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How Does Information Acquisition Ability Affect Farmers' Green Production Behaviors: Evidence from Chinese Apple Growers

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Abstract: Green production is crucial in promoting sustainable agricultural practices, ensuring food safety, and protecting the rural ecological environment. Farmers, as the main decision makers of agricultural production, and their green production behaviors (GPBs), directly determine the process of agricultural green development. Based on the survey data of 656 apple growers in Shaanxi and Gansu provinces in 2022, this paper uses a graded response model to measure the information acquisition ability (IAA) of farmers and constructs an ordered Logit model to empirically explore the influence mechanisms of IAA, green benefit cognition (GBC), and new technology learning attitude (NTLA) on farmers' GPBs. The results show the following: (1) IAA has a significantly positive impact on the adoption of GPBs by farmers, and farmers with a high IAA are more conscious to adopt green production technologies; (2) in the process of IAA affecting farmers' adoption of GPBs, GBC plays a positive mediating role; (3) NTLAs have a positive moderating effect on the process of GBC affecting farmers' GPB adoption; (4) there are generational, educational and regional differences in the impact of IAA on farmers' GPBs. Policy makers should improve rural information facilities, strengthen agricultural technology promotion and training, improve farmers' IAA and benefit awareness level, and formulate relevant policies to mobilize farmers' enthusiasm for learning new technologies.

Keywords: information acquisition ability; graded response theory; green benefits perception; new technology learning attitude; moderated mediation analysis; green production behaviors

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1. Introduction

Pesticides and chemical fertilizers play an important role in the economic growth of agriculture in China, but their excessive and inefficient application lead to severe problems, such as environmental pollution, ecological damage, quality decline of agricultural products, and so on [1,2]. It is very important to implement green agricultural production and development modes in China. Agricultural green production refers to a production method that achieves resource conservation, reduces ecological pollution, and promotes sustainable agricultural development through reasonable field management models and scientific cultivation techniques [3,4]. It is crucial in promoting sustainable agricultural practices, ensuring food safety for consumers, and protecting the rural ecological environment [5,6]. The extensive global practice of green production has since had its functions of enhancing ecosystem services, increasing agricultural productivity and profitability, and reducing the use of agricultural inputs confirmed [7]. The Chinese government has promoted agricultural green production ever since 2015, with the introduction of the "Action Plan for Zero Growth in Fertilizer Use by 2020" by the Ministry of Agriculture and Rural Affairs. This commitment was further confirmed in the central government's "Number One Document" in the years following. The report to the 20th National Congress of the Communist Party of China emphasized that China should continue to promote green development, promote the harmonious coexistence between humans and nature, and accelerate green transformation. Therefore, it is necessary for farmers to adopt green production [8,9]. Existing research indicates that farmers exhibit limited enthusiasm and low adoption rates for green production technologies [10]. The incentive measures taken by the Chinese government have insufficient momentum and are not a long-term solution to maintain green agricultural development. The fundamental solution to this problem lies in stimulating the endogenous driving force of farmers to implement green production. Many studies have been conducted on the decision-making mechanism of farmers' green production behaviors. Some researchers focus on individual green production technologies, such as pesticide and chemical fertilizer application [11], soil testing and formula fertilization technology [12], straw recycling technology [13], agricultural film recycling [14], and water-saving irrigation [15], and empirically explore the relevant mechanisms with the help of micro-research data from farmers. Others have conducted extensive demonstrations on the factors influencing farmers' green production behaviors, including internal factors such as farmers' cognition of benefits from green development, perceived value, and educational level [16–18], as well as external factors such as policy incentives, social networks, and organizational supports [19–21].

With the rapid development of information technology, all kinds of information resources have flooded agricultural production, and farmers' information acquisition ability (IAA) has gradually become an important factor influencing their production behavior. Khataza et al. (2018) found that access to information is a key factor in promoting conservation agricultural practices in Malawi [22]. IAA can contribute to the adoption of productive services by farmers by facilitating their perception of ease-of-use and thus their adoption of productive services [23]. When information asymmetry exists, farmers are skeptical about the selection of new varieties in order to reduce production risks [24].

The existing research results are rich, but there are still some areas for expansion. (1) Farmers are essential micro-objects of agricultural green production. In addition to cognition, willingness, policy, and other factors, IAA is also an important factor influencing farmers' behaviors; the stronger the IAA of farmers, the more frequently they communicate with the outside world and the more likely they are to obtain adequate policy, market, and financial information. If farmers had all the information on the economic and ecological benefits of green production, the probability of its adoption would increase. Existing studies only take IAA as a moderating or mediating variable, ignoring its direct impact on the green production behaviors of farmers and its indirect impact on green production behaviors through the mediating role of green benefit cognition. (2) Through different information channels, farmers can fully understand the economic and ecological benefits of green production technologies and improve their knowledge of green benefits. When farmers develop a positive perception of a new technology, they naturally improve their learning attitudes towards the new technology and increase the probability of adopting green production behaviors. However, existing studies have only examined the impact of benefit cognition on the adoption of farmers' production behaviors, ignoring the moderating role played by new technology learning attitudes. Therefore, it is urgent to integrate IAA, green benefit cognition, and new technology learning attitudes into the same framework for systematic analysis and to further discuss the possible mediating effect of green benefit cognition and the possible moderating effect of new technology learning attitudes. (3) The Loess Plateau is one of the most ecologically fragile regions in China, and as a cash crop, apples play an important role in local ecological protection and economic development. Therefore, research on green production behaviors for apples in ecologically fragile regions can not only make up for the gaps in the existing research but also provide reference value for green production practices in other regions and even globally. (4) Most of the existing studies treat farmers as a homogeneous group, but the production behaviors of farmers is obviously affected by their personal ability, cognition, and the social environment in which they live, and thus the degree of adoption of green production behaviors is expected to vary among farmers of different ages, education levels, and regions, and it is necessary to analyze the heterogeneity of the sample farmers.

