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# Factors associated with farmers' adoption of standardized planting methods: evidence from China

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**Introduction:** The standardization of planting techniques has substantially enhanced production efficiency and agricultural output. Understanding farmers' perceptions and adoption of standardized planting practices is essential.

**Methods:** In this study, the binary logistic model and the interpretive structural model was employed to analyze the factors influencing farmers' adoption of standardized planting methods and the hierarchical structure and internal mechanisms of the influential factors.

**Results:** The questionnaire responses of 244 farmers from Zhejiang Province, China, revealed farmers' predominantly positive perceptions of standardized planting methods. Farmers' planting experience and participation in cooperatives significantly affected their perceptions. The results of the regression analysis revealed that significant influencing factors included farmers' education level, planting experience, participation in cooperatives, awareness of standardized planting methods, the perceived effects of standardized planting methods on household income and on village ecological environment. The interpretive structural model results revealed that the surface level factors influencing farmers' adoption of standardized planting methods were farmers' village cadre status, participation in cooperatives, and awareness of standardized planting methods. Farmers' education level and planting experience were the fundamental factors.

**Discussion:** In the future, the influence of farmers' education level and characteristics of arable land on the adoption of standardized planting methods by farmers should be further explored, as well as the need for non-value studies on farmers' willingness to accept standardized planting methods.

KEYWORDS

**standardized planting methods, planting standards, farmers' perspectives, logistic regression, ISM**

## 1 Introduction

Global agricultural standardization has progressed rapidly since the 1970s, particularly in developed countries, as Japan, the United States, and Germany are world leaders in standardized agricultural production. In any case, agriculture is the foundation of China, and despite the country's tremendous macroeconomic growth and strong government support for agricultural programs, China's agricultural growth has shown ups and downs (Chen and Wang, 2022). China's agricultural standardization began in 1949 and entered a new stage of development in 1996 (Geng and Zhang, 2016). With the continual modernization of China's agricultural system, the decisive influence of standardization in agricultural production has attracted widespread public and governmental attention.

Agricultural standardization is based on agricultural science, technology, and practical experience. Relevant standards are developed and implemented in preproduction, production, and postproduction processes to standardize production and management. Agricultural standardization boosts the development of the technical and management aspects of the agricultural industry; maximizes economic, social, and ecological benefits; and transforms traditional agriculture into modern agriculture (Xiong et al., 2015).

The relevant literature has primarily focused on two aspects of agricultural standardization. The first aspect involves the analysis of the current state, underlying mechanisms, and implementation path of agricultural standardization. The second aspect includes the factors that influence the behavioral choices of farmers and their engagement in standardized production practices. Extensive and detailed studies have examined the second aspect.

Many studies have investigated the factors affecting farmers' perceptions and participation in standardized agricultural practices. Such studies have primarily examined four aspects of this topic. First, extensive research has widely analyzed the effects of personal characteristics, such as sex, age, level of education, and number of labors, on the aforementioned perceptions and adoption of standardized agricultural practices. Guo et al. (2022) studied the acceptance of conservation tillage techniques by farmers in black soil regions and their results revealed that age, education level, and other factors influenced farmers' acceptance of conservation tillage techniques. Benaboud et al. (2021) revealed that older farmers preferred chemical pesticides because of their established use in long-term agricultural practices. Second, research on cognitive characteristics has primarily focused on farmers' risk perception and awareness of agricultural standards. Pan et al. (2021) demonstrated that technology perception significantly influenced farmers' purchases of biopesticide. Furthermore, Walton et al. (2021) concluded that farmers who were informed about the effectiveness of biopesticides and were concerned about the quality and safety of their products were more willing to choose biopesticides over chemical pesticides. Third, researchers have examined external environmental factors affecting the adoption of standardized agricultural practices, such as government policies and the promotion of standardized technology. Toma and Mathijs (2007) argued that social factors such as policies, financial pressure, moral standards, and values play an essential role in the production decisions of farmers. The results of Liu et al. (2021) indicated that government subsidies can incentivize farmers to adopt water and soil conservation technologies. In their research on smallholder farmers, Singh et al. (2016) explored how farmer household interactions, social systems, the environment, institutions, and market dynamics affect farming choices. Stupak (2016) studied shifts in Ukrainian agricultural soil protection policies and their effects on agricultural producers' behavior and concrete soil protection practices. Their results demonstrated that policy instability and changes in institutions influenced the behavior of agricultural participants' behaviors. Fourth is the other aspects, including the features of production, characteristics of the cultivated land, and access to information. Xu et al. (2021) discovered that land fragmentation decreased agricultural productivity, increased production costs, and affected mechanization. The results of Si et al. (2021) revealed that the execution of land transfer contracts influenced farmers' acceptance of the technology of protective farming in Gansu Province, China.

However, most studies that have analyzed the factors affecting farmers' participation in standardized planting have focused on a single standard. For instance, Illukpitiya and Gopalakrishnan (2004) analyzed farmers' decisions about and behavior toward soil and water conservation practices on the basis of the assumption that farmers' production choices are influenced by subsidies and social factors. Xiang et al. (2020) analyzed the factors that influenced farmers' adoption of organic fertilizer with respect to the following four dimensions of capital: natural, economic, human, and social.

Although an abundance of international studies examined the factors influencing farmers' perceptions and adoption of standardized planting methods, the following deficiencies remain in the relevant literature. First, although studies on standardized planting have examined various provinces and cities in China, the study area of this paper is focused more on the digital transformation of agriculture and less on agricultural standardized planting. Second, most scholars focus their research on a single agricultural standard. Thus, the relevant literature lacks holistic studies. Figure 1 illustrates the article roadmap. The present study employed data obtained from 244 surveys of farmers from Zhejiang Province in China. The chi-squared test was employed to examine factors influencing the framers' perceptions of standardized planting. The present study first implemented a logistic model to explore the factors influencing the farmers' adoption of standardized planting and then employed an interpretive structural model (ISM) to analyze the hierarchical structure and internal mechanisms of the influential factors.

