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Determinants of KUML mung bean technology adoption among farmers in post-rice areas of Suphan Buri Province, Thailand

Jaikham, R.[1], Mankeb, P.[1] *, Suwanmaneepong, S.[1], Chulilung, P.[2], Charoenkittayawut, S.[3], Luenam, L.[1] and Thongkaew, E.[1]

[1]School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand; [2]Valaya Alongkorn Rajabhat University under the Royal Patronage, Phahonyothin Road, Khlong Nueng Subdistrict, Khlong Luang District, Pathumtani, Thailand; [3]Faculty of Education, Chulalongkorn University, Bangkok, Thailand.

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Abstract The results revealed that almost half of the farmers (48.75%) had a high level of knowledge regarding the production of KUML mung beans, and all farmers (100%) exhibited positive attitudes toward KUML mung bean production. Regarding the level of adoption of KUML mung bean post-rice cropping technology, farmers showed the highest level of adoption in the stages of assessment of genetic purity, harvesting, and storage. Mixture preparation, crop planting, and management are crucial in site selection and moderate soil preparation. In addition, the findings based on multiple regression analysis showed that statistically significant factors influencing adoption related to frequency of contact with agricultural extension officers ($p<.05$), knowledge regarding KUML mung bean cultivation ($p<.05$), and attitude toward KUML mung bean production ($p<.01$).

Keywords: Technology adoption, Mung bean technology cultivation, Post-rice areas, Suphan Buri Province

Introduction

Mung bean (*Vigna radiata* (L.) Wilczek.) is economic crops that are important to the Thai economy. It is consumed domestically and serves as a raw material in various processed food industries. Domestic demand exceeds domestic production, making additional imports necessary. (DOAE, 2022). Amid ongoing drought conditions exacerbated by climate change and El Niño phenomena, the Thai government has implemented policies encouraging farmers to reduce the cultivation of ratoon rice and instead plant alternative crops, emphasizing drought-tolerant, water-efficient species. Mung bean, a legume crop, meets these conditions by requiring only about one-fifth of the water used

* **Corresponding Author:** Mankeb, P.; **Email:** panmankeb@gmail.com

for rice cultivation. It has a short growing period, drought tolerance, simple management, soil improvement benefits, and potential for year-round cultivation. Mung bean is therefore considered a suitable alternative for increasing farmers' income in drought-prone areas (NSTDA, 2024).

KUML mung bean variety, developed by Kasetsart University, has the following characteristics: high yield, good resistance to diseases and pests, drought tolerance, and suitability for cultivation in areas with limited water. It can also be planted multiple times a year. As such, the KUML variety presents an attractive option for farmers seeking sustainable increases in productivity and income (AGRITEC, 2024).

Samchuk District, Suphan Buri Province, predominantly cultivates rice but also produces other upland crops such as sugarcane, cassava, and maize (SBPAO, 2024). There are water shortage problems during the off-season, from the beginning of the rice growing season until April. The Sustainable Agriculture Group (SAG) of Ban Nong Phak Naek shifted to mung bean cultivation as a post-rice crop, especially Chai Nat 72 and Kamphaeng Saen 2 varieties. Over the past years (2018–2021), yields from these varieties have been relatively low. Consequently, during 2022–2023, experimental cultivation of the KUML variety was conducted on 80 rai (approximately 12.8 hectares) under the project "*Technology Transfer for High-Quality Mung Bean Production Using Market-Driven Mechanisms for KUML Variety*" Results showed that KUML had high yield potential and responded well to local needs. Farmer groups aimed to expand production capacity to increase income and strengthen sustainability (SCDAEO, 2024).

However, successful adoption of the KUML mung bean cultivation technology requires understanding farmers' acceptance, which is a psychological process influenced by economic, social, and communicative factors (Rogers, 1983). Additionally, research by Tarbud *et al.* (2023) The study results reflect that the individual characteristics, knowledge, and attitudes of farmers are factors that are significantly related to the acceptance of KUML mung bean seed production technology.