This study uses the survey data of 656 apple growers in Shaanxi and Gansu provinces in the Loess Plateau region, takes the IAA of apple growers as a key factor, and analyzes the influence of IAA and other factors on farmers' green production behaviors (GPBs) with the help of an ordered Logit model. Additionally, this paper also introduces green production cognition (GBC) and new technology learning attitude (NTLA) as mediator and regulator variables, respectively, so as to do an in-depth analysis on the influencing mechanism of farmers' GPBs. An analysis of heterogeneity is also conducted according to the age of the farmers to investigate whether there are intergenerational differences in IAA on farmers' GBC. Finally, based on the findings of the study, targeted recommendations are proposed to provide a scientific basis and decision-making reference for improving farmers' GPBs.

2. Theoretical Analysis and Research Hypotheses

IAA can affect an individual's behavior by improving cognitive levels and optimizing resource allocation [25]. By referring to the existing research of scholars, this paper defines IAA as the ability of farmers to obtain, identify, and absorb relevant agricultural policies or technical information through different information dissemination channels. Theoretically, IAA can have an impact on apple growers' GPBs through at least the following two aspects: First, in the process of using information technology, farmers continuously improve their understanding of agricultural knowledge and technology [26]. IAA can significantly improve a farmers' environmental cognition and technical expertise, making them realize the environmental pollution and resource waste caused by the excessive application of chemical fertilizers and pesticides and increase their understanding of green production technology policies, such as the biological control of pests and diseases. This can encourage farmers to abandon their original rough production behaviors and actively adopt green production to practice environmental protection [27]. Second, in the era of big data and information technology, IAA contributes to the accumulation of more advanced production technology and experience for farmers. Different from the traditional planting and management methods of teaching by words and example, farmers can learn about new agricultural policies and advanced technologies at multiple levels and in an all-round way through different channels, such as the Internet and new media, without leaving home, which greatly reduces the cost of searching information and learning technology. They can apply the screened and assimilated agricultural information to agricultural production practices more quickly. The optimal allocation of agricultural resources in time and space can be realized, and the constraints of technology adoption caused by irrational factors can be alleviated so as to improve the degree of adoption of GPBs by farmers [28]. Accordingly, hypothesis 1 of this paper is proposed.

H1: *IAA significantly positively influences apple growers' GPBs.*

The three key nodes of the "Knowledge–Altitude–Practice" theory are "Forming Knowledge–Generating Beliefs–Changing Behavior" [29], which is reflected in this paper as "information acquisition–benefit cognition–technology adoption". Many scholars have found that cognitive levels have a significant positive impact on farmers' behaviors [30,31]. In this paper, GBC is defined as the degree of recognition apple growers show for the benefits brought by green production, based on their experience and knowledge in the production process. On the one hand, cognition is the basis for behavior, and an individual's cognition shapes his or her preferences, which then affects his or her final behaviors [16]. IAA significantly improves farmers' environmental and technological perceptions as well as their perceptions of the benefits of adopting green production practices. The higher the IAA of farmers, the richer the knowledge of agricultural production technologies they absorb, the more they understand the role of GPBs in promoting farmers' incomes, benefiting ecological protection to achieve synergistic developments, and the higher the level of farmers' benefit cognition encourages their GPBs. On the other hand, many of the new green production technologies remain at the level of technology demonstration due to their high capital investment and learning costs, resulting in low rates of actual adoption by farmers. The improvement of IAA makes it more convenient for farmers to communicate and share information with technical experts and other professionals, or with other farmers, so that they have the opportunity to understand and learn more about the knowledge and experience of green production technologies, learn about the operation techniques and expected benefits of advanced technologies, and reduce losses caused by technical errors or improper risk prevention, thus increasing the likelihood of green production [22]. Accordingly, hypothesis 2 of this paper is proposed.

H2: *GBC plays a mediating role in the influence of information accessibility on apple growers' GPBs.*

The theory of "attitude–context–behavior" points out that individual attitudes and external contextual factors jointly determine individual behaviors [32]. New technology learning attitude (NTLA) refers to the tendency of apple growers to learn green production technologies in the process of apple planting and production, taking soil testing and formula fertilization technology as examples. Farmers understood the economic and ecological benefits brought by green production after they learned through different information channels that the technology could increase apple production, raise their income, and alleviate environmental pollution caused by the over-application of chemical fertilizers and pesticides. This is consistent with the idea of achieving a coordinated development of farmers' income growth with environmental protection, which enhances farmers' willingness to learn new green production technologies, improves farmers' attitude towards learning green production technologies, and then increases the possibility of farmers' adoption of green production. However, although some farmers recognize the economic and ecological benefits of green production technologies, due to the influence of risk aversion or cognitive bias, even if farmers are willing to adopt green production technologies, their low tolerance for risk often causes them to have a low attitude towards learning new technologies, which is specifically manifested as decision-making difficulties and reduces the possibility of adopting GPBs [33]. Therefore, the authors believe that new technology learning attitude has a significant moderating effect on the process of green benefit cognition and farmers' GPBs. Accordingly, hypothesis 3 of this paper is proposed.

H3: *NTLA has a positive moderating role in the process of benefit perception influencing the adoption of GPBs among farmers.*

In summary, IAA, GBC, and NTLA are included in the same analytical framework to analyze the impact of IAA on farmers' GPBs and the mediating effects of GBC and moderating effects of NTLA, as shown in Figure 1.

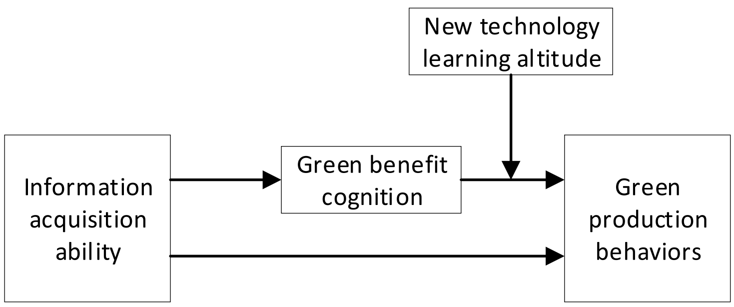

Figure 1. Research analysis framework.

3. Data and Methods

3.1. Data Source

The data in this paper are from a field investigation of apple farmers in Shaanxi and Gansu provinces from July to August 2023. In order to ensure the validity and accuracy of the survey data, a multi-stage sampling method was used to delimit the sample area. Eight sample counties were selected from the main apple producing areas of Shaanxi and Gansu provinces, and four to eight towns were randomly selected from each sample county. Then, two to four villages were selected in each town. Some 10 to 20 farmers were randomly selected from each village as the interviewees. Face to face interviews were conducted to ensure that the questionnaire could reflect the actual situation as truly as possible. A total of 671 questionnaires were collected, and 15 questionnaires with key information missing were excluded, and so, 656 valid questionnaires were collected, with an effective rate of 97.8%.

3.2. Selection of Model Variables

3.2.1. Explained Variable

Based on a comprehensive analysis of the current situation of apple planting in the research area and the research of relevant scholars, the GPBs defined in this paper refer to a series of methods apple farmers use to reduce pollution and improve agricultural efficiency with the goal of saving energy, reducing consumption, and reducing pollution in the process of apple planting and production. Referring to existing research [34], this paper studies the following five GPBs: (1) water and fertilizer integration technology; (2) soil testing and formulation technology; (3) physical pest control technology (including frequency vibration insecticidal lamps, color plate trapping, sweet and sour liquid trapping, tying insecticidal belts, and white tree trunk painting technology); (4) biological control technology (including the artificial release of insects, the use of biological pesticides, and insect preparation trapping); and (5) soil improvement and quality conservation technology. The total number of types of green production adopted is used as the measurement index of farmers' GPBs.

3.2.2. Explanatory Variable

Information acquisition ability: this paper defines IAA as the ability of farmers to obtain, identify, and absorb relevant agricultural policy or technical information through different information dissemination channels [23,35]. Specifically, this paper uses the ability of apple growers to obtain agriculture-related production technology and national policy information through the Internet and other channels to reflect farmers' IAA. The items involved are "I can obtain national policy information through the Internet", "I can obtain agricultural green production information through the Internet", "I can find the information I want from multiple search results of the search engine", "I often use we chat to ask others about production issues", and "I know some websites/anchors about agricultural production".

3.2.3. Control Variables

Drawing on the relevant studies of existing scholars [36–38], this paper, from the three aspects of individual, family, and land characteristics, selected a total of 14 control variables. Individual variables include the major decision maker of the family, the household head's gender, age, education level, health status, livelihood mode, apple planting years, and whether they are a village cadre and a certified new professional farmer. Family and land variables refer to the proportion of household agricultural labor force, apple garden size, whether to join the cooperative, number of plots, planting density, irrigation conditions, and one regional dummy variable.

3.2.4. Mechanism Variables

Green benefit cognition: In this paper, GBC is defined as the degree of farmers' recognition of the benefits brought by adopting GPBs based on their experience and knowledge in the production process. Building on existing research [39,40], farmers' GBC was measured in terms of economic, social, and ecological values, with questions such as "Do you think green production behavior will improve the quality of apples?", "Do you think green production behavior will increase farmers' income", and "Do you think green production behavior will protect the environment?" The average of the responses of the three items is used to measure the GPBs. Each of the above questions adopts a Likert scale from 1 to 5, and the larger the value, the higher the farmers' GPBs are.

New technology learning attitude: the NTLA defined in this paper refers to the tendency of apple farmers to learn green production, which reflects the willingness of farmers to learn new technologies independently, and judges the farmers' new technology learning attitude by their answers to "whether you will try to learn new methods and new technologies of agricultural cultivation"; the question is also based on a Likert scale from 1 to 5, and the larger the value, the stronger the farmers' attitude to learn new technologies (Table 1).

Table 1. The definition and data description of the variables in the model.

Variables	Definition	Mean	S.D
GPBs	The number of green production technology adoptions	2.582	1.373
IAA	The scores of farmers' information acquisition ability	−0.000	0.949
GBC	The scores of farmers' green benefits cognition	3.761	0.766
NTLA	The scores of farmers' new technology learning attitude	3.700	1.299
Gender	1 if the household head is male, 0 otherwise	0.775	0.424
Age	The age of the household head	54.177	9.052
Education	Educational years of the household head	7.341	3.639
Health	Unhealthy = 1; general = 2; healthy = 3	2.797	0.475
Village cadre	1 if the household head is a village cadre, 0 otherwise	0.116	0.320
Livelihood	Pure farming = 1; semi-farming and semi ranging = 2; semi-agriculture and semi-industry = 3; own family business in conjunction with farming = 4	1.808	0.979
Planting years	Planting years of the household head	19.893	9.673
Professional farmer	1 if the household head is a certified New Professional Farmer, 0 otherwise	0.159	0.366
Labor	Proportion of apple cultivation labor	0.530	0.239
Cooperative	1 if the household joins the cooperative, 0 otherwise	0.572	0.495
Land size	Size of apple garden	11.890	21.393
Plot No.	Number of apple plots	4.284	4.709
Density	Number of apple trees per Mu (1 Mu = 1/15 hectare)	52.047	18.392
Irrigation	1 if the land can be irrigated, 0 otherwise	0.348	0.477
Region	1 if the household is located in Gansu, 0 otherwise	0.500	0.500
Access to national policy information through the Internet	1 = strongly disagree, 2 = disagree, 3 = fair, 4 = agree and 5 = strongly agree	3.683	1.255
Access to agricultural green production information through the Internet	1 = strongly disagree, 2 = disagree, 3 = fair, 4 = agree and 5 = strongly agree	3.608	1.215
Find the information you want from multiple search results from a search engine	1 = strongly disagree, 2 = disagree, 3 = fair, 4 = agree and 5 = strongly agree	3.352	1.326
Use Wechat to ask others about production problems	1 = strongly disagree, 2 = disagree, 3 = fair, 4 = agree and 5 = strongly agree	3.686	1.199
Learn about websites/anchors about agricultural production	1 = strongly disagree, 2 = disagree, 3 = fair, 4 = agree and 5 = strongly agree	3.224	1.301

3.3. *Adoption of Green Production Behaviors by Farmers*

Table 2 summarizes the adoption of green production technologies by the sample farmers. From Table 2, Shaanxi and Gansu provinces have a higher percentage of GPBs, with only 4.4% of farmers not adopting any of the technologies. The level of green technology adoption by farmers in Shaanxi Province is higher than that in Gansu, and the proportion of farmers adopting four and five technologies is 21% and 15.9%, respectively, which is higher than that of Gansu Province, which is 14.3% and 4.3%. There is still room for improvement for farmers in Gansu Province in terms of green production technology adoption. Therefore, the main question of this paper is to analyze what factors can influence the GPBs of farmers and how to improve the adoption of green production.

Table 2. Adoption of Green Production Behaviors by Sample Apple Farmers.

No. of GP Tech. Adopted	Shaanxi (n = 328)		Gansu (n = 328)		Total (n = 656)	
	Number of Adopters	Adoption Rate (%)	Number of Adopters	Adoption Rate (%)	Number of Adopters	Adoption Rate (%)
0	16	4.9	13	4	29	4.4
1	76	23.2	61	18.6	137	20.9
2	54	16.5	107	32.6	161	24.5
3	61	18.6	86	26.2	147	22.4
4	69	21	47	14.3	116	17.7
5	52	15.9	14	4.3	66	10.1

4. Methodology

4.1. Graded Response Model

IAA in this paper is defined as the ability of farmers to obtain, identify, and absorb relevant agricultural policy or technical information through different information dissemination channels, which involves related items measured by Likert scale values 1–5. The graded response model (GRM) [41] is used to estimate the IAA of farmers. The GRM is a multivariate IRT model for item responses characterized by ordered categories. It is specified with respect to the probability that a response will be observed in category k or higher and consists of cumulative probabilities. The model expression is shown in Equation (1).

$$P\left(x_{ij} \geq k \middle| \theta_i, \alpha_j, d_j\right) = \frac{\exp\left[\alpha_j\left(\theta_i - b_{jk}\right)\right]}{1 + \exp\left[\alpha_j\left(\theta_i - b_{jk}\right)\right]}, k = 1, 2, \ldots, K \tag{1}$$

In order to further calculate the probability that the ith farmer assigns a score level of k when responding to the jth question, the formulation (2) is constructed as follows:

$$P^*\left(x_{ij} = k \middle| \theta_i, \alpha_j, d_j\right) = P\left(x_{ij} \geq k \middle| \theta_i\right) - P\left(x_{ij} \geq k + 1 \middle| \theta_i\right), k = 1, 2, \ldots, K \tag{2}$$

where K is the number of item levels that the farmer answers, α_j is the discrimination degree of item j, b_{jk} is the difficulty of item j at the kth level, θ_i is the information acquisition ability of farmer i, and x_{ij} is the answer of the ith farmer to the jth item. $P_k(\theta)$ represents the probability that a farmer with the information acquisition ability θ reaches the score level k or above on item j, and $P_k^*(\theta)$ represents the probability that a farmer with the information acquisition ability θ just gets the score level k on item j. The probability that a farmer gets a score of 1 or above is 1 (that is, $P\left(x_{ij} \geq 1 \middle| \theta\right) = 1$), while the probability that a farmer gets a grade of K + 1 or above is 0 (that is, $P\left(x_{ij} \geq k + 1 \middle| \theta\right)$ = 0).

4.2. The Ordered Logit Model

The dependent variable in this paper is the green production behaviors of apple growers, which is measured by the number of green production technologies adopted by farmers, which can be divided into five types. The order logit model is set as follows:

$$P = \frac{exp(\sum \beta_i X_i)}{1 + exp(\sum \beta_i X_i)} \tag{3}$$

P represents the probability that farmers adopt green production; X_i is the independent variable, indicating the factors that affect apple grower' GPBs, including information acquisition ability, green benefit cognition, personal characteristics of the household head, and household land and production characteristics; and β_i is the regression coefficient, indicating the influence coefficient of individual variables on the dependent variable.

4.3. A Moderated Mediating Effect Test Method Based on Bootstrap

Based on the Bootstrap moderated mediating effect test method [42], this paper discusses the mediating effect of GBC and the moderating effect of NTLA in the process of farmers' IAA affecting their GPBs. The confidence interval and significance of the mediating effect can be estimated more accurately by repeated sampling of samples using the Bootstrap method and testing the significance of the mediating effect in combination with the Sobel test. The basic model used in this paper is as follows:

$$Y_i = cX + \mu_1 \tag{4}$$

$$M = aX + \mu_2 \tag{5}$$

$$Y_i = c'X + bM + dI + eM * I + \mu_3 \tag{6}$$

Y_i represents the adoption degree of a green production technology of the ith farmer; M represents the benefit cognition of the mediating variable; I represents the learning degree of new technology of the moderating variable; $a, b,$ c, c$'$$, d, e$ are all parameters to be estimated; μ_1 μ_2 μ_3 are random error terms; Equation (4) represents the total impact of IAA on the adoption degree of GPBs of farmers; Equation (5) represents the impact of IAA on benefit cognition; and Equation (6) represents the indirect impact of IAA on benefit cognition on the adoption degree of GPBs through the new technology learning attitude.

4.4. The Ordered Probit Model

To verify the robustness of the benchmark regression results, the ordered Probit model is set as follows:

$$Y_i^* = \alpha_i X_i + \varepsilon_1 \tag{7}$$

$$Y_i = \begin{cases} 0,\ if\ Y_i^* \leq r_0 \\ 1,\ if\ r_0 < Y_i^* \leq r_1 \\ 2,\ if\ r_1 < Y_i^* \leq r_2 \\ 3,\ if\ r_2 < Y_i^* \leq r_3 \\ 4,\ if\ r_3 < Y_i^* \leq r_4 \\ 5,\ if\ Y_i^* > r_4 \end{cases} \tag{8}$$

In Equations (7) and (8), Y_i^* represents the latent variable of farmers' green production behaviors and is used to derive a maximum likelihood estimator; Y_i represents the number of green production practices participated in by farmers; X_i is the independent variable, indicating the factors that affect apple grower' GPBs, including information acquisition ability, green benefit cognition, personal characteristics of the household head, and household land and production characteristics; α_i is the regression coefficient, indicating the influence coefficient of individual variables on the dependent variable.

Equation (8) shows the relationship between Y_i and Y_i^*. r_0, r_1, r_2, r_3, and r_4 are unknown split points of the number of farmers' participation in green production practices, and $r_0 < r_1 < r_2 < r_3 < r_4$. The resulting probabilities of the number of farmers' participation in green production practices, respectively, are:

$$\begin{gathered} P(Y_i = 0|X_i) = \Phi(r_0 - \alpha_i X_i) \\ P(Y_i = 1|X_i) = \Phi(r_1 - \alpha_i X_i) - \Phi(r_0 - \alpha_i X_i) \\ P(Y_i = 2|X_i) = \Phi(r_2 - \alpha_i X_i) - \Phi(r_1 - \alpha_i X_i) \\ P(Y_i = 3|X_i) = \Phi(r_3 - \alpha_i X_i) - \Phi(r_2 - \alpha_i X_i) \\ P(Y_i = 4|X_i) = \Phi(r_4 - \alpha_i X_i) - \Phi(r_3 - \alpha_i X_i) \\ P(Y_i = 5|X_i) = 1 - \Phi(r_4 - \alpha_i X_i) \end{gathered} \tag{9}$$

Φ represents the standard normal distribution's cumulative probability density function.

4.5. The Propensity Score Matching Method (PSM) Model

The propensity score matching (PSM) method is used to evaluate the influence of IAA on GPBs. Therefore, this paper attempts to divide the whole sample into two categories: the group with higher IAA and the group with lower IAA. The parameter of interest is the average treatment effect (ATT) of the farmers with higher IAA on the treated households, which can be expressed by the following equation:

$$ATT = E(Y_1|D = 1) - E(Y_0|D = 1) = E(Y_1 - Y_0|D = 1) \quad (10)$$

Y_1 is the level of adoption of green production technologies in the high IAA group, and Y_0 is the level of adoption of green production technologies in the low IAA group.

5. Empirical Analysis

Firstly, the reliability and validity of the questionnaire are tested by SPSS26.0 statistical software, and Cronbach's α coefficient is 0.870, indicating a high degree of consistency for each item. The KMO value is 0.818, and the significance of Bartlett's test of sphericity is 0.000 (χ^2 = 1799.403), which reflects the high reliability of the principal component analysis. The principal component analysis method is used to verify the unidimensional hypothesis. The estimation results show that the first factor eigenvalue is 3.319, the second eigenvalue is 0.656, and the ratio is 5.06, which is greater than 3, indicating that the data is unidimensional and suitable for analysis using IRT. Therefore, this paper uses the IRT program package in R 4.3.0 software to calculate farmers' IAA [43], and the estimated results are shown in Tables 3 and 4.

Table 3. IAA item characteristics based on IRT.

Item	a	b1	b2	b3	b4
Access to national policy information through the Internet	4.657	−1.633	−0.876	−0.276	0.563
Access to agricultural green production information through the Internet	4.885	−1.627	−0.815	−0.329	0.750
Find the information you want from multiple search results from a search engine	1.739	−1.674	−0.792	0.089	1.006
Use Wechat to ask others about production problems	1.642	−2.119	−1.294	−0.495	0.877
Learn about websites/anchors about agricultural production	1.455	−1.698	−0.772	0.062	1.386

Table 4. Distribution of farmers' information acquisition ability.

IAA Parameter Interval	Number of Farmers (Person)	Percentage (%)
[−3, −2]	27	4.12
[−2, −1]	84	12.80
[−1, 0]	154	23.48
[0, 1]	300	45.73
[1, 2]	91	13.87

Based on the analysis in Table 3, it can be seen that the two items "Access to national policy information through the Internet" and "Access to agricultural green production information through the Internet" have a high degree of discrimination, indicating that farmers obtaining national policy information and green production information from the Internet plays an important role in apple grower information acquisition. The discrimination parameters of the "Find the information you want from multiple search results from a search engine", "Use Wechat to ask others about production problems", and "Learn about websites/anchors about agricultural production" are small, indicating that these three items may have less obvious effects on farmers' information acquisition. The difficulty parameter in the five items increases monotonically with the increase of difficulty level, which indicates that it is more difficult to obtain higher scores. In addition, the difficulty parameter of the item "Learn about websites/anchors about agricultural production" is higher than that of other items, which indicates that sample farmers have great difficulties in obtaining relevant information about websites or anchors about agricultural production. This may be because the sample farmers still have a wait-and-see attitude towards new social media websites or anchors, and their acceptance and trust of this type of information needs to be improved.

This paper assumes that the parameters of the IAA of the sample apple growers follow a standard normal distribution, and the estimation results are shown in Table 4. The estimated values of farmers' IAA parameters in this study are all within [−3, 3], indicating that the hypothesis of deviation from standard normal distribution can be rejected; that is, it is reasonable to set the prior distribution of farmers' IAA parameters as a standard normal distribution [44]. According to Table 3, the total number of farmers whose IAA is not greater than 0 is 265, which is 40.39%, indicating that some of the farmers have a low ability to acquire information on agricultural technology. A total of 300 farmers' IAA is located in the interval (0,1), which is 45.735%, indicating that most of the farmers have a medium level of IAA. In addition, there are 91 farmers whose IAA interval is greater than 1, accounting for 13.87%, indicating that there are still a small number of farmers with strong IAA. In general, the distribution of the parameters of the sample farmers' IAA is relatively average, which further proves that the samples selected in this paper are representative.

5.1. Benchmark Regression Analysis

With the help of stata17.0 software to analyze the total impact of IAA on farmers' GPBs, the results are shown in Table 5. Based on the results of Regression 3 of the ordered Logit model, it can be found that IAA positively affects the adoption of GBC by farmers, and it is significant at a 1% level, and the higher the IAA of farmers, the more inclined they are to adopt multiple green production technologies; that is, hypothesis H1 has been verified. Based on the results of the ordered Logit model and Equation (3), it can be found that fixing other factors constant, for every one unit increase in the farmers' IAA, the probability of not adopting GPBs decreases by 1.1%, the probability of adopting one green production technology decreases by 3.6%, the probability of adopting two green production technologies decreases by 1.4%, the probability of adopting three green production technologies increases by 1.2%, the probability of adopting four green production technologies increases by 2.7%, and the probability of adopting five green production technologies increases by 2.3%.

For the control variables, age has a negative impact on farmers' GPBs, and it is significant at a level of 1%. Livelihood mode, whether to join the cooperative or not, apple garden size, and the number of plots all positively affect the green production adoption behavior of farmers, which are significant at levels of 1%, 1%, 5%, and 5%, respectively. Specifically, farmers who are younger, have a higher proportion of off-farm income in their household income, have a larger area of apple cultivation, have a larger number of plots, and join cooperatives are more likely to adopt GPBs. Regression 2 is the regression result of the ordered Probit model, which is basically consistent with the regression result of the ordered Logit model, indicating that the results are robust to some extent.

5.2. Robustness Test

5.2.1. Replacement of Empirical Model

Regression 2 shows the regression results of the ordered Probit model, which are basically consistent with the regression results of the ordered Logit model, indicating that the results are somewhat robust.

Table 5. IAA and GPBs: benchmark regression results.

Variable	Regression 1	Marginal Effect						Regression 2
		0	1	2	3	4	5	
IAA	0.273 ***	−0.011 ***	−0.036 ***	−0.014 ***	0.012 ***	0.027 ***	0.023 ***	0.165 ***
	(0.084)	(0.004)	(0.011)	(0.005)	(0.004)	(0.008)	(0.008)	(0.049)
Gender	0.082	−0.003	−0.011	−0.004	0.003	0.008	0.007	0.023
	(0.182)	(0.008)	(0.024)	(0.010)	(0.008)	(0.018)	(0.015)	(0.107)
Age	−0.025 ***	0.001 **	0.003 ***	0.001 **	−0.001 **	−0.002 ***	−0.002 **	−0.012 **
	(0.010)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.005)
Education	0.022	−0.001	−0.003	−0.001	0.001	0.002	0.002	0.013
	(0.022)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)	(0.013)
Health	0.032	−0.001	−0.004	−0.002	0.001	0.003	0.003	0.051
	(0.154)	(0.006)	(0.020)	(0.008)	(0.007)	(0.015)	(0.013)	(0.089)
Village cadre	0.067	−0.003	−0.009	−0.004	0.003	0.007	0.006	0.070
	(0.229)	(0.010)	(0.030)	(0.012)	(0.010)	(0.023)	(0.020)	(0.136)
Livelihood	0.226 ***	−0.009 ***	−0.030 ***	−0.012 ***	0.010 ***	0.022 ***	0.019 ***	0.129 ***
	(0.078)	(0.004)	(0.010)	(0.004)	(0.004)	(0.008)	(0.007)	(0.045)
Planting years	0.012	−0.001	−0.002	−0.001	0.001	0.001	0.001	0.006
	(0.008)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.005)
Professional farmer	0.15	−0.006	−0.020	−0.008	0.006	0.015	0.013	0.080
	(0.206)	(0.009)	(0.027)	(0.011)	(0.009)	(0.020)	(0.018)	(0.119)
Labor	0.046	−0.002	−0.006	−0.002	0.002	0.005	0.004	−0.037
	(0.328)	(0.014)	(0.043)	(0.017)	(0.014)	(0.032)	(0.028)	(0.187)
Cooperative	0.437 ***	−0.018 ***	−0.058 ***	−0.023 ***	0.018 ***	0.043 ***	0.037 ***	0.252 ***
	(0.145)	(0.007)	(0.019)	(0.008)	(0.007)	(0.014)	(0.013)	(0.085)
Land size	0.011 **	0.000 **	−0.001 **	−0.001 **	0.000 **	0.001 **	0.001 **	0.007 ***
	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Plots No.	0.036 **	−0.001 *	−0.005 **	−0.002 **	0.002 **	0.004 **	0.003 **	0.021 **
	(0.017)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.010)
Density	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Irrigation	0.071	−0.003	−0.009	−0.004	0.003	0.007	0.006	0.030
	(0.202)	(0.008)	(0.027)	(0.011)	(0.009)	(0.020)	(0.017)	(0.113)
Region	−0.338	0.014	0.045	0.018	−0.014	−0.033	−0.029	−0.229
	(0.213)	(0.009)	(0.028)	(0.011)	(0.009)	(0.021)	(0.018)	(0.123)
Pseudo R2	0.0429							0.0430
Prob > chi2	0.0000							0.0000

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses.

5.2.2. PSM

There may be self-selection problems and deviations between IAA and GPBs, for example, farmers will actively explore relevant channels to acquire new knowledge about green production after using green production technologies. In order to solve this problem, this paper uses propensity score matching to test the influence of IAA on GPBs, and defines farmers with an IAA greater than 0 as the "strong information acquisition ability group" and farmers with an IAA lower than 0 as the "weak information acquisition ability group". The nearest neighbor matching, near neighbor matching (K = 4), radius matching (0.01), kernel matching (0.06), and local liner matching methods are selected for estimation.

As can be seen in Table 6, under all five matching methods, the level of difference in smallholder GPBs induced by IAA was found to be around 0.299 after controlling for selectivity bias between the treatment and control groups, with T-values ranging from 1.85 to 2.59 for each of the matching results, and all of them were statistically significant, which is in line with the results of Regression 1 in Table 5, indicating that the test results are significant and robust. Therefore, the empirical results derived from the PSM method tend to accept that IAA has a significant positive effect on apple growers' GPBs, validating H1.

Table 6. Robustness test considering self-selection bias (PSM).

Method of Matching	Processing Group	Control Group	Average Treatment Effect	Bootstrap Standard Error	*t*-Test Value
Nearest neighbor matching	2.598	2.295	0.303 ***	0.117	2.59
Near neighbor matching (K = 4)	2.759	2.467	0.292 **	0.129	2.27
Radius matching (caliper = 0.01)	2.759	2.445	0.314 **	0.128	2.46
Kernel matching (bandwidth = 0.06)	2.759	2.465	0.294 **	0.122	2.40
Local liner matching	2.759	2.469	0.291 *	0.157	1.85
Average value	2.727	2.428	0.299		

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels.

5.3. Mechanism Analysis

In this paper, a stepwise regression method is used to test the mediating role of green benefit cognition in the relationship between IAA and farmers' GPBs.

Regression 3 results from Table 7 show that the total effect of IAA on farmers' GPBs is 0.202, which also verifies hypothesis H1. When farmers' IAA improves by one unit, the adoption of green production technologies increases by 0.202. Regression 4 results show that IAA has a positive impact on green benefit perception. When farmers' IAA improves by one unit, GBC increases by 0.204. Regression 5 results show that when IAA and GBC are put into the model, both of them have a significant positive impact on farmers' GPBs. The result shows that when farmers' GBC is constant, an increase of one unit in IAA directly contributes to farmers' adoption of green production technologies by 0.166. And when farmers' IAA is constant, each unit increase in GBC directly promotes farmers' adoption of green production technologies by 0.175. The above results verify that GBC plays an obvious mediating role in the influence of IAA on farmers' GPBs; that is, hypothesis H2 is verified. As each unit increases in a farmer's IAA, their GPBs increase by 0.202 units; this is due to the fact that an increase in IAA by one unit not only directly contributes to an increase in GPBs by 0.166 units, but also leads to an increase in GBC by 0.204 units, which contributes to an increase in farmer's GPBs by 0.036 (resulting in a multiplication of 0.204 by 0.175).

Table 7. Decomposition of direct and mediating effects.

	Regression 3 GPBs	Regression 4 GBC	Regression 5 GPBs
IAA	0.202 *** (0.061)	0.204 *** (0.035)	0.166 *** (0.063)
GBC			0.175 ** (0.070)
Control	YES	YES	YES
Observation	656	656	656
Adj R-sq	0.1130	0.0849	0.1204

Note: **, and *** denote significance at the 5%, and 1% levels, respectively. Standard errors are in parentheses.

Model 14 (Model 14 belongs to the models set up in the Process plugin. The exact method can be learned from the website SPSS PROCESS Macro—The Complete Guide (spss-tutorials.com)) in the Process plug-in is used to conduct the moderated mediating effect test. The judgment method is as follows: if the significance of the conditional mediating effect of the three groups is such that some are significant while some are not, then the moderating effect is significant.

As can be seen from Table 8, the output displays the conditional indirect effect for three values of the moderator variable: the mean (0.0358), one standard deviation above the mean (0.0716), and one standard deviation below (−0.0358). The efficiency values correspond to Equations (4)–(6) to obtain coefficient values of $a_{I\hat{A}A}\left(\hat{b}+\hat{e}I\right)$. The conditional mediating effect is not significant at the low-level group of the moderating variable- NTLA, while it is significant at the mean and at the high-level group. NTLA plays a positive moderating role in the process of benefit perception affecting the adoption of GPBs; H3 is proved.

The subgroups with low attitudes toward learning new technologies were not significant, probably because such farmers lacked sufficient attention to new technologies and tended to be less able to recognize the benefits of green production technologies, and thus such farmers had a lower level of adoption of green production methods in the process of apple cultivation. In addition, green production technology often requires certain learning costs, and farmers with low attitudes toward learning new technologies may be influenced by being risk averse, unwilling to invest in learning, and ignoring the benefits generated by new technologies, leading to a lower degree of adoption of green production technologies.

Table 8. Test of conditional mediating and moderating effects.

NBLA	Efficiency Value	Boot S.E.	Lower Boot CI	Upper Boot CI	Significance of Conditional Mediation	Significance of the Moderating Effect
M − 1SD	−0.0001	0.0196	−0.0411	0.0373	insignificant	
M	0.0358	0.0160	0.0081	0.0700	significant	significant
M + 1SD	0.0716	0.0242	0.0295	0.1240	significant	

Note: The Boot standard error, lower Boot CI limit and upper Boot CI limit are the estimated standard error and lower and upper 95% confidence interval using the non-parametric percentile Bootstrap method with bias correction, respectively, and the number of replicates is 5000.

5.4. Heterogeneity Analysis

5.4.1. Age Structure

Since there is an obvious gap between apple farmers of different ages for IAA and green benefit cognition, it is necessary to group sample farmers according to age. In this paper, respondents over 55 years old are classified as the old generation of farmers, and respondents under 55 years old are classified as the new generation of farmers in order to observe intergenerational differences on the influence of IAA, GBC, and NTLA on farmers' GPBs.

Outcomes in columns (2) and (3) of Table 9 show the results of the subsample regression based on age structure. All in all, the results in columns (2) and (3) are significant, indicating that IAA is conducive to promoting farmers' GPBs for different age groups. Comparing the results of the two columns, it is found that IAA is more conducive to promoting GPBs among farmers over 55 years old. Based on previous research, a possible explanation is as follows: younger farmers have a higher inclination to off-farm work. They pay less attention to apple cultivation and technology adaptation. But green benefit perceptions of the younger farmer group significantly affect their GPBs. Due to the low possibility to work off farm, elder farmers rely heavily on agriculture to make a living. Therefore, their IAA has a higher impact on the adoption of GPBs.

Table 9. Heterogeneity analysis in the impact of farmers' green production behavior.

Variable	Age		Education Level		Region	
	Age < 55	Age ≥ 55	Low	High	Shaanxi	Gansu
IAA	0.285 **	0.327 ***	0.233 **	0.305 ***	0.349 ***	0.137
	(0.133)	(0.105)	(0.110)	(0.136)	(0.119)	(0.124)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Observation	328	328	359	297	328	328
pseudo R-sq	0.039	0.054	0.031	0.060	0.048	0.054

Note: **, and *** denote significance at the 5%, and 1% levels, respectively. Standard errors are in parentheses.

5.4.2. Education Level

Differences in level of education lead to differences in IAA, which in turn affect the adoption of GPBs by farmers. According to years of education, the sample farmers are divided into two groups: one group is farmers with less than 9 years of education; that is, those who have not completed compulsory education; the other group is farmers with more than or equal to 9 years of education. Group regression was then conducted to obtain the difference in the impact of IAA on farmers' GPBs under different years of education.

The results in columns (4) and (5) of Table 9 are the results of subsample regression based on educational attainment. The results are consistent with the basic regression. Farmers with higher levels of education are more likely to adopt GPBs. Possible explanations would be, firstly, farmers with a higher level of education have a high awareness of environmental protection, which makes them more likely to support the adoption of green production technologies. Secondly, more-educated farmers tend to have more social capital and are able to bear the costs and risks of adopting new technology. Therefore, IAA can play a more effective role in farmers with higher levels of education.

5.4.3. Region

A further analysis for the research is whether there any differences between Shaanxi and Gansu in terms of green technology adoption? Shaanxi and Gansu are located in the northwest, and both have favorable climatic conditions for apple growth. However, there are large differences in precipitation, sunshine, and temperature, and there are certain differences in economic development levels. There would be some differences in the apple growers' ability to acquire information.

The empirical analysis results in columns (6) and (7) of Table 9 show that IAA in Shaanxi significantly and positively promotes the adoption of green production technologies at a level of 1%. However, in Gansu, this effect is not significant. One possible explanation is that the climate of Shaanxi is sub-humid and semi-arid with more precipitation, most of which is concentrated in the summer. Shaanxi has long sunshine hours and abundant sunshine, which is conducive to apple growth. In addition, the temperature in Shaanxi is relatively suitable, and although there is a certain temperature difference, it is generally conducive to apple growth. However, Gansu has a relatively dry climate, especially in spring and winter, with less precipitation, which requires artificial irrigation, and it is difficult to meet the application conditions of green production technologies. Another possible explanation is that for the popularization of green production technologies, Shaanxi has a higher penetration rate than Gansu, which can also be seen from the adoption of green production technologies in the two places.

6. Conclusions and Recommendations

6.1. Conclusions

Based on the field research data of 656 apple growers in Shaanxi and Gansu provinces, this paper measures their IAA using the hierarchical response model of Item Response Theory, and explores the mechanism of the influence of IAA on the GPBs of apple growers by using the perception of the benefits of green technology and the attitude to learning new technology as mediating and moderating variables, respectively, while also controlling for the farmers' personal characteristics, family characteristics, and cultivated land characteristics. The following conclusions were drawn:

(1) Obtaining national policy information and agricultural production information from the Internet has is of great assistance for farmers' information accessibility. It is more difficult for farmers to get information from websites or anchors.
(2) The information acquisition ability of apple growers has a positive impact on the adoption of green production behaviors; the higher the information acquisition ability of farmers, the more likely they are to adopt green production.
(3) Green benefit cognition plays a positive mediating role in the influence of information acquisition ability on the adoption of green production behaviors by apple growers, which is specifically manifested in the following ways: the stronger the information acquisition ability of farmers, the higher the level of farmers' cognition of the economic and ecological benefits of green production behaviors, and the more likely it is to promote the adoption of green production behaviors by farmers.
(4) Attitude towards learning new technologies plays a positive regulatory role in the adoption of green production behaviors by apple growers in the perception of green benefits. After farmers are informed of the multiple benefits brought by green pro-

duction, it is easier to generate a willingness to learn green production technologies, which in turn improves learning attitudes and enhances farmers' green production behaviors.

(5) There are generational differences, educational differences, and regional differences in the influence of information accessibility and green benefit perceptions on farmers' green production behavior. Information accessibility is more conducive to the promotion of green production technologies among farmers over 55 years of age. GPBs are more likely to be adopted by farmers with higher levels of education. The effect of information acquisition ability is significant for Shaanxi, but not for Gansu.

Reviewing the theoretical assumptions, research methods, and conclusions of this study, there are still the following shortcomings: first, the adoption of green production behaviors by farmers is a complex process, and the mechanistic analysis of the factors influencing the degree of their adoption may require more rigorous derivation, and a more scientific theoretical basis for further research and exploration is needed in the future. Second, this study only examines the influence of information acquisition ability, perceived benefits of green technology and attitude towards learning new technology on farmers' green production behaviors, but the important influences of economic, social, and other factors, such as production profitability, labor resources, and other factors, on the "green production" of fruits in China is not explored, which will be the focus of further research and analysis. Finally, the consistency of the findings based on micro-farmer data from Shaanxi and Gansu provinces in China for other regions and countries around the world remains to be confirmed.

6.2. Recommendