few (6.11%) of the respondents. Kruskal-Wallis test revealed a significant difference in adoption of fertilizer transport among farmer groups at the 0.01 level of probability ($\chi^2 = 41.025$, $df = 5$).

Table 8: Extent of adoption of fertilizer transport practices (*n*=360)

Fertilizer transport practices	Extent of adoption	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Packaging and protection during transport	Partially adopted	30 (50.00)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	330 (91.67)
	Fully adopted	30 (50.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	30 (8.33)
Safe fertilizer transportation	Not adopted	15 (25.00)	17 (28.33)	15 (25.00)	22 (36.67)	23 (38.33)	25 (41.67)	117 (32.50)
	Partially adopted	14 (23.33)	23 (38.33)	14 (23.33)	29 (48.33)	25 (41.67)	25 (41.67)	130 (36.11)
	Fully adopted	31 (51.67)	20 (33.33)	31 (51.67)	9 (15.00)	12 (20.00)	10 (16.67)	113 (31.39)
Careful loading/ unloading	Not adopted	22 (36.67)	19 (31.67)	20 (33.33)	24 (40.00)	26 (43.33)	24 (40.00)	135 (37.50)
	Partially adopted	8 (13.33)	16 (26.67)	14 (23.33)	26 (43.33)	26 (43.33)	25 (41.67)	115 (31.94)
	Fully adopted	30 (50.00)	25 (41.67)	26 (43.33)	10 (16.67)	8 (13.33)	11 (18.33)	110 (30.56)
Checking of vehicle during transportation	Not adopted	26 (43.33)	39 (65.00)	35 (58.33)	35 (58.33)	37 (61.67)	45 (75.00)	217 (60.28)
	Partially adopted	21 (35.00)	21 (35.00)	16 (26.67)	25 (41.67)	23 (38.33)	15 (25.00)	121 (33.61)
	Fully adopted	13 (21.67)	0 (0.00)	9 (15.00)	0 (0.00)	0 (0.00)	0 (0.00)	22 (6.11)

Kruskal–Wallis test $\chi2$ (5) = 41.025, $p < 0.01$

The moderate adoption of fertilizer transport practices could be because of farmers giving greater importance to safe transportation of fertilizer bags while paying less attention to recommended precautions such as vehicle inspection, proper covering and separate transportation (Ranabhat *et al.*, 2021). Better adoption among paddy farmers might be associated with group purchase of fertilizers through cooperative societies, which facilitated safer transportation practices (Ngoya *et al.*, 2023).

Adoption of fertilizer storage practices

The findings in Table 9 revealed mixed levels of adoption of fertilizer storage practices. All respondents maintained appropriate storage conditions. Adoption of other recommended storage practices was comparatively low. Nearly half of the respondents did not follow the recommended stacking method, while the FEFO (First Expiry, First Out) principle was not adopted by 78.61 per cent. None of the respondents maintained stock or issue registers, indicating poor record-keeping practices related to fertilizer storage. There was no significant difference among farmer groups in adoption of fertilizer storge.

Table 9: Extent of adoption of fertilizer storage practices (n=360)

Fertilizer storage practices	Categories	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Proximity of fertilizer storage	Not adopted	23 (38.33)	28 (46.67)	16 (26.67)	29 (48.33)	20 (33.33)	25 (41.67)	141 (39.17)
	Partially adopted	19 (31.67)	20 (33.33)	28 (46.67)	19 (31.67)	19 (31.67)	25 (41.67)	130 (36.11)
	Fully adopted	18 (30.00)	12 (20.00)	16 (26.67)	12 (20.00)	21 (35.00)	10 (16.67)	89 (24.72)
Storage condition	Fully adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)
Stacking method	Not adopted	31 (51.67)	32 (53.33)	29 (48.33)	34 (56.67)	28 (46.67)	29 (48.33)	183 (50.83)
	Partially adopted	19 (31.67)	18 (30.00)	18 (30.00)	16 (26.67)	24 (40.00)	21 (35.00)	116 (32.22)
	Fully adopted	10 (16.67)	10 (16.67)	13 (21.67)	10 (16.67)	8 (13.33)	10 (16.67)	61 (16.94)
First Expiry, First Out (FEFO) principle	Not adopted	46 (76.67)	52 (86.67)	41 (68.33)	51 (85.00)	48 (80.00)	45 (75.00)	283 (78.61)
	Partially adopted	14 (23.33)	8 (13.33)	19 (31.67)	9 (15.00)	12 (20.00)	15 (25.00)	77 (21.39)
Stock register maintenance	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)
Issue register maintenance	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)

