

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 12; December 2025; Page No. 360-366

Received: 21-10-2025
Accepted: 25-11-2025

Indexed Journal
Peer Reviewed Journal

Adoption of improved chilli production technologies and its effect on the technical efficiency of smallholder farmers in Andhra Pradesh

¹Mangalapuri Pavani, ²N Sivaramane, ³K Suseela, ⁴D Ramesh and ⁵G Sivanarayana

¹Ph.D. Scholar, Department of Agricultural Economics, Agricultural College, Bapatla, ANGRAU, Andhra Pradesh, India

²Principal Scientist, Division of Agribusiness Management, ICAR-NAARM, Hyderabad, Telangana, India

³Professor and Head, Department of Agricultural Economics, Agricultural College, Bapatla, ANGRAU, Andhra Pradesh, India

⁴Assistant Professor, Statistics and Computer Applications, Agricultural College, Bapatla, ANGRAU, Andhra Pradesh, India

⁵Senior Professor and Director of Extension, Department of Agricultural Extension Education, Guntur, ANGRAU, Andhra Pradesh, India

DOI: <https://www.doi.org/10.33545/26180723.2025.v8.i12e.2834>

Corresponding Author: Mangalapuri Pavani

Abstract

The adoption of improved production technologies plays a crucial role in enhancing productivity and efficiency in chilli cultivation, particularly among smallholder farmers. This study analyses adoption behaviour of small holder chilli farmers using the Technology Adoption Index (TAI), Data Envelopment Analysis (DEA), and Tobit regression. Primary data was collected from 360 smallholder chilli farmers using a multistage sampling technique. The TAI results indicated that, among chilli production technologies, the application of plant growth regulators, the selection of disease and pest resistant chilli varieties and the spraying of micronutrient mixtures were the major technologies adopted by chilli farmers. The DEA results revealed a mean technical efficiency of 85 per cent, indicating a potential reduction in input use of 15 per cent without affecting output. The mean technical efficiency of technology adopters (89.47%) was substantially higher than that of non-adopters (80.83%). The Tobit regression results showed that education, occupation, organizational membership, access to agricultural extension services and the adoption of chilli production technologies significantly influenced technical efficiency.

Keywords: Chilli cultivation, smallholders, technology adoption index, technical efficiency, data envelopment analysis and Tobit regression

Introduction

India, popularly known as the “Land of Spices,” is the world’s leading producer, consumer, and exporter of spices, with a total production of 1.24 crore tonnes and exports of 15.39 lakh tonnes valued at Rs. 36,958 crores (Spices Board of India, 2024) ^[31]. In 2024-25, the spices sector played a vital role in the national economy, contributing nearly 9 per cent to India’s total agricultural exports and over 40 per cent to horticultural exports (PIB, 2025) ^[22]. Among the spices, chilli holds a dominant position both in India and globally. India ranks first in the world in chilli production, contributing 27.8 lakh tonnes followed by Bangladesh, China, Thailand, and Ethiopia (PJTAU, 2025) ^[23]. Indian chillies are in high demand in both domestic and international markets due to their unique flavour profiles and vibrant colour (Meena *et al.*, 2006 and Kiruthika, 2024) ^[17, 12].

India not only stands as the world’s largest producer but also as a leading exporter of chilli, exporting 6.01 lakh tonnes valued at Rs. 12,492 crores and contributing 31 per cent of the total spices export earnings (Spices Board of India, 2024) ^[31]. Chilli is not only a major spice crop but also a nutritionally and medicinally important crop, rich in

bioactive compounds such as vitamins A, C, and E, minerals, antioxidants, proteins, fibre, essential oils, and natural pigments—particularly capsanthin and capsorubin which give chilli its vibrant red colour and enhance its appeal in spice powders and food products worldwide (Baenas *et al.*, 2019) ^[4]. In India, Andhra Pradesh occupies a leading position in chilli production with 12.13 lakh tonnes, followed by Telangana, Madhya Pradesh, and Karnataka (Spices Board of India, 2024) ^[31]. Within Andhra Pradesh, the districts of Guntur, Prakasam, and Kurnool have emerged as major chilli belts, well known for producing high-quality chillies.

Chilli is a versatile tropical and subtropical crop that thrives in warm, humid climates and adapts well to a wide range of soil types, making it a major commercial crop cultivated extensively for its economic returns (Reddy *et al.*, 2018) ^[25]. It serves as a key driver of productivity enhancement and income generation, particularly among smallholder farmers in India. Despite its economic importance, many farmers continue to rely on traditional cultivation practices, which often result in reduced productivity, increased vulnerability to climate variability and pest outbreaks, and a consequent decline in the quality and market value of chilli. To enhance

farm productivity and ensure livelihood security of chilli farmers, the development and adoption of improved crop technologies are essential (Ali *et al.*, 2020) ^[2]. Several improved chilli production technologies such as improved varieties, use of plant growth regulators, farm mechanization, integrated pest management practices, and post-harvest technologies have been promoted to enhance productivity and profitability. However, the extent of adoption of these technologies varies considerably across farmers, leading to differences in resource-use efficiency. The adoption of improved technologies not only affects agricultural productivity but also the efficient use of available resources. In this context, examining the technology adoption and technical efficiency of smallholder chilli farmers is crucial for improved farm performance. Although several studies, such as Ahmad *et al.* (2017) ^[1], Pakpahan and Nababan (2018) ^[19], Guha and Mandal (2021) ^[18], Krasachat (2023) ^[13] and Malleswari *et al.* (2023) ^[16], have examined efficiency in different agricultural crops, empirical evidence on the technical efficiency of chilli farmers in relation to technology adoption particularly among smallholders remains limited. Therefore, the specific objectives of this study were to analyse the technical efficiency of chilli farmers adopting improved production technologies and to identify the factors influencing the efficiency of chilli farmers.

Materials and Methods

Sampling design

A multistage sampling technique was employed to select the study area and respondents. Andhra Pradesh was purposively selected for the study, as it ranks highest in terms of area and production of chilli in India. Within the state, two districts, viz., Guntur and Prakasam districts were purposively selected based on their leading contribution to chilli production. From each selected district, four mandals with the highest area under chilli cultivation were identified and purposively selected. Subsequently, three villages were selected from each mandal. From each selected village, 15 smallholder chilli farmers were randomly selected as respondents and thus, the final sample of 360 smallholder chilli farmers were selected.

Data collection

Both primary and secondary data were collected to examine the adoption of chilli production technologies. The primary data was collected from smallholder chilli farmers using a structured and pre-tested survey schedule. The primary data pertained to the agricultural year 2022-23 and includes detailed information on input use, output levels, socio-economic and institutional characteristics and the adoption of chilli production technologies. The secondary data pertaining to various improved chilli production technologies was collected from government publications, official reports and research articles. Subsequently,

Technology Adoption index

The Technology Adoption Index (TAI) is a composite measure that quantifies the extent to which a farmer or a group of farmers has adopted a set of recommended technologies or practices and is typically expressed as a

percentage. In this study, the TAI was employed to assess the extent of chilli technology adoption among chilli farmers (Karthikeyan, 1994) ^[11]. The index evaluates the degree to which a farmer has implemented the recommended chilli production technologies. For each farmer, the TAI was calculated using the following formula:

$$\text{Technology Adoption Index (TAI)}_i \text{ of } i^{\text{th}} \text{ farmer} = \left(\frac{\text{No. of chilli technologies adopted by the } i^{\text{th}} \text{ farmer}}{\text{Total no. of chilli technologies}} \right) \times 100 \quad \text{. (eq1)}$$

Through a detailed review and discussion, a total of 30 improved chilli production technologies were considered. Based on the number of technologies adopted, the farmers were equally divided into adopters and non-adopters. The average cut-off of TAI is 15.5 for the sample and hence farmers who adopted more than 15 technologies were classified as technology adopters, while those adopting 15 or fewer technologies were classified as non-adopters.

Data Envelopment Analysis

Technical efficiency is a measure indicating ability of the farm to achieve maximum possible output to a given set of inputs or getting minimum of inputs use, given a level of output produced (Farrell, 1957) ^[8]. To estimate farm-level technical efficiency, this study employed Data Envelopment Analysis (DEA), a non-parametric linear programming technique used to construct a production frontier (Hiebert, 1974) ^[10]. Consistent with standard practice in agricultural efficiency studies, an input-oriented model was adopted, as farmers generally have greater control over input utilization than over output realization (Pahlavan *et al.*, 2012) ^[18]. Technical efficiency was estimated under the Variable Returns to Scale (VRS) assumption to account for scale inefficiencies arising from constraints such as farm size and limited access to inputs (Banker *et al.*, 1984; Coelli *et al.*, 1998) ^[5, 7].

The DEA-VRS model is specified as:

$$\text{Min}_{\theta, \lambda} \theta$$

Subject to

$$\sum_{j=1}^N \lambda_j Y_j \geq Y_i$$

$$\sum_{j=1}^N \lambda_j X_{kj} \leq \theta X_{ki}, \quad k = 1, 2, \dots, n$$

$$\sum_{j=1}^N \lambda_j = 1, \lambda_j \geq 0 \quad \dots \dots \text{(eq 2)}$$

where θ represents the technical efficiency score of the i^{th} chilli farm

Y_i = Chilli yield (quintals/ha)

X_{ki} = K^{th} input used by the i^{th} farm

λ_j = Vector of intensity variables and

N = Total number of chilli farms,

A value of $\theta = 1$ indicates full technical efficiency, whereas $\theta < 1$ reflects technical inefficiency. The input and output variables used to analyze the technical efficiency of chilli farmers are presented below.

Y_i = Yield of chilli farm (quintals/ha)

X_1 = Seed (grams/ha)

X_2 = Fertilizer (kgs/ha)

X_3 = Organic manure (tonnes/ha)

X_4 = Plant protection chemicals (litres/ha)

X_5 = Human power (labour mandays)

X_6 = Irrigation (hours/ha)

Tobit regression model

The study employed a censored regression model to analyze the role of socio-economic, demographic, and institutional factors in explaining technical efficiency in chilli production. Tobit regression, introduced by Tobin (1958) [13], provides a framework for estimating models with censored dependent variables. Since the efficiency index derived from DEA is bounded between 0 and 1, the Tobit model is appropriate for identifying the determinants of technical efficiency among farmers. The efficiency indices derived from equations (2) was used as measures of farm performance. The empirical Tobit regression model can be specified as follows:

$$Y_i^* = \beta_0 + \sum_{k=1}^K \beta_k X_{ik} + \varepsilon_i \quad \dots\dots(\text{eq } 3)$$

Where

Y_i^* = latent technical efficiency score

X_{ik} = Vector of input variables used in chilli production

β_k = Parameters to be estimated

$\varepsilon_i \sim N(0, \sigma^2)$

The Tobit model assumes the existence of an unobserved (latent) variable Y_i^* , which represents the underlying technical efficiency of the i^{th} farmer. The observed dependent variable Y_i is linked to the latent variable Y_i^* as per the following formulation

$$Y_i = \begin{cases} Y_i^* & \text{if } 0 < Y_i^* \leq 1 \\ 0 & \text{if } Y_i^* \leq 0 \\ 1 & \text{if } Y_i^* > 1 \end{cases} \quad \dots\dots\dots(\text{eq } 4)$$

The empirical model examining the effects of a set of explanatory variables on efficiency scores, estimated using the maximum likelihood estimation technique, is specified

by the following linear relationship:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + u_i \dots(\text{eq } 5)$$

Where

Y_i = Efficiency score obtained from DEA model ranging between 0 and 1

X_1 = Age of the farmer (years)

X_2 = Levels of education (0-Illiterate, 1-Primary, 2-Secondary, 3-Intermediate and 4-Graduation and above)

X_3 = Occupation of the farmers (1- Agriculture, 2-Livestock and 3- others)

X_4 = Chilli farm size (ha)

X_5 = Access to membership in farmers' organization (1=yes, 0=otherwise)

X_6 = Access to the credit sources (numbers)

X_7 = Access to the agricultural extension services (1=yes, 0=otherwise)

X_8 = Adoption of chilli technologies (1= yes and 0= otherwise)

Results and Discussion

The socio-economic characteristics of the sample chilli farmers are presented in Table 1, which indicate that chilli cultivation was predominantly undertaken by middle-aged farmers, with 69.17 per cent of respondents belonging to the 31-50 years age group. Nearly 47.23 per cent of chilli farmers had completed intermediate or graduation level education, reflecting a moderate level of educational attainment. Agriculture was the primary occupation for the majority of farmers (86.67%) indicating a strong dependence on farming for their livelihood. With respect to farm size, most chilli farmers were small farmers (65.56%), followed by marginal farmers (34.44%), highlighting the predominance of small landholdings. About 63 per cent of the farmers had membership in farmer organizations, which facilitated access to information, collective support and institutional services. Regarding access to credit, nearly 80 per cent of farmers had access to one or more credit sources, while 20 per cent reported no access, indicating persistent financial constraints. Access to agricultural extension services was relatively high (82.78%), suggesting effective extension outreach in the study area. Overall, the socio-economic profile reflects a farming community largely composed of smallholders with moderate educational attainment and substantial institutional and extension support, creating a conducive environment for the adoption of improved chilli technologies and improvements in technical efficiency.

Table 1: Descriptive statistics of the socio-economic profile of chilli farmers (n=360)

Variables	Category	Frequency	Percentage
Age(years)	21-30	20	5.56
	31-40	96	26.67
	41-50	117	32.50
	51-60	82	22.78
	≥61	45	12.50
Education (Levels of education)	Illiterate	62	17.22
	Primary	70	19.44
	Secondary	58	16.11
	Intermediate	78	21.67
	Graduation and above	92	25.56
Primary occupation	Agriculture	312	86.67
	Livestock	40	11.11
	Others	8	2.22
Chilli farm size (hectares)	Marginal farmer (< 1ha)	124	34.44
	Small farmer (1-2 ha)	236	65.56
Organization membership	Yes	225	62.50
	No	135	37.50
Access to credit source(number)	0	72	20.00
	1-2	151	41.94
	3-4	114	38.06
Access to Agricultural extension services	Yes	298	82.78
	No	62	17.22

Assessing the technologies adoption index in the chilli production

In this study, the Technology Adoption Index (TAI) was used to assess the level of adoption of various chilli cultivation technologies among smallholder farmers. The analysis of the TAI revealed considerable variation in the adoption of recommended chilli production technologies among smallholder farmers (Table 2).

The results revealed that the application of plant growth regulators ranked first, with the highest frequency of adoption (360 farmers) with a 100 per cent adoption level. Similar findings were reported by Soni and Bose, (2024) [30] who observed about 80 per cent adoption of plant growth regulators in chilli cultivation in Uttar Pradesh. Other chilli technologies adoption followed by the selection of disease and pest resistant varieties (TAI 98.96%) and the spraying

of micronutrient mixtures (TAI 93.75%). Mechanization-related practices, such as mechanized weed control and the use of modern farm machinery for ploughing, ranked fourth and fifth, respectively, with both recording an adoption index of 88.54 per cent which reflects increasing labour scarcity and the growing need to reduce labour costs in chilli cultivation. Technologies related to varietal improvement, including varietal replacement and the adoption of high-yielding varieties, exhibited moderate levels of adoption, suggesting that although farmers were willing to adopt improved varieties, adoption may have been constrained by limited seed availability and farmers' risk perceptions. Similar results were reported by Asha *et al.* (2019) [3], who found that about 84 per cent of integrated chilli farmers adopted high-yielding varieties.

Table 2: TAI for chilli technologies among smallholder farmers (n=360)

S.no	Chilli technologies	Frequency	TAI	Rank
1.	Application of plant growth regulators	360	100	1
2.	Selection of disease/pest-resistant varieties	356	98.96	2
3.	Spraying a micronutrient mixture	338	93.75	3
4.	Mechanization in weed control	319	88.54	4
5.	Modern farm machinery/ equipment in ploughing	319	88.54	5
6.	Varietal replacement	313	86.81	6
7.	Selection of high-yielding varieties	275	76.39	7
8.	Manure application	271	75.35	8
9.	Insect sticky traps	265	73.61	9
10.	Pheromone traps	259	71.87	10
11.	Use of cold storage facilities	255	70.83	11
12.	Using trap crops	249	69.1	12
13.	Participation in e-NAM	244	67.71	13
14.	Using pro-trays for seedling production	225	62.5	14
15.	Light traps	218	60.42	15
16.	Seed treatment	199	55.21	16
17.	Application of bio-fertilizer	181	50.35	17
18.	Neem oil application	166	46.18	18
19.	Pre-emergence application of herbicides	163	45.14	19
20.	Adoption of green manure cropping	158	43.75	20