Therefore, the research finding aimed to study the application of KUML mung bean cultivation technology by farmers in the post-rice paddy fields of Suphan Buri Province.

Materials and methods

Population and sample

The population for this study consisted of KUML mungbean farmers who were members of the Sustainable Agriculture Group (SAG) in Ban Nong Pak

Nak, Sam Chuk District, Suphan Buri Province. Data from the Samchuk District Agricultural Extension Office (SCDAEO) indicated that in 2024 there were 80 registered farmers (SCDAEO, 2024). Therefore, it was collected data from the entire population, including all registered farmer groups as the research unit.

Research instruments

Data collection was conducted using a structured questionnaire divided into five parts:

Part I: Socio-demographic background of respondents: This section covered gender, age, marital status, education level, household size, income from mungbean cultivation, farming experience, and related socioeconomic factors.

Part II: Post-harvest care: This assesses agricultural activities related to soil preparation before planting, seed supply, water management, fertilization, and weed control.

Part III: Knowledge of KUML mung bean production: This section included 19 true–false items developed based on Bloom's taxonomy (Bloom, 1956; Mondal *et al*., 2014). The items measured knowledge across the production cycle, including seed selection, soil preparation, planting methods, crop management (fertilization, irrigation, weed control, and disease and insect pest management), and harvesting.

Part IV: Attitudes toward KUML mung bean production: It consisted of 15 items, measured using a 5-level Likert scale, with response options reflecting levels of agreement: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1).

Part V: Adoption of KUML mung bean cultivation technology: This section assessed adherence to the KUML cultivation manual and recommendations, covering planting, crop management, and harvesting. It consisted of 20 items that were rated on a five-point scale. (Mondal *et al*., 2014), The answer options are: Strongly Agree (5), Agree (4), Unsure (3), Disagree (2), and Strongly Disagree (1).

The questionnaire was subjected to content validity by three subject-matter experts. Analysis using the Item–Objective Congruence (IOC) index revealed that all questions had a value greater than 0.50, indicating that their content was accurated and appropriated. Subsequently, the instrument was pilot tested with 30 respondents. The results of the reliability assessment in terms of internal consistency using the Kuder–Richardson Formula 20 (KR-20) indicated that the items in the knowledge regarding the production of KUML mung beans section (Part III) yielded a KR-20 coefficient of 0.784. For the attitudes toward KUML mung bean production (Part IV) and adoption of KUML mung bean cultivation

technology (Part V), the findings were related to Cronbach's alpha coefficients which were 0.897 and 0.741, respectively. Therefore, this result is demonstrated satisfactory content accuracy and reliability for the research tools used in this study.

Data analysis

Data analysis was performed using frequency, percentage, mean, and standard deviation. Multiple regression analysis was then employed to identify determinants of KUML mung bean technology adoption among farmers in post-rice areas of Suphan Buri Province.

The regression model is expressed implicitly as follows:

$Y_i = \beta_0+\beta_1x_1+\beta_2x_2+...+\beta_{11}x_{11} +\varepsilon_i$

Where:

Y_i = the level of KUML mung bean technology adoption (unit: scores)

β_0 = constant term

β_k = regression coefficients

X_1 = Gender (male = 1, female = 0)

X_2 = Age (unit: years)

X_3 = Education level (unit: years of schooling)

X_4 = Number of household members (unit: persons)

X_5 = Experience in KUML mung bean cultivation (unit: years)

X_6 = Cultivation area of KUML mung beans (unit: rais)

X_7 = Income from KUML mung bean cultivation (unit: Thai Baht)

X_8 = Frequency of training on KUML mung beans (unit: number of times)

X_9 = Frequency of contact with agricultural extension officers (unit: number of contacts)

X_{10} = Knowledge regarding KUML mung bean cultivation (unit: scores)

X_{11} = Attitude toward KUML mung bean production (unit: scores)