Kruskal–Wallis test $\chi 2$ (5) = 9.275, $p > 0.05$

The findings suggest that farmers generally maintained suitable storage conditions but neglected recommended storage management practices such as the FEFO principle, proper stacking and maintenance of stock and issue registers (Sai *et al.,* 2019). This may be because fertilizers were stored mainly for immediate seasonal use and farmers were unaware of systematic storage management (Ranabhat *et al.,* 2021).

Adoption of fertilizer handling practices

Adoption of recommended fertilizer handling practices varied considerably among the farmers (Table 10). The use of nutrient management software or mobile applications was negligible. A majority of the farmers did not consider compatibility of agrochemicals, wind direction or the appropriate time of application during fertilizer application. Whereas, practices such as measuring fertilizers, washing hands and taking a bath after fertilizer application showed relatively better adoption. However, the use of personal protective equipment was absent among all the respondents indicating poor adherence to safety precautions during fertilizer handling. There was no significant difference among farmer groups in adoption of fertilizer handling.

The variation in fertilizer handling practices may be attributed to differences in farmers' awareness regarding safe fertilizer use. Basic practices such as measuring fertilizers and personal hygiene after application were followed by many respondents (Ranabhat *et al.,* 2021). Whereas, the use of nutrient management software, consideration of agrochemical compatibility and personal protective equipment remained negligible (Ngoya *et al.,* 2023). These findings indicate the need for greater emphasis on occupational safety and scientific fertilizer handling practices.

Table 10: Extent of adoption of practicing of fertilizer handling practices (n=360)