21.	Participation in FPO platforms	158	43.75	21
22.	Micro irrigation systems	153	42.36	22
23.	Growing border crops	64	17.71	23
24.	Neem cake application	34	9.37	24
25.	Application of precision farming, mulching, soil drenching with biopesticides, arranging bird perches, deep summer ploughing, and mechanical drying of produce	0	0	25

Input management practices, including manure application and seed treatment, exhibited moderate levels of adoption. Similar findings were reported by Pandey *et al.* (2018) ^[20], who observed a 60 per cent adoption of seed treatment in cauliflower cultivation, and by Sarada and Kumar (2017) ^[28] who reported a 45 per cent adoption of manure application in chilli cultivation in Prakasam district.

Integrated pest management (IPM) practices such as sticky traps, pheromone traps, trap crops, and light traps also showed moderate adoption, with adoption indices ranging from 60.42 to 73.61 per cent. Although these practices were environmentally sustainable, their adoption may be constrained by higher knowledge requirements and the need for continuous monitoring. These findings are consistent with Ramulamma *et al.* (2017) ^[24], who reported that nearly 80 per cent of chilli farmers in Telangana had adopted IPM practices, and Mahalakshmi *et al.* (2018) ^[15], who observed a medium level of IPM adoption in chilli cultivation.

Post-harvest and market-oriented innovations, including the use of cold storage facilities, participation in the electronic National Agriculture Market (e-NAM), and membership in Farmer Producer Organization (FPO) platforms, recorded moderate adoption levels, indicating partial integration of market-linked technologies among chilli farmers. Relatively low adoption was observed for bio-fertilizers, neem oil application, pre-emergence herbicides, green manuring, micro-irrigation systems, border cropping, and neem cake application, with adoption indices below 50 per cent. These low adoption levels may be attributed to limited awareness, delayed benefits, financial constraints, and inadequate technical support. Similar patterns were reported by Sharma *et al.* (2015) ^[29], Tengli and Sharma (2017) ^[32] and Chowdary *et al.* (2021) ^[6], who documented moderate adoption of bio-fertilizers, green manuring, and pre-emergence herbicides across different crop systems. Zero adoption was recorded for advanced and knowledge-intensive practices such as precision farming, mulching, soil drenching with biopesticides, installation of bird perches, deep summer ploughing, and mechanical drying of produce, indicating limited awareness, technical know-how, and institutional support for these practices in the study area.

Technical efficiency of chilli farms

The technical efficiency of chilli farmers adopting improved

technologies was analyzed using the Data Envelopment Analysis (DEA) approach, and the results are presented in Table 3 and Figure 1. The findings revealed that the majority of chilli farmers (63.71%) had technical efficiency scores ranged between 0.81-1.00, followed by 0.71-0.80 category (28.33% of farmers) and 0.61-0.70 category (6.94% of farmers). The mean technical efficiency was 85.10 per cent, indicating that, on average, farmers could potentially reduce input use by 14.90 per cent without reducing output. Similar findings were reported by Kumar (2022) ^[14], who observed a technical efficiency of about 85 per cent among rice farmers in the Jagtial district of Telangana.

The distribution of technical efficiency scores for chilli technology adopters and non-adopters also presented in Table 3, to analyze the effect of chilli technologies effect, revealed that there were differences in efficiency levels between them. Among technology adopters, the majority of farmers were concentrated in the higher efficiency ranges. About 46.11 per cent of adopters operated at an efficiency level between 0.91 and 1.00, indicating that a substantial proportion of adopters were operating close to the best-practice frontier. In addition, 37.22 per cent of adopters fell within the 0.81-0.90 efficiency range. A significant proportion of non-adopters (41.11%) operated within the 0.71-0.80 efficiency interval, followed by 27.78 per cent in the 0.81-0.90 range. Only 18.33 per cent of non-adopters achieved efficiency scores between 0.91 and 1.00, which is considerably lower than that of adopters. The mean technical efficiency of adopters was 89.47 per cent, which was substantially higher than that of non-adopters (80.83%). This indicated that, on average, chilli technology adopters could reduce input use by only about 10.53%, whereas non-adopters could potentially reduce inputs by 19.17% without reducing output. A similar result was reported by Malleswari *et al.* (2023) ^[16], who found that farmers adopting e-commerce platforms achieved higher technical efficiency than non-adopters. Overall, the results clearly demonstrated that adoption of improved chilli production technologies was associated with higher technical efficiency. The higher concentration of adopters near the efficiency frontier suggests that improved technologies play a significant role in enhancing resource-use efficiency in chilli cultivation.

Table 3: Distribution of TE scores of chilli technologies

Efficiency level	Adopters (n ₁ =180)		Non-adopters (n ₂ =180)		Total sample size (n=360)	
	Frequency	%	Frequency	%	Frequency	%
0.61-0.70	2	01.11	23	12.78	25	06.94
0.71-0.80	28	15.56	74	41.11	102	28.33
0.81-0.90	67	37.22	50	27.78	117	32.51
0.91-1.00	83	46.11	33	18.33	116	32.22
Mean TE	0.896		0.808		0.851	
Maximum TE	1.000		1.000		1.000	
Minimum TE	0.686		0.650		0.650	

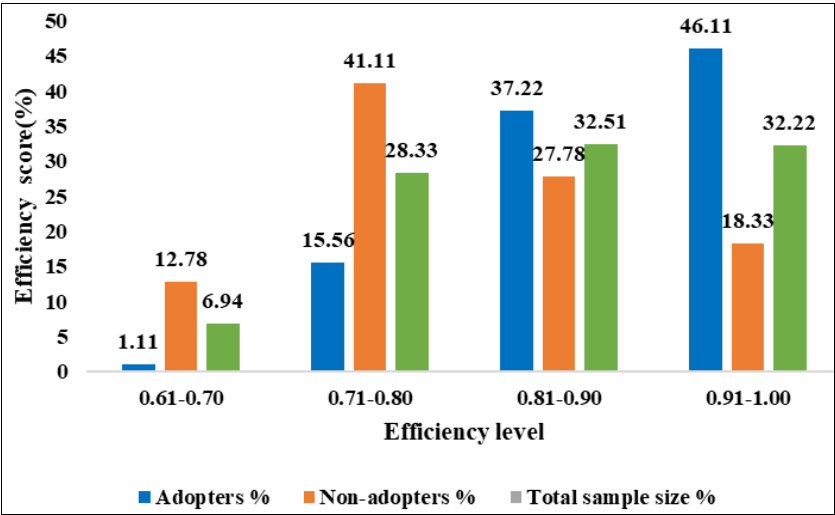


Fig 1: TE scores of sample farmers

Determinants of technical efficiency

The Tobit regression results revealed that education, occupation, organizational membership, access to agricultural extension services, and adopters of chilli production technologies had a significant positive effect on the technical efficiency of chilli farmers (Table 4). Among these factors, adoption of chilli production technologies exerted the strongest influence on technical efficiency, increasing efficiency by 7.7 per cent at the 1 per cent level of significance. As the level of technology adoption increased, the technical efficiency of chilli farmers also increased, enabling them to obtain higher yields with the available inputs. Similar results were reported by Patel *et al.* (2021)^[21], who demonstrated that adoption of Krishi Vigyan

Kendra (KVK) recommended technologies significantly enhanced technical efficiency. Access to agricultural extension services also found significant which enhances technical efficiency by 3.8 per cent, highlighted the crucial role of extension services in disseminating information on recommended chilli production technologies, enhances efficient input use which increases likely to adopt improved technologies and implement them effectively, resulting in higher efficiency levels. Education had a positive and significant effect on technical efficiency, increasing efficiency by about 1 per cent. This result aligned with Santosa *et al.* (2024)^[27] for rainfed sugarcane farmers in Indonesia and Saeri *et al.* (2021)^[26] for rice farmers.

Table 4: Tobit regression results

Determinants	Coefficient	SE
Age (years)	0.001 ^{NS}	0.001
Education levels	0.010 ^{**}	0.004
Occupation (1=Agriculture, 2= livestock and 3=others)	0.028 ^{**}	0.013
Chilli farm size (ha)	0.001 ^{NS}	0.011
Organizational membership (1=Yes, 0=no)	0.021 [*]	0.011
Access to credit (no)	0.001 ^{NS}	0.005
Agricultural extension (1=Yes, 0=no)	0.038 ^{***}	0.014
Chilli technology adoption (1=Yes, 0=no)	0.077 ^{***}	0.012

Note: SE = Standard Error; ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; NS = Not significant

The occupation variable also showed a positive effect on technical efficiency, indicating that farmers whose primary occupation was agriculture were more technically efficient than those engaged in livestock or other non-farm activities. This efficiency advantage was attributed to greater specialization in agriculture, which enabled farmers to devote more managerial effort, time, and attention to chilli cultivation, thereby improving technical efficiency. Furthermore, membership in farmer organizations increased the technical efficiency of chilli farmers due to adoption of chilli technologies, reflecting the role of institutional participation in improving decision-making and input-use efficiency. These findings were consistent with Santosa *et al.* (2024), who reported that membership in farmer-based organizations significantly increased the technical efficiency of rainfed sugarcane farming in Indonesia.

Summary and conclusion

Among all the chilli technologies, application of plant growth regulators, selection of disease- and pest-resistant varieties and spraying of micronutrient mixtures were the major technologies adopted by the chilli farmers which indicating that farmers were majorly focusing on the practices that are easily implementable, cost-effective, and immediate productivity gains. Chilli farmers operated at a relatively high level of technical efficiency, with considerable scope for reducing input use without compromising output. Furthermore, farmers who adopted improved chilli production technologies were substantially more technically efficient than non-adopters, highlighting the important role of technology adoption in enhancing resource-use efficiency. Moreover, education, occupation, organizational membership, access to agricultural extension

services and adoption of improved chilli technologies were identified as the major factors exerting a positive influence on technical efficiency, underscoring the importance of human capital development, institutional support, and technology dissemination in improving farm-level efficiency.