ε_i = error term

Results

Socio-demographic backgrounds of respondents

This study investigated the socio-demographic characteristics of respondents involved in KUML mung bean cultivation. The descriptive statistics summarizing the study sample's profile is shown in Table 1. Out of 80 respondents, there was a higher proportion of females than males (62.5%) as

compared to males (37.5%). Ages varied widely, with the 51-60 age group being the largest (41.25%), followed the 61-70 age group (27.5%). Most respondents were married (67.5%) at the educational level, the majority of the sample had completed primary education (45%), followed by lower secondary education (22.5%). Occupationally, a significant majority of respondents identified as farmers (92.5%). Most households were small, consisting of 1-3 individuals (57.5%). The average number of farm laborers employed was 1.8, with a range of 1 to 5 laborers. On average, respondents had 5.15 years of experience growing the KUML mung bean variety, with experience ranging from 1 to 15 years. Income derived from KUML mung bean cultivation in 2024 varied, with the largest proportion of respondents (56.25%) reporting earnings between 2,001-4,000 Baht per rai. Most respondents (41.25%) received agricultural extension services 1-2 times. Most respondents (78.75%) had received training on mung bean cultivation 1-3 times. The majority of respondents (71.25%) were never participated in a field trip related to mung bean cultivation before.

Table 1. Socio-demographic backgrounds of respondents

Variables	Frequency	Percent
Gender		
Male	30	37.50
Female	50	62.50
Age (unit: years)		
≤ 30	2	2.50
31-40	8	10.00
41-50	10	12.50
51-60	33	41.25
61-70	22	27.50
> 70	5	6.25
Marital Status		
Single	13	16.25
Married	54	67.50
Divorced	13	16.25
Highest education		
No education	2	2.50
Primary school	36	45.00
Junior high School	18	22.50
High school	11	13.75

Variables	Frequency	Percent
Vocational certificate	1	1.25
Higher vocational certificate	2	2.50
Bachelor's degree	7	8.75
Postgraduate degree	2	2.50
Other	1	1.25
Main occupation		
Farmer	74	92.50
Private Sector Employee	2	2.50
Government Official	1	1.25
Self-Employed	2	2.50
Employee	1	1.25
Household size (unit: persons)		
1-3	46	57.50
4-6	32	40.00
7-9	2	2.50
Number of farm labors (unit: persons) ($\bar{x}$ = 1.8, SD = 0.75, Max = 5, Min = 1)		
Experiences in cultivating KUML mung bean ($\bar{x}$ = 5.15, SD = 3.2, Max = 15, Min = 1)		
Income from cultivating KUML mung beans (Baht/rai)		
≤ 1000 Baht	25	31.25
2,001- 4,000 Baht	45	56.25
> 4,000 Baht	10	12.50
Agricultural extension services (times)		
Never	23	28.75
1-2 times	33	41.25
3-4 times	12	15.00
5-6 times	7	8.75
9-10 times	2	2.50
11-12 times	3	3.75
Training on mung bean cultivation (times)		
Never	8	10.00
1-3 times	63	78.75
4-5 times	7	8.75
> 7 times	2	2.50
Study visits to mung bean cultivation (times)		

Variables	Frequency	Percent
Never	57	71.25
1-5 times	19	23.75
6-10 times	3	3.75
> 15 times	1	1.25

Knowledge regarding the production of KUML mung bean

The level of farmers' knowledge regarding KUML mung bean production is shown Table 2. Nearly half of the farmers (48.75%) had a high level of knowledge, followed by a moderate level at 42.50%. Only 8.75% of the farmers had a low level of knowledge regarding KUML mung bean production. It suggested that while many farmers demonstrate high levels of knowledge, targeted training programs may be beneficial for those with moderate and low knowledge levels to enhance production practices.

Table 2. Farmers' knowledge regarding the production of KUML mung bean

Knowledge	Frequency	Percentage
Low (less than 60%) (0-11 scores)	7	8.75
Moderate (60-79%) (12-14 scores)	34	42.50
High (Greater than or equal to 80%) (15-19 scores)	39	48.75
Total	**80**	**100**

Farmers' attitudes toward KUML mung bean production

The farmers' attitudes toward KUML mungbean production is summarized in Table 3. The results showed that all respondents expressed a positive attitude toward KUML mung bean production, with mean scores ranging from 3.50 to 5.00, and no neutral or negative attitudes were reported. This study's findings explained the potential economic benefits associated with producing the KUML mung bean variety, such as increased yield, improved market access, or higher profits.