# 2 Materials and methods

## 2.1 Study area

Zhejiang Province in southeast China is a high-yielding and diversified agricultural region and a top producer of tea, silk, seafood, and bamboo products. Zhejiang has 1,290,500 hectares of arable land, which is composed of 82.36% of paddy fields and 17.64% of dry land. Zhejiang Province has a well-developed economy, but its agricultural production is relatively small. Agricultural value added accounts for only about 3% of the province's annual gross domestic product (GDP). Of the 65.77 million people in Zhejiang Province, only 2.03 million are engaged in agricultural production, and they are relatively decentralized. The government has strongly emphasized the implementation of agricultural standards in Zhejiang as evidenced by the 2016 agricultural project. This project was mainly to control the quality and safety risk of the whole industrial chain of characteristic agricultural products to prevent the occurrence of unsafe or excessive use of pesticides (Zhao et al., 2022). The advancement of agricultural standardization projects has introduced more farmers to agricultural regulations and standardized production techniques.

## 2.2 Data collection

In December 2019, Zhejiang Province recognized 21 counties (cities and districts), including Yuhang District of Hangzhou

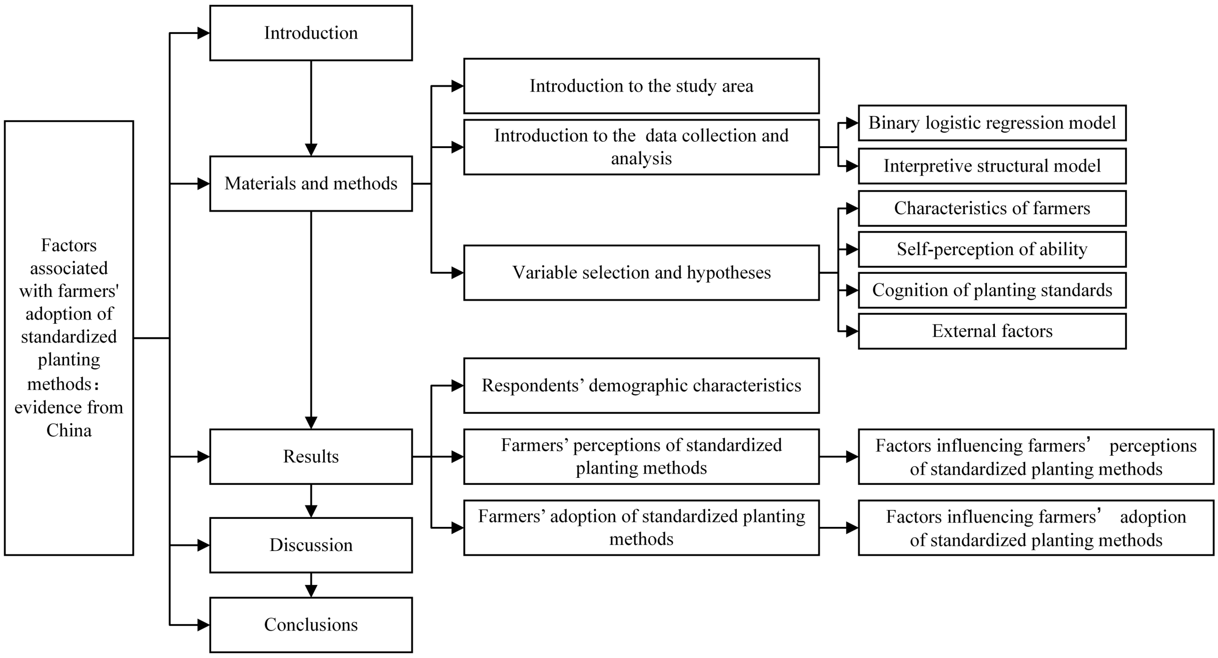


FIGURE 1
The road map of this study.

City, Jiande City, Yinzhou District of Ningbo City, as the leading counties of agricultural green development. Thess counties (cities and districts) have relatively good agricultural development, are representative of the province, and farmers may have a more comprehensive knowledge of standardized agricultural methods.

To improve the validity of the questionnaire, based on this list, this study conducted a random survey of farmers in 11 cities of Zhejiang Province in July 2022. Based on the questionnaire designed by the study, the optimal number of questionnaires for this study was 360 and above, due to the lack of financial and human resources for the study, only 301 questionnaires were collected, and after eliminating the invalid questionnaires, finally 244 valid questionnaires were obtained, which is 13.5 times larger than the dependent variable of this study. The questionnaire covers people of different ages, genders, education levels and income levels. Therefore, the sample size of this study is adequate and representative. All questionnaire data used for this paper were obtained through randomized anonymous surveys and did not contain any detailed information that could be used to identify respondents. Table 1 presents the key questions included in the questionnaire.

## 2.3 Data processing and analysis

The collected data were processed using SPSS 25.0. First, descriptive statistics were determined, and then the chi-square test was conducted. The logistic regression model was then adopted to analyze the influential variables. The significant influential variables derived from the logistic regression model were incorporated into an ISM model.

### 2.3.1 Binary logistic regression model

This study established the dependent variable of "whether standardized planting methods are adopted," and employed the binary decision variables of "adoption" and "non-adoption." Research has indicated that logistic regression models can be applied to handle binary decision variables (Barnes et al., 2015; Tran et al., 2018; Foguesatto et al., 2020; Pokhrel et al., 2020). Therefore, this study employed a binary logistic regression model to identify which factors influenced farmers' adoption of standardized planting methods. The adopted binary logistic regression model is presented in Equation (1):

$$Y = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i \tag{1}$$

where $Y$ is the dependent variable and represents whether farmers adopt standardized planting methods, $p_i$ indicates the possibility of adopting standardized planting methods, $x_i$ is an independent variable indicating the influential factors, $\beta_0$ is a constant, and $\beta_i$ is the regression coefficient of each influential factor.

### 2.3.2 Interpretive structural model

The ISMs are employed to analyze socioeconomic systems with multiple factors and complex structures (Garg and Kumar, 2021) as these models implement the principles of incidence matrices from computer technology and graph theory to analyze and model the complex relationships between factors in a system. The analyzed system is organized into a multilayer hierarchical model with well-structured relationships (Sushil, 2012, 2018; Jayalakshmi and Pramod, 2015). The construction of an ISM involves the following steps:

The adjacency matrix $R$ between all factors is identified.

TABLE 1 Key survey questions.

| Questions | Options |
|---|---|
| Do you plant according to the standardize planting methods? | Yes/no |
| Characteristics of farmers | |
| 1. What's your gender? | Male/female |
| 2. What's your age? | Open |
| 3. How about your education? | Below elementary school/ Elementary school/Middle school/High school or vocational high school/Junior college or college and above |
| 4. Do you serve as a village cadre? | Yes/no |
| 5. Are you a member of an agricultural cooperative? | Yes/no |
| 6. What's your planting year? | open |
| 7. Do you have part-time jobs? | Yes/no |
| 8. How much of your household income is from agriculture? | 0–20% /20–40% /40–60% /60–80% /80–100% |
| Self-perception of ability | |
| 1. How would you rate your planting ability? | 1–5 points |
| 2. How would you rate your ability to accept and learn new things? | |
| Cognition of planting standards | |
| 1. Have you ever heard of planting standards? | Yes/no |
| 2. What impact do you think standardized planting methods will have on the environment? | Significant deterioration/Slight deterioration/No change/Slight improvement/Significant improvement |
| 3. What impact do you think standardized planting methods will have on yields? | Significantly reduced/Slightly reduced/ No change/Slightly increased/ Significantly increased |
| 4. What impact do you think standardized planting methods will have on crop quality? | |
| 5. What impact do you think standardized planting methods will have on income? | |
| External factors | |
| 1. How much does the planting behavior of your relatives affect you? | Almost no effect/ Slight effect/ General effect/Strong effect/Very strong effect |
| 2. How much does the planting behavior of capable growers affect you | |
| 3. Do you think you will benefit from agricultural policies? | Strongly disagree/ Disagree/ General effect/Agree/Strongly agree |

If $k$ significant factors affect farmers' adoption of standardized planting methods, $S_0$ indicates whether farmers adopt standardized planting methods, and $S_i$ ($i=1, 2, 3......k$) indicates the factors that significantly influence farmers' adoption of standardized planting methods. An adjacency matrix $R$ contains the elements presented in Equation (2).

$$\mathbf{R} = \begin{cases} \mathbf{1\ S_i \text{ is related to } S_j} \\ \mathbf{0\ S_i \text{ is not related to } S_j} \end{cases} \tag{2}$$

The reachable matrix $M$ of the influencing factors is obtained using Equation (3).

$$M = (R+I)^{\lambda+1} = (R+I)^{\lambda} \neq (R+I)^{\lambda-1} \neq \cdots \neq (R+I)^2 \neq (R+I) \tag{3}$$

In Equation (3), $2 \leq \lambda \leq k$, $I$ represents the unit matrix, and a Boolean operator is applied in the power operation of the matrix.

The adjacency matrix can express the direct relationships between components, and the reachability matrix can express the indirect relationships between components.

The hierarchy of each factor is determined.

Equation (4) is divided into a reachable set $P$ ($S_i$) and an antecedent set $Q$ ($S_i$), both of which indicate the set of all factors $S_i$ reachable in the reachable matrix. The terms $m_{ij}$ and $m_{ji}$ are the components of the reachable matrix. Equation (5) is used to compute the factors of the top layer $L_i$ and the factors of other layers of the system model.

$$P(S_i) = \{S_j | m_{ij} = 1\}, Q(S_j) = \{S_j | m_{ji} = 1\} \tag{4}$$

$$L_i = \{S_i | P(S_i) \cap Q(S_i) = P(S_i); i = 0, 1, 2, \cdots, k\} \tag{5}$$

The hierarchical structure of the influential factors is determined.

The hierarchical structure of the influential factors is represented by directional arrows that connect factors within the same layer and between adjacent layers.

## 2.4 Variable selection and hypotheses

Agricultural planting in Zhejiang Province is primarily conducted by small-scale family units. The dominant view in China espouses the economically rational behavior of smallholder farmers (Bernstein and Byres, 2001). Farmers make rational production decisions to achieve their goal of maximizing profit (Popkin, 1980). On the basis of this assumption, this study selected 18 independent variables divided into four dimensions to investigate the factors influencing farmers' adoption of standardized planting methods. The variables in each dimension and the corresponding assumptions are described in the following paragraphs.

The examined characteristics of farmers were sex, age, education level, village cadre status, participation in cooperatives, years of planting experience, part-time job status, and the percentage of income from planting. Because men are more physically suited to planting than women, men are more likely to engage in standardized planting. As farmers age, they are more likely adopt traditional practices and resist change, thus rejecting standardized planting and new agricultural technologies. Farmers with higher education levels are more likely to understand the implementation of standardized planting methods and therefore more inclined to participate in standardized planting than are those with lower education levels. In rural China, village cadres exert a strong leadership effect. Farmers who are village cadres are generally more likely to accept standardized planting methods than are ordinary farmers. Ordinary farmers who join agricultural cooperatives have greater access to information about standardized planting, which increases their likelihood to adopt standardized planting methods. Famers with more years of planting experience are less receptive to new planting techniques and are therefore less likely to participate in standardized planting. Farmers engaged not only in agriculture but also in other occupations have a higher part-time income than agricultural income. The enhanced efficiency of standardized planting can provide farmers with more non-planting time to earn additional income, thus encouraging their acceptance of standardized planting methods. The percentage of income from planting indicates farmers' level of dependence on planting income; farmers with a higher level of dependence on planting income are more likely to participate in standardized planting.