Fertilizer handling practices	Categories	Farmer groups						
		Paddy (n_1=60)	Cotton (n_2=60)	Maize (n_3=60)	Red gram (n_4=60)	Soybean (n_5=60)	Bengal gram (n_6=60)	Overall (n=360)
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Utilization of nutrient management software or apps	Not adopted	57 (95.00)	60 (100)	58 (96.67)	60 (100)	60 (100)	53 (88.33)	348 (96.67)
	Partially adopted	3 (5.00)	0 (0.00)	2 (3.33)	0 (0.00)	0 (0.00)	5 (8.33)	10 (2.78)
	Fully adopted	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (3.33)	2 (0.56)
Consideration of agrochemicals compatibility	Not adopted	34 (56.67)	28 (46.67)	28 (46.67)	48 (80.00)	46 (76.67)	50 (83.33)	234 (65.00)
	Partially adopted	21 (35.00)	21 (35.00)	24 (40.00)	12 (20.00)	14 (23.33)	10 (16.67)	102 (28.33)
	Fully adopted	5 (8.33)	11 (18.33)	8 (13.33)	0 (0.00)	0 (0.00)	0 (0.00)	24 (6.67)
Consideration of winds during application/spraying	Not adopted	29 (48.33)	31 (51.67)	33 (55.00)	33 (55.00)	38 (63.33)	33 (55.00)	197 (54.72)
	Partially adopted	15 (25.00)	17 (28.33)	7 (11.67)	7 (11.67)	7 (11.67)	7 (11.67)	60 (16.67)
	Fully adopted	16 (26.67)	12 (20.00)	20 (33.33)	20 (33.33)	15 (25.00)	20 (33.33)	103 (28.61)
Right time of application/spraying in a day	Not adopted	31 (51.67)	31 (51.67)	29 (48.33)	32 (53.33)	32 (53.33)	30 (50.00)	185 (51.39)
	Partially adopted	13 (21.67)	13 (21.67)	15 (25.00)	11 (18.33)	18 (30.00)	15 (25.00)	85 (23.61)
	Fully adopted	16 (26.67)	16 (26.67)	16 (26.67)	17 (28.33)	10 (16.67)	15 (25.00)	90 (25.00)
Proper mixing of fertilizers	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)
Measurement of solid fertilizers	Not adopted	5 (8.33)	9 (15.00)	7 (11.67)	9 (15.00)	7 (11.67)	9 (15.00)	46 (12.78)
	Partially adopted	55 (91.67)	51 (85.00)	53 (88.33)	51 (85.00)	53 (88.33)	51 (85.00)	314 (87.22)
Measurement of liquid fertilizers	Not adopted	3 (5.00)	5 (8.33)	7 (11.67)	8 (13.33)	6 (10.00)	8 (13.33)	37 (10.28)
	Partially adopted	57 (95.00)	55 (91.67)	53 (88.33)	52 (86.67)	54 (90.00)	52 (86.67)	323 (89.72)
Wearing safety equipment (PPE) during fertilizer application	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)
Avoiding eating/chewing/ drinking during application	Not adopted	10 (16.67)	8 (13.33)	10 (16.67)	10 (16.67)	7 (11.67)	10 (16.67)	55 (15.28)
	Partially adopted	24 (40.00)	24 (40.00)	21 (35.00)	15 (25.00)	29 (48.33)	29 (48.33)	142 (39.44)
	Fully adopted	26 (43.33)	28 (46.67)	29 (48.33)	35 (58.33)	24 (40.00)	21 (35.00)	163 (45.28)
Taking bath after application/spraying	Not adopted	21 (35.00)	19 (31.67)	17 (28.33)	21 (35.00)	15 (25.00)	19 (31.67)	112 (31.11)
	Fully adopted	39 (65.00)	41 (68.33)	43 (71.67)	39 (65.00)	45 (75.00)	41 (68.33)	248 (68.89)

Washing hands after application/spraying	Not adopted	10 (16.67)	9 (15.00)	10 (16.67)	14 (23.33)	11 (18.33)	12 (20.00)	66 (18.33)
	Partially adopted	14 (23.33)	17 (28.33)	9 (15.00)	9 (15.00)	11 (18.33)	13 (21.67)	73 (20.28)
	Fully adopted	36 (60.00)	34 (56.67)	41 (68.33)	37 (61.67)	38 (63.33)	35 (58.33)	221 (61.39)
Washing cloths after application/spraying	Not adopted	26 (43.33)	31 (51.67)	25 (41.67)	33 (55.00)	24 (40.00)	29 (48.33)	168 (46.67)
	Fully adopted	34 (56.67)	29 (48.33)	35 (58.33)	27 (45.00)	36 (60.00)	31 (51.67)	192 (53.33)
Washing equipment after application/ spraying	Not adopted	31 (51.67)	36 (60.00)	32 (53.33)	31 (51.67)	32 (53.33)	35 (58.33)	197 (54.72)
	Partially adopted	18 (30.00)	14 (23.33)	16 (26.67)	16 (26.67)	18 (30.00)	17 (28.33)	99 (27.50)
	Fully adopted	11 (18.33)	10 (16.67)	12 (20.00)	13 (21.67)	10 (16.67)	8 (13.33)	64 (17.78)

Kruskal–Wallis test $\chi 2$ (5) = 8.484, $p > 0.05$

Adoption of Fertilizer Disposal Practices

The data presented in Table 11 indicate that the adoption of recommended fertilizer disposal practices was generally poor. Most respondents did not follow the recommended methods for disposal of leftover fertilizers, fertilizer containers, washing water or expired fertilizers. In particular, none of the respondents adopted the recommended method for disposal of expired fertilizers. The findings indicate limited awareness and adoption of environmentally safe fertilizer disposal practices among the farmers. Kruskal-Wallis test revealed a significant difference in adoption of fertilizer disposal among farmer groups at the 0.01 level of probability ($\chi^2 = 11.153$, $df = 5$).