Table 3. Farmers' attitudes toward KUML mung bean production

Attitude towards GAP	Frequency	Percentage
Negative attitude (1.00-2.49)	-	-
Neutral attitude (2.50-3.49)	-	-
Positive attitude (3.50-5.00)	80	100
Total	**80**	**100**

Farmers' adoption of KUML mung bean post-rice cropping technology

The adoption levels of the KUML mungbean post-rice cropping technology among farmers in Suphan Buri Province is shown in Table 4. Overall, the average adoption level was high (Mean=3.99, SD=0.56), which indicated a generally positive adoption of KUML mung bean post-rice cropping technology by the farmers. Among the adoption components, 'storage' ranked highest (mean=4.45, SD=0.72), followed by 'harvesting' (mean=4.41, SD=0.69) and 'assessment of genetic purity' (mean=4.31, SD=0.97), all of which were classified at the highest adoption level. Seed preparation showed high acceptance (mean = 3.83, standard deviation = 0.82), and crop planting and management also exhibited high levels of acceptance (mean=3.76, SD=0.88). In contrast, 'site selection and soil preparation' exhibited a moderate level of adoption (mean= 3.17, SD = 1.14), ranking lowest among the components.

Therefore, although adoption of the KUML mungbean after-rice cropping technology is encouraged and targeted interventions to enhance adoption of site selection and soil-preparation practices are warranted. Addressing the challenges in fully implementing pre-planting practices was significantly improved the efficiency and sustainability of agricultural systems.

Table 4. Farmers' adoption of KUML mung bean post-rice cropping technology

Items	Mean	SD	Adoption Level	Rank
1. Site selection and soil preparation	3.17	1.14	Moderate	6
2. Seed preparation	3.83	.82	High	4
3. Planting and crop management	3.76	.88	High	5
4. Assessment of genetic purity	4.31	.97	Highest	2
5. Harvesting	4.41	.69	Highest	3
6. Storage	4.45	.72	Highest	1
Average	3.99	.56	**High**	

Note: Highest =4.21-5.00, High=3.41-4.20, Moderate=2.61-3.40, Low=1.81-2.60, Lowest=1.00-1.80

Determinants of KUML mung bean technology adoption among farmers in post-rice areas

The multiple regression analysis was examined the factors affecting farmers' adoption of post-rice KUML mungbean cultivation technology in Suphan Buri Province is shown in Table 5. The regression model indicated that the set of independent variables explained approximately 28.8% of the variance in KUML mung bean technology adoption (R^2=0.288).

Among the independent variables, three factors were statistically significant affected on the adoption of KUML mungbean cultivation technology.

First, the frequency of contact with agricultural extension officers (X_9) had positively significant affected (β=0.291, p=.013), indicating that farmers who frequently interact with extension officers are more likely to adopt the KUML mung bean cultivation technology. Second, knowledge regarding KUML mung bean cultivation (X_{10}) was positively associated with adoption (β=0.215, p=037), suggesting that higher levels of knowledge increase the likelihood of technology adoption. Third, attitude toward KUML mung bean production (X_{11}) exerted the strongest influence (β=0.347, p=.002), highlighting the critical role of positive attitudes in promoting technology adoption. However, other factors, including gender, age, educational level, household size, farming experience, cultivated area, income from mungbean production, and the number of training sessions were not significantly affected on technology adoption (p>.05).

In conclusion, the research is highlighted the importance of interaction between farmers and agricultural extension officers, knowledge enhancement, and the development of positive attitudes in promoting the adoption of KUML mung bean cultivation technology.

Table 5. Determinants of KUML mung bean technology adoption among farmers in post-rice areas

Independent variables	b	SE	Beta	t	p-value
Constant	-.684	1.297		-.527	.600
Gender (X1)	.040	.136	.034	.293	.771
Age (X2)	.000	.020	-.008	-.021	.983
Education level (X3)	-.013	.019	-.104	-.723	.472
Number of household members (X4)	-.002	.037	-.007	-.066	.948
Experience in KUML mung bean cultivation (X5)	.077	.181	.156	.427	.671
Cultivation area of KUML mung beans (X6)	.002	.003	.048	.479	.634
Income from KUML mung bean cultivation (X7)	1.332E-5	.000	.033	.321	.749
Frequency of training on KUML mung beans (X8)	.047	.040	.124	1.172	.245
Frequency of contact with agricultural extension officers (X9)	.058	.023	.291	2.546	.013*
Knowledge regarding KUML mung bean cultivation (X10)	.057	.027	.215	2.130	.037*
Attitude toward KUML mung bean production (X11)	.721	.218	.347	3.306	.002**
$R = 0.537$, $R^2 = 0.288$, $SE_{est} = 6.90821$, $F = 2.793$, Sig.F=0.006, Durbin Watson =1.764					

Note: * p<0.05, **p<0.01

Discussion

The findings provided the important insights into factors influencing adoption of KUML mungbean cultivation technology among farmers in post-rice areas of Suphan Buri Province. The regression model explained 28.8% of the variation in adoption, suggesting that psychological and informational factors played a greater role in farmers' decision-making than other variables.

Firstly, attitude toward KUML mungbean production was found to be the strongest predictor of adoption. Farmers with more favorable perceptions of KUML mungbean technology were significantly more likely to adopt the practice. This aligns with Rogers' (2003) theory, who emphasized the importance of people's perceptions and attitudes in determining innovation adoption behavior. Previous studies have similarly demonstrated that positive attitudes toward agricultural innovations to enhance the likelihood of adoption, as farmers perceive greater compatibility and relative advantage (Mwangi and Kariuki, 2015; Chen, 2024; Habanyama and Chibomba, 2025).

Secondly, knowledge regarding KUML mungbean cultivation had significantly positive affected on adoption. This research is described the continuous transfer of knowledge and experiential learning that enhanced farmers' nutrition. Knowledge acquisition reduces uncertainty, enabling farmers to make decisions regarding resource allocation and risk management (Feder *et al.*, 1985; Katya Kule *et al*, 2025) Similar results have been reported in studies on technology adoption in other crop systems, where farmers with higher knowledge levels exhibited greater willingness to adopt improved practices (Kirui *et al.*, 2025).

Finally, the frequency of contact with agricultural extension officers significantly influenced adoption. Regular interaction with agricultural extension officers is allowed the farmers to receive timely advice, practical demonstrations, and encouragement, all of which helped to reduce the barriers to adopting innovations. This finding is consistent with the literature emphasizing the critical role of extension services in disseminating knowledge and fostering innovation adoption in agriculture (Davis and Sulaiman, 2014; Saha *et al.*, 2025; Kirui *et al*., 2025). Agricultural extension work serves as a link between research knowledge and practical application, making technologies that are difficult to access easier to apply and adapted to the context of farmers.

However, the variables of gender, age, education level, household size, experience, cultivated area, income, and amount of training were not statistically significant impacted on the studied outcomes. This is suggested that while demographic and socioeconomic factors may shape general farming capacity, they do not directly drive the adoption of KUML mungbean technology. This finding is consistent with research indicating that perception, attitude, and access

to information important social factors significantly influenced the adoption of innovation. (Meijer *et al*., 2015; Kirungi *et al.*, 2025).

Overall, the results underscored the importance of extension services, farmer knowledge, and positive attitudes as the core levers to enhance adoption of KUML mung bean cultivation technology. Strengthening extension systems, designing participatory training programs, and fostering favorable perceptions of the technology are found to be essential strategies for scaling up adoption and improving productivity in post-rice cropping systems.

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Conflicts of interest

The authors declare no conflicts of interest.

References

Agricultural Technology and Innovation Management Institute (AGRITEC). (2024). High-yield mung bean cultivation through improved knowledge for enhanced income (Revised ed.). YCH Media, Bangkok. 44 p.

Bloom, B. S. (1956). Taxonomy of Educational Objectives, Handbook: The Cognitive Domain. David McKay, New York. 207 p.

Chen, R. (2024). A study applying Rogers' innovation diffusion theory on the adoption process of new teaching methods in secondary education. Research and Advances in Education, 3:6-10.

Davis, K. and Sulaiman, R. V. (2014). The new extensionist: Roles and capacities to strengthen extension and advisory services. Journal of International Agricultural and Extension Education, 21:6-18. https://doi.org/10.5191/jiaee.2014.21301.

Department of Agricultural Extension (DOAE). (2022). Agricultural Promotion Project Manual for Fiscal Year 202. Retrieved from http://www.agriman.doae.go.th/home/agriman62/65 Website Project/6513Legumes.pdf.

Feder, G., Just, R. E. and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. Economic Development and Cultural Change, 33:255-298.

Habanyama, M. and Chibomba, K. (2025). Examining the effects of agricultural technology adoption for agricultural productivity and household income on small scale farmers: A study of Mkushi district. Journal of Arts, Humanities and Social Science, 2:74-85. https://doi.org/10.69739/jahss.v2i1.304.

Katya Kule, E., Agole, D., Obia, A., Okello, D. M. and Odongo, W. (2025). Adoption of sustainable agricultural intensification practices: assessing the role of institutional and socio-economic factors amongst smallholder farmers. Cogent Social Sciences, 11:2470373. https://doi.org/10.3390/su17031148.

Kirui, E. C., Kidoido, M. M., Akutse, K. S., Wanyama, R., Boni, S. B., Dubois, T., and Mutyambai, D. M. (2025). Factors Influencing the Adoption of Agroecological Vegetable Cropping Systems by Smallholder Farmers in Tanzania. Sustainability, 17:1148. https://doi.org/10.3390/su17031148

Kirungi, D., Wesana, J., Sseguya, H., Gellynck, X. and De Steur, H. (2025). Smallholder coffee farmers' perceptions of climate variability and the adoption intensity of climate-smart agriculture technologies in Uganda. International Journal of Agricultural Sustainability, 23:2531727. https://doi.org/10.1080/14735903.2025.2531727.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W. and Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. International Journal of Agricultural Sustainability, 13:40-54. https://doi.org/10.1080/14735903.2014.912493.

Mondal, S., Haitook, T. and Simaraks, S. (2014). Farmer's knowledge, attitude and practice toward organic vegetables cultivation in Northeast Thailand. Kasetsart Journal of Social Sciences, 35:158-166.

Mwangi, M. and Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. Journal of Economics and Sustainable Development, 6:208-216.

National Science and Technology Development Agency (NSTDA). (2024). Farmers celebrate high returns from cultivating KUML-quality mung beans: NSTDA and partners support integrated production through a "market-led production" mechanism. Retrieved from https://www.nstda.or.th/agritec/kuml-press/.

Rogers, E. M. (1983). Diffusion of innovation. 3rd ed. New York: The Free Press. 453 p.

Rogers, E. M. (2003). Diffusion of innovations. 5th ed. Free Press. 576 p.

Saha, P., Prusty, A. K. and Nanda, C. (2025). An overview of pluralism in agricultural extension and advisory services. International Research Journal of Multidisciplinary Scope, 6:131-138. https://doi.org/10.47857/irjms.2025.v06i01.02074.

Sam Chuk District Agricultural Office (SCDAEO) (2024). Post-rice-season mung bean cultivation areas in Sam Chuk District, Suphan Buri Province. Retrieved from https://suphanburi.doae.go.th/province/?pageid=253.

Suphan Buri Provincial Administrative Organization (SBPAO) (2024). Basic information on natural resources and the environment. Retrieved from https://www.suphan.go.th/content-10-421.html.

Tarbud, P., Seerasarn, N. and Signkum, J. (2023). Adoption of mung bean seed production technology of farmers in Lopburi province. Agricultural Science and Management Journal, 6:33-45.

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