References

- Ahmad N, Sinha DK, Singh KM. Estimating production efficiency in rice cultivation of Bihar: An economic approach. *Economic Affairs*. 2017;62(3):353-360.
- Ali S, Singh B, Gupta A, Kumar A. Assessment of technological gap and productivity gain in cowpea through frontline demonstrations. *Int J Curr Microbiol Appl Sci*. 2020;9(5):2771-2777.
- Asha R, Umadevi K, Suseela K, Umar SKN. Backward integration: Impact on resource use efficiency and problems under chilli farming. *Andhra Agric J*. 2019;66(3):539-543.
- Baenas N, Belović M, Ilic N, Moreno DA, García-Viguera C. Industrial use of pepper (*Capsicum annum* L.) derived products: Technological benefits and biological advantages. *Food Chem*. 2019;274:872-885.
- Banker RD, Charnes A, Cooper WW. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Manage Sci*. 1984;30(9):1078-1092.
- Chowdary KR, Tejaswini M, Kumar MR. Extent of adoption of ANGRAU technologies in groundnut crop by farmers of Rayalaseema zone of Andhra Pradesh. *Asian J Agric Ext Econ Sociol*. 2021;39(5):29-33.
- Coelli TJ, Rao DSP, O'Donnell CJ, Battese GE. An introduction to productivity and efficiency analysis. Boston: Kluwer Academic Publishers; 1998.
- Farrell MJ. The measurement of productive efficiency. *J R Stat Soc Ser A*. 1957;120(3):253-281.
- Guha P, Mandal R. Technical inefficiency of maize farming and its determinants in different agro-climatic regions of Sikkim, India. *Indian J Agric Econ*. 2021;76(2):225-244.
- Hiebert LD. Risk, learning, and the adoption of fertilizer-responsive seed varieties. *Am J Agric Econ*. 1974;56(4):764-768.
- Karthikeyan C. Sugar factory registered growers: An analysis of their involvement and impact. M.Sc. (Agri.) Thesis. Coimbatore: Tamil Nadu Agricultural University; 1994.
- Kiruthika N. Economics of Mundu chilli cultivation in Ramanathapuram district of Tamil Nadu, India. *Asian J Agric Ext Econ Sociol*. 2024;42(1):44-48.
- Krasachat W. The effect of good agricultural practices on the technical efficiency of chili production in Thailand. *Sustainability*. 2023;15:866.
- Kumar KN. Technical efficiency of rice farmers in Telangana, India: Data envelopment analysis. *Res World Agric Econ*. 2022;3(3):1-2.
- Mahalakshmi SM, Tulasiram J, Kammar S, Hosamani AK. Adoption behavior of integrated pest management among chilli farmers in Raichur district of Karnataka. *Int J Adv Biotechnol Res*. 2018;8(2):234-237.
- Malleswari B, Devi KU, Rupavatharam S, Suseela K. Economic efficiency of farmers adopting e-commerce for production and marketing of chilli in Guntur district of Andhra Pradesh. *Biological Forum - Int J*. 2023;15(3):147-155.
- Meena GL, Pant DC, Kumar S. Economics of chilli processing in Rajasthan. *Agric Sci Dig*. 2006;26(2):83-86.
- Pahlavan R, Omid M, Akram A. Energy efficiency analysis of greenhouse cucumber production using DEA. *Energy*. 2012;42:84-91.
- Pakpahan HT, Nababan MB. Influence of chili inputs and technical efficiency of chili farmers in Lingga village, North Sumatera Province. *Int J Prog Sci Technol*. 2018;7:43-50.
- Pandey N, Kumar N, Singh AK, Sharma A. Technological gap in recommended cultivation practices of cauliflower in Bokaro district, Jharkhand. *Int J Curr Microbiol Appl Sci*. 2018;7(1):5237-5241.
- Patel S, Khan N, Sharma NR, Mishra S, Patidar P. Assessment of farm efficiency and profitability of adopted and non-adopted farmers in Kymore plateau and Satpura hills region of Madhya Pradesh. *J Pharmacogn Phytochem*. 2021;10(3):21-25.
- Press Information Bureau (PIB). Trading aromas: The rise of the spice economy. Government of India; 2025 Mar 1.
- Professor Jayashankar Telangana State Agricultural University (PJTSAU). Agricultural market intelligence centre: Chilli outlook. Hyderabad: PJTSAU; 2025.
- Ramulamma A, Rakesh G, Chaitanya T, Kumar MS, Kumari AS. Adoption of integrated pest management practices in chilli (*Capsicum annum* L.). *Trends Biosci*. 2017;10(31):6469-6473.
- Reddy IV, Wakle PK, Koshti NR, Tingrae AS. Extent adoption and utilization of sources of information in recommended chilli production technology. *Int J Curr Microbiol Appl Sci*. 2018;7(2):3220-3227.
- Saeri M, Lativah E, Antarlina SS, Arifin Z. Technical efficiency analysis of rice farmers in Ngawi district, East Java Province. *IOP Conf Ser Earth Environ Sci*. 2021;782:022007.
- Santosa A, Rahayu ES, Sutrisno J, Kusnandar K. Technical efficiency of sugarcane farming in East Java, Indonesia: A bootstrap data envelopment analysis. *Open Agric*. 2024;9(1):20220378.
- Sarada O, Kumar GS. Technological gap analysis in chilli production technology in Prakasam district of Andhra Pradesh. *J Res PJTSAU*. 2017;45(6):49-54.
- Sharma A, Singh M, Sharma SN, Tambe SB. Adoption of chilli production technology among chilli growers in Sehore district of Madhya Pradesh. *Indian J Ext Educ*. 2015;51(1-2):95-98.
- Soni K, Bose DK. Knowledge of farmers towards improved chilli cultivation practices in Sonbhadra district of Uttar Pradesh. *Int J Agric Ext Soc Dev*. 2024;7(8):140-143.
- Spices Board of India. Major spice/state-wise area and production of spices 2024. Ministry of Commerce and Industry, Government of India; 2024.
- Tengli MB, Sharma OP. Technological gap in adoption of improved paddy cultivation practices. *Int J Curr Microbiol Appl Sci*. 2017;6(11):1224-1229.
- Tobin J. Estimation of relationships for limited dependent variables. *Econometrica*. 1958;26:24-36.