The poor adoption of recommended fertilizer disposal practices may be attributed to inadequate awareness regarding environmentally safe disposal methods. Farmers generally reused or left residual fertilizers in the field and paid little attention to the safe disposal of fertilizer containers, washing water and expired fertilizers (Sai *et al.*, 2019; Ranabhat *et al.*, 2021). These findings highlight the need to strengthen extension efforts on environmentally responsible fertilizer management.

Table 11: Extent of adoption of fertilizer disposal practices (*n*=360)

Fertilizer disposal practices	Categories	Farmer groups						
		Paddy (n_1=60) f (%)	Cotton (n_2=60) f (%)	Maize (n_3=60) f (%)	Red gram (n_4=60) f (%)	Soybean (n_5=60) f (%)	Bengal gram (n_6=60) f (%)	Overall (n=360) f (%)
Disposal of left over fertilizers	Not adopted	47 (78.33)	55 (91.67)	50 (83.33)	53 (88.33)	51 (85.00)	55 (91.67)	311 (86.39)
	Partially adopted	13 (21.67)	5 (8.33)	10 (16.67)	7 (11.67)	9 (15.00)	5 (8.33)	49 (13.61)
Disposal of fertilizer bottles/bags	Not adopted	42 (70.00)	49 (81.67)	37 (61.67)	49 (81.67)	51 (85.00)	48 (80.00)	276 (76.67)
	Partially adopted	18 (30.00)	11 (18.33)	23 (38.33)	11 (18.33)	9 (15.00)	12 (20.00)	84 (23.33)
Disposal of water used for washing	Not adopted	46 (76.67)	43 (71.67)	46 (76.67)	51 (85.00)	53 (88.33)	51 (85.00)	290 (80.56)
	Partially adopted	14 (23.33)	17 (28.33)	14 (23.33)	9 (15.00)	7 (11.67)	9 (15.00)	70 (19.44)
Disposal of expired fertilizers	Not adopted	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	360 (100)

Kruskal–Wallis test $\chi 2$ (5) = 11.153, $p < 0.05$

The findings indicate the need for targeted extension interventions to improve adoption of recommended fertilizer use practices. Regular capacity-building programmes on balanced nutrient management, soil test-based fertilizer application, integrated use of organic and inorganic nutrient sources, and safe fertilizer transport, storage, handling and disposal should be strengthened. Improving access to soil testing services, specialty fertilizers and timely technical guidance through extension agencies will further enhance fertilizer use efficiency and promote sustainable crop production in Telangana.

[1]�� In-text citation not in reference list: (Kumaresh and Praveena, 2012) — surname 'Praveena' does not match reference entry 'Praveen'

[KP2]Reference was corrected as Praveena

CONCLUSION

The study revealed that the adoption of recommended fertilizer use practices among farmers in Telangana was predominantly at low to medium levels, with significant differences observed among the six farmer groups. The findings highlight the need for location-specific extension strategies to improve the adoption of balanced fertilizer use and safe fertilizer handling practices, thereby enhancing nutrient use efficiency, soil health and sustainable agricultural production.

Author's contribution: The first author conceptualized the study, collected the data, performed the analysis, prepared the manuscript and coordinated with the co-authors. The second author contributed to the study design, manuscript review and academic guidance. The third, fourth and fifth authors reviewed and edited the manuscript. The sixth author provided technical inputs and contributed to improving the scientific quality of the manuscript.

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