> *H1*: Older age and more years of planting experience negatively influence farmers' adoption of standardized planting methods. Sex, higher education level, village cadre status, participation in cooperatives, part-time employment, and a higher percentage of income from planting positively influence farmers' adoption of standardized planting methods.

Farmers' self-efficacy primarily refers to their self-perceived planting and learning abilities. Farmers who believe that they have the ability to grow and learn are more likely to participate in standardized planting.

> *H2*: Farmers' self-perception of their ability to grow and learn positively influences their adoption of standardized planting methods.

The level of farmers' cognition of agricultural standards primarily includes their knowledge of agricultural standards and the perceived effects of standardized planting on the environment, crop yield, crop quality, and income. Farmers with knowledge of agricultural standards have access to relevant information and are thus better equipped to adopt standardized planting methods. The implementation of agricultural standards might affect the environment and the farmers themselves. Farmers comprehensively evaluate their participation in standardized planting, and their perceptions of various aspects can therefore influence adoption.

> *H3*: Farmers with a knowledge of agricultural standards and a deeper understanding of the effects of standardized planting on the environment, crop yield, crop quality, and income are more likely to adopt standardized planting methods.

External factors primarily include the influence of relatives and capable growers and whether agricultural policies benefit farmers. When relatives or capable growers participate in standardized planting, other farmers might follow their example and therefore be more inclined to adopt standardized practices. Farmers primarily focus on the effects of agricultural policies on profits.

> *H4*: The planting behaviors of relatives and capable growers and the beneficial effects of agricultural policies on farmers positively influence farmers' adoption of standardized planting methods.

For the dependent variable of "whether standardized planting methods are adopted," this study assigned a value of 1 to farmers who adopted standardized planting methods and a value of 0 to farmers who did not adopt these methods.

# 3 Results

## 3.1 Respondents' demographic characteristics

Table 2 presents the basic characteristics of the respondents. A total of 244 valid questionnaires (n = 244) were obtained, and men comprised 70.90% of all the respondents. Approximately 61% of the respondents were between the ages of 46 and 65 years. Approximately 93% of respondents had a middle school education level or lower. Only 3.70% of respondents were village cadres, and 6.6% participated in cooperatives. Among the respondents, approximately 20% had planted for less than 10 years and approximately 66% had planted for less than 30 years. Approximately half of the respondents had part-time jobs, and 72% of the respondents reported that income from planting accounted for 60% or less of their total household income.

## 3.2 Farmers' perceptions of standardized planting methods

Table 3 presents the farmers' perceptions of standardized planting methods. The survey results revealed that the farmers' perceptions of standardized planting methods were primarily positive. Among the respondents, 77% had heard of standardized planting methods. All the mean scores for the perceived effects of standardized planting on the environment, crop yield, crop quality, and income exceeded 3. Approximately 70% of the respondents believed that standardized planting methods can marginally improve the environment. Approximately 50% of the respondents believed that standardized planting methods can marginally improve crop yields and increase their income. Approximately 59% of the respondents believed that planting standards can slightly improve crop quality.

## 3.3 Farmers' adoption of standardized planting methods

The study survey asked the respondents whether they were currently planting in accordance with planting standards. The results indicated that 59% of the respondents were not currently following planting standards, and the remaining 41% of the respondents had participated in agricultural standardized planting (Figure 2). Some farmers had already adopted standardized planting methods. However, farmers' adoption of standardized planting

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TABLE 2 Basic characteristics of the survey respondents.

| Variable Name | Variable definition | Frequency number | Frequency |
|---|---|---|---|
| Gender | Male = 1 | 173 | 70.90% |
| | Female = 0 | 71 | 29.10% |
| Age | 35 years old and blow = 1 | 1 | 0.40% |
| | 36–45 years old = 2 | 22 | 9.00% |
| | 46–55 years old = 3 | 67 | 27.50% |
| | 56–65 years old = 4 | 82 | 33.60% |
| | 65 years old and above = 5 | 72 | 29.50% |
| Education level | Below elementary school = 1 | 22 | 9.00% |
| | Elementary school = 2 | 149 | 61.10% |
| | Middle school = 3 | 57 | 23.40% |
| | High school or vocational high school = 4 | 15 | 6.10% |
| | Junior college or college and above = 5 | 1 | 0.40% |
| Village cadre status | Yes = 1 | 9 | 3.70% |
| | No = 0 | 235 | 96.30% |
| Participation in cooperatives | Yes = 1 | 16 | 6.60% |
| | No = 0 | 228 | 93.40% |
| Years of planting experience | 10 years and below = 1 | 51 | 20.90% |
| | 11–20 years = 2 | 54 | 22.10% |
| | 21–30 years = 3 | 57 | 23.40% |
| | 31–40 years = 4 | 37 | 15.20% |
| | 40 years and above = 5 | 45 | 18.40% |
| Part-time status | Yes = 1 | 126 | 51.60% |
| | No = 0 | 118 | 48.40% |
| Percentage of income from planting | 0–20% = 1 | 86 | 35.20% |
| | 20–40% = 2 | 51 | 20.90% |
| | 40–60% = 3 | 39 | 16% |
| | 60–80% = 4 | 39 | 16% |
| | 80–100% =5 | 29 | 11.90% |

methods was considerably lower than expected considering the years of implementation of agricultural standardization policies and the surveyed area.

## 3.4 Factors influencing farmers' perceptions of standardized planting methods

This study employed the chi-square test to examine the factors that affected farmers' perceptions of standardized planting methods (Table 4). The factors that significantly influenced farmers' perceptions of the environmental effects of standardized planting methods were age, participation in cooperatives, and years of planting experience. All factors excluding education level and village cadre status significantly influenced farmers' perceptions of the effects of standardized planting methods on crop yield. The factors that significantly influenced famers' perceptions of the effects of standardized planting methods on crop quality were age, participation in cooperatives, years of planting experience, and percentage of income from planting. The factors that significantly influenced famers' perceptions on income were the farmers' sex, participation in cooperatives, years of planting experience, and percentage of income from planting.

## 3.5 Factors influencing farmers' adoption of standardized planting methods

### 3.5.1 Analysis of the binary logistic regression results

This study implemented tests for reliability, validity, and multicollinearity before conducting logistic regression. Reliability analysis is a common method employed to measure the reliability and consistency of test results. This study employed the Cronbach's $\alpha$ coefficient to analyze the factors in each dimension. The results revealed that all dimensions had a Cronbach's $\alpha$ coefficient of higher than 0.7. The Cronbach's $\alpha$ coefficients can be employed as a measure of the constructs (Bruijnis et al., 2013; Borges et al., 2014). Test validity generally includes content and structure validity. Content validity indicates the extent to which a test is relevant to and representative of a measured construct. Construct validity represents the extent to which indicators can measure a construct (Wang et al., 2018). Factor analysis was conducted to assess the validity of the constructs. Statistical significance was indicated by a Kaiser–Meyer–Olkin value of higher than 0.6 and a $p$ value of less than 0.05 for Bartlett's test. The results indicated that the constructs of the present study had acceptable reliability and validity. A multicollinearity test was performed to identify possible multicollinearity among variables. All the variance inflation coefficients were below 10, which indicated the absence of multicollinearity. Logistic regression analysis was then conducted, and its results are presented in Table 5.

The results of the regression analysis revealed eight significant factors influenced farmers' adoption of standardized planting methods. The factors with a significant positive influence were village cadre status, participation in cooperatives, awareness of standardized planting methods, and the perceived effect of standardized planting methods on income. The factors with a significant negative influence were education level, years of planting experience, the perceived effect of standardized planting methods on the environment, and the influence of relatives.

Consistent with the anticipated hypothesis, the data revealed that village cadre status and participation in cooperatives significantly and

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TABLE 3 Farmers' perceptions of standardized planting methods.

| Variable Name | Variable definition | Frequency number | Frequency | Mean | S.D. |
|---|---|---|---|---|---|
| Awareness of standardized planting methods | Yes = 1 | 188 | 77.00% | 0.77 | 0.42 |
| | No = 0 | 56 | 23.00% | | |
| The perceived effect of standardized planting methods on the environment | Significant deterioration = 1 | 0 | 0.00% | 3.90 | 0.53 |
| | Slight deterioration =2 | 0 | 0.00% | | |
| | No change = 3 | 47 | 19.30% | | |
| | Slight improvement = 4; | 174 | 71.30% | | |
| | Significant improvement = 5 | 23 | 9.40% | | |
| The perceived effect of standardized planting methods on crop yield | Significantly reduced = 1 | 4 | 1.64% | 3.73 | 0.84 |
| | Slightly reduced = 2 | 13 | 5.33% | | |
| | No change = 3 | 65 | 26.64% | | |
| | Slightly increased = 4 | 126 | 51.64% | | |
| | Significantly increased = 5 | 36 | 14.75% | | |
| The perceived effect of standardized planting methods on crop quality | Significantly reduced = 1 | 0 | 0.00% | 3.94 | 0.65 |
| | Slightly reduced = 2 | 1 | 0.41% | | |
| | No change = 3 | 56 | 22.95% | | |
| | Slightly increased = 4 | 144 | 59.02% | | |
| | Significantly increased = 5 | 43 | 17.62% | | |
| The perceived effect of standardized planting methods on income | Significantly reduced = 1 | 3 | 1.23% | 3.70 | 0.81 |
| | Slightly reduced = 2 | 13 | 5.33% | | |
| | No change = 3 | 70 | 28.69% | | |
| | Slightly increased = 4 | 125 | 51.23% | | |
| | Significantly increased = 5 | 33 | 13.52% | | |

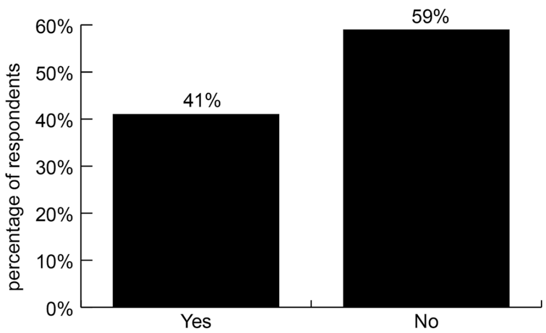


FIGURE 2
Farmers' adoption of standardized planting methods.

positively affected farmers' adoption of standardized planting methods. These two factors exerted a positive effect for a similar reason. Farmers who become village cadres or join cooperatives have more access to information about standardized planting methods than other farmers (Liu and Wu, 2022; Hao et al., 2023). Greater knowledge of standardized planting methods increases the likelihood of the acceptance of standardized planting.

Farmers' education level and years of planting experience had significant negative effects on farmers' adoption of standardized planting methods. Studies have established that farmers with a higher level of education are more capable of learning and accepting new methods and are more resilient to unknown risks (Nastis et al., 2019); therefore, they tend to adopt standardized planting methods. The reasons for this phenomenon might be twofold. First, highly educated farmers prefer to obtain planting information on the Internet rather than relying solely on standardized planting methods. Second, some standardized planting methods encounter barriers to adoption because of their long development cycle. Farmers who have planted for many years become entrenched in a traditional mindset, thereby resulting in a lower acceptance of standardized planting.

The awareness of standardized planting methods and their perceived effect on income had a significant positive influence on farmers' adoption of standardized planting methods. Farmers' subjective cognitive is the most direct factor influencing actual behavior (Liu et al., 2023), so the awareness of standardized planting methods largely determined farmers' participation. Farmers who believe that the adoption of standardized planting methods results in a significant increase in income are more inclined to adopt such methods. In contrast to the anticipated results, the data revealed that the perceived effect of standardized planting on the environment had a significantly negative influence on participation in standardized planting. Although the farmers believed that the adoption of standardized planting methods yields environmental benefits, adopting standardized planting methods also involves higher overhead in the form of increased

TABLE 4 Results of the chi-square test for farmers' perceptions of standardized planting methods.

| Factors | The perceived effect of standardized planting methods on the environment | | The perceived effect of standardized planting methods on crop yield | | The perceived effect of standardized planting methods on crop quality | | The perceived effect of standardized planting methods on income | |
|---|---|---|---|---|---|---|---|---|
| | Chi-Square | Sig. | Chi-Square | Sig. | Chi-Square | Sig. | Chi-Square | Sig. |
| Gender | 3.16 | 0.21 | 13.14 | 0.01 | 1.16 | 0.76 | 11.61 | 0.02 |
| Age | 14.75 | 0.06 | 33.73 | 0.01 | 24.10 | 0.02 | 21.18 | 0.17 |
| Education level | 3.12 | 0.93 | 10.36 | 0.85 | 10.52 | 0.57 | 20.79 | 0.19 |
| Village cadre status | 0.10 | 0.95 | 1.94 | 0.75 | 0.93 | 0.82 | 0.76 | 0.94 |
| Participation in cooperatives | 9.74 | 0.01 | 31.70 | 0.00 | 23.81 | 0.00 | 20.72 | 0.00 |
| Years of planting experience | 34.01 | 0.00 | 73.94 | 0.00 | 27.78 | 0.01 | 76.67 | 0.00 |
| Part-time job status | 2.08 | 0.35 | 11.97 | 0.02 | 1.74 | 0.63 | 6.05 | 0.20 |
| Percentage of income from planting | 12.25 | 0.14 | 56.08 | 0.00 | 23.96 | 0.02 | 63.03 | 0.00 |

planting costs, which results in increased hesitance to adopt standardized planting methods.

The influence of relatives exerted a significant negative influence on participation in standardized planting, which suggested that farmers depend heavily on their relatives. The influence of relatives can be interpreted as peer pressure or social norms (Guo et al., 2021). Most farmers follow planting methods according to their own experiences. This phenomenon compels some farmers who are likely to adopt standardized planting methods to submit to the behavioral expectations of their relatives.

### 3.5.2 Hierarchical structure of significant factors

This study first determined the elements of the system model. The term $S_0$ represents whether standardized planting methods are adopted. Moreover, $S_1$–$S_8$ represent the eight significant variables of village cadre status, participation in cooperatives, the awareness of standardized planting methods, the perceived effect of standardized planting on income, education level, years of planting experience, the perceived effect of standardized planting methods on the environment, and the influence of relatives, respectively. The logical relationships between these eight variables were then determined in accordance with the relevant literature and experts' opinions.

Equation (6) presents the adjacency matrix $R$ between the significant factors.

$$R = \begin{array}{c} \boldsymbol{S_0} \\ \boldsymbol{S_1} \\ \boldsymbol{S_2} \\ \boldsymbol{S_3} \\ \boldsymbol{S_4} \\ \boldsymbol{S_5} \\ \boldsymbol{S_6} \\ \boldsymbol{S_7} \\ \boldsymbol{S_8} \end{array} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (6)$$

The reachable matrix $M$ was calculated using Python, and the obtained result is presented in Equation (7).

$$M = \begin{array}{c} \boldsymbol{S_0} \\ \boldsymbol{S_1} \\ \boldsymbol{S_2} \\ \boldsymbol{S_3} \\ \boldsymbol{S_4} \\ \boldsymbol{S_5} \\ \boldsymbol{S_6} \\ \boldsymbol{S_7} \\ \boldsymbol{S_8} \end{array} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

According to Equation (5), $S_0$–$S_8$ can be divided into the following four levels through calculations performed with Python: $L_1 = \{S_0\}$, $L_2 = \{S_1, S_2, S_3\}$, $L_3 = \{S_4, S_7, S_8\}$, $L_4 = \{S_5, S_6\}$.

Through interpretative structural analysis, the eight significant factors were divided into three layers. The first layer contained three factors: $S_1$ (village cadre status), $S_2$ (participation in cooperatives), and $S_3$ (awareness of standardized planting methods). The second layer also contained three factors: $S_4$ (perceived effect of standardized planting on income), $S_7$ (perceived effect of standardized planting on the environment), and $S_8$ (influence of relatives). Finally, the third layer contained two factors: $S_5$ (education level) and $S_6$ (years of planting experience). The relationships between and hierarchy among the factors are depicted in Figure 3.

Figure 3 clearly reveals that the most direct influential factors were village cadre status, participation in cooperatives, and the awareness of standardized planting methods, which are at the top of the hierarchy. Furthermore, the factors at the intermediate level were perceived effect of standardized planting methods on income, perceived effect of standardized planting methods on the environment, and influence of relatives. The factors at the bottom of the hierarchy

TABLE 5 Logistic regression results.

| Variable Category | Variable Name | Regression Coefficient $\beta$ | Inspection Error S.E. | Power Value Exp ($\beta_i$) |
|---|---|---|---|---|
| Characteristics of farmers | Gender | −0.60 | 0.50 | 0.55 |
| | Age | 0.43 | 0.30 | 1.53 |
| | Education level | −0.62* | 0.33 | 0.54 |
| | Village cadre status | 2.04** | 0.88 | 7.71 |
| | Participation in cooperatives | 4.20*** | 1.12 | 66.44 |
| | Years of planting experience | −1.34*** | 0.24 | 0.26 |
| | Part-time job status | −0.57 | 0.52 | 0.56 |
| | Percentage of income from planting | −0.24 | 0.17 | 0.79 |
| Self-perception of ability | Planting ability | 0.37 | 0.44 | 1.45 |
| | Learning ability | −0.13 | 0.37 | 0.88 |
| Cognition of planting standards | Awareness of standardized planting methods | 2.44*** | 0.70 | 11.49 |
| | The perceived effect of standardized planting methods on the environment | −0.77* | 0.45 | 0.46 |
| | The perceived effect of standardized planting methods on crop yield | 0.28 | 0.32 | 1.32 |
| | The perceived effect of standardized planting methods on crop quality | −0.70 | 0.48 | 0.50 |
| | The perceived effect of standardized planting methods on income | 2.44*** | 0.57 | 11.42 |
| External factors | Influence of relatives | −0.97*** | 0.35 | 0.38 |
| | Influence of capable growers | −0.20 | 0.28 | 0.82 |
| | Agricultural policies | −0.20 | 0.33 | 0.82 |
| −2 Log Likelihood | | 152.04 | | |
| Prob>chi$^2$ | | 0.00 | | |

*, **, and *** represent significance at the 10, 5, and 1% levels, respectively.

were education level and years of planting experience. These two factors were underlying factors.

The hierarchy revealed two distinct paths. Path 1 was as follows: education level and years of planting experience → perceived effects of standardized planting on income and the environment → participation in cooperatives → whether standardized planting methods are adopted. The underlying factors for path 1 were age and education level. These two factors influence farmers' level of awareness and information reception, which leads to different perceptions of the effects of standardized planting methods on income and the environment. This different view on standardized planting directly determines whether farmers join cooperatives. Farmers who join cooperatives are highly likely to adopt standardized planting methods.

Path 2 was as follows: influence of relatives → participation in cooperatives and awareness of standardized planting methods → whether standardized planting methods are adopted. Path 2 involved no underlying factors. However, relatives strongly influence whether farmers join cooperatives and famers' awareness of standardized planting methods. These relationships further influence farmers' adoption of standardized planting methods.

# 4 Discussion

This study identified and established the hierarchical structure of eight significant factors influencing farmers' adoption of standardized planting methods. Ten other nonsignificant factors were also evaluated.

The results revealed the following four nonsignificant characteristics of farmers: sex, age, part-time job status, and percentage of income from planting. The following reasons might explain the nonsignificant effects of these four factors. First, the primary agricultural products in Zhejiang Province are rice and various cash crops, the physical advantage of men over women is not obvious when growing such crops. Second, age exerted a less direct effect on farmers' adoption of standardized planting methods than did years of planting experience. Third, most farmers in Zhejiang Province have additional

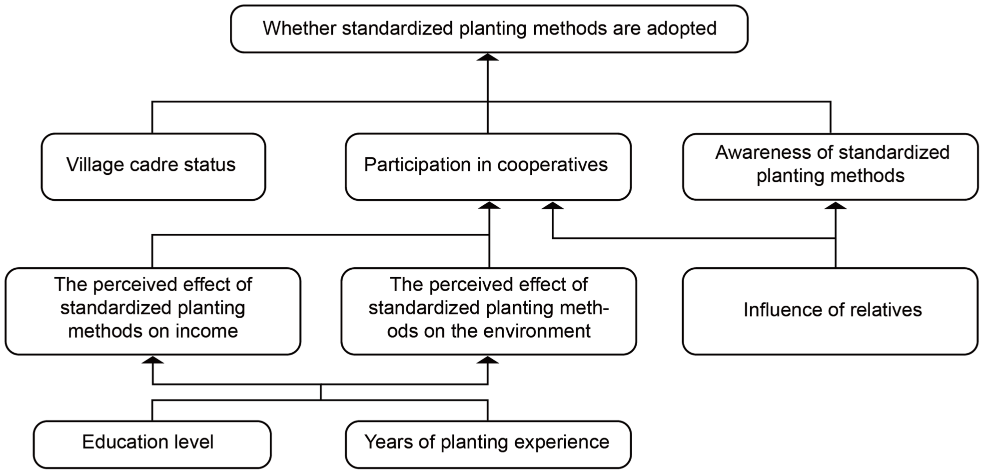


FIGURE 3
ISM of the significant factors influencing farmers' adoption of standardized planting methods.

part-time employment, and the share of income from planting is relatively low.

With respect to self-perceptions of ability, planting and learning abilities were nonsignificant factors. Most farmers rated their planting and learning abilities at 3 points and above. Farmers' self-perceived abilities are based on their mastery of existing planting methods and technologies and do not directly influence their participation in standardized planting.

With respect to the cognition of standardized planting methods, the perceived effects of standardized planting methods on crop yield and crop quality were nonsignificant. Although farmers believe that the adoption of standardized planting improves crop yield and quality, the associated increased cost directly affects their profits. Farmers most easily perceive the effect of standardized planting on income, whereas its effects on crop yield and quality are not as easily perceived.

In terms of external factors, the results revealed the nonsignificant effects of capable growers and agricultural policies. Most of the farmers believed that capable growers exert a relatively mild influence on the farmers' adoption of standardized planting methods. More than half of the farmers doubted that agricultural policies would benefit them. Farmers often possess only a superficial understanding of agricultural policies and might be unaware of agricultural subsidies and other economically beneficial policies.

This study demonstrated that education level negatively affected farmers' participation in standardized planting. Relevant theoretical and empirical studies have concluded that farmers with a higher education level are more inclined to adopt new agricultural technologies (O'Donoghue and Heanue, 2018; Paltasingh and Goyari, 2018; Li and Wu, 2021). Because education level constitutes a deep-rooted factor influencing the behavioral choices of farmers, its influence on farmers' adoption of standardized planting methods requires further investigation.

In addition, future studies must examine the influence of the characteristics of arable land on farmers' adoption of standardized planting methods. Models should incorporate the area, fragmentation, and slope of arable land. These variables are particularly meaningful in Zhejiang Province, in which approximately 70% of the land is hilly and mountainous. The results of Guo et al. (2022) demonstrated that the cultivated area and whether the land is dispersed had significantly negative effects on farmers' acceptance of conservation tillage techniques. Furthermore, rural reforms, land transfer policies, and the standardized implementation of arable land policies are increasingly affecting farmers and are likely affect their adoption of standardized planting methods. However, the current study cannot definitively conclude whether the aforementioned factors influence farmers' adoption of standardized planting methods.

This study has identified the key factors affecting farmers' adoption of standardized planting methods. Based on this, non-market valuation studies can be carried out with reference to existing studies on farmers' willingness to adopt or pay for agricultural technologies. Colin Castillo et al. (2022) conducted a discrete choice experiment based on non-monetary and monetary attributes to explore the willingness of Mexican smallholder farmers to adopt chemical-free fertilizers and pesticides and to participate in two cooperative arrangements. Similarly, Ortiz et al. (2023) accessed the preferences of Mejía dairy farmers for water conservation measures based on a discrete choice experiment. They calculated the average willingness to pay (WTP) of dairy farmers for solid rainwater irrigation systems as well as for training on conflict resolution and explored the heterogeneity of WTP. Abebe et al. (2020) examined the factors influencing WTP and farmers' average WTP for monitoring tools using CV methods and various econometric techniques to reduce hypothesis bias. Houessionon et al. (2017) used a choice experiment to estimate farmers' preferences for ecosystem services and their willingness to pay (WTP) for ecosystem services generated by four agricultural water management and resource recovery and reuse intervention programs in Burkina Faso. In the future, non-market valuation studies can be used to explore the willingness of farmers to adopt standardized planting methods, the factors affecting farmers' willingness to pay for standardized planting methods, and the amount of compensation needed for non-adopting farmers of standardized planting methods to become adopters. These further studies will make this study more comprehensive and adequate.

## 5 Conclusion

This study implemented a binary logistic regression model and ISM to analyze the factors that influence the perceptions and adoption of standardized planting methods among 244 farmers in Zhejiang Province. The results of this study revealed that farmers' perceptions of standardized planting methods were primarily positive. Farmers' years of planting experience and participation in cooperatives significantly affected their perceptions of the effects of standardized planting on the environment, crop yield, crop quality and income. Farmers' age significantly affected their perceived effects of standardized planting on the environment, crop yield, and crop quality. In addition, the percentage of income from planting significantly affected the perceived effects of standardized planting on crop yield, crop quality, and income.

More than half of the respondents had adopted standardized planting methods. The factors that positively influenced the adoption of these methods were village cadre status, participation in cooperatives, awareness of planting standards, and the perceived effect of standardized planting methods on income. The factors that negatively influenced the adoption of the aforementioned methods were education level, years of planting experience, the perceived effect of standardized planting methods on the environment, and the influence of relatives.

This study described the hierarchical structure of the significant factors influencing farmers' adoption of standardized planting methods in the form of "two paths with two drivers." Among the eight significant factors, the fundamental influential factors were farmers' age and years of planting experience. These two factors directly affected farmers' perceptions of standardized planting methods, primarily the perceived effects of standardized planting on income and the environment. The most superficial factors that influenced farmers' participation in standardized planting were village cadre status, participation in cooperatives, and the awareness of planting standards.

This analytical study clarified the factors that influence farmers' adoption of standardized planting methods and offers recommendations based on the obtained results. The study found that many farmers have limited access to relevant knowledge due to age, education level, and other factors, leading to the emergence of information asymmetry. As a result, standardized cultivation methods have not been effectively promoted in rural areas. To address this issue, Zhejiang Province should give full play to the leading and communicating role of village cadres and cooperatives, enhance the communication and interaction between farmers and capable growers and technical experts, and strengthen the training of standardized planting methods. This will improve farmers' understanding of the role of standardized planting methods in promoting increased agricultural production and farmers' income. The focus should be on training in standardized planting techniques, such as the use of chemical fertilizers and techniques for controlling crop pests and epidemics. In addition, the government should formulate policies to support the development of standardized planting methods in terms of finance, taxation, and insurance. The first initiative is to establish financial special funds to support the development of standardized planting methods, and to form a diversified investment and financing system for agricultural science and technology services, with government investment as the main body and social input as a supplement. At the same time, the government needs to effectively raise farmers' incomes and fully take into account the cost of the risks associated with farmers' participation in standardized planting as a result of uncertainties in the production, distribution and marketing chain.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Ethics statement

Ethical approval was not required for the studies involving humans because all questionnaire data used for this paper were obtained through random anonymous surveys. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because all questionnaire data do not contain any detailed information that can be used to identify respondents.

## Author contributions

CH: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft. LL: Data curation, Software, Visualization, Writing – review & editing. AW: Supervision, Validation, Writing – review & editing. QZ: Data curation, Software, Validation, Writing – review & editing. NL: Writing – review & editing. SH: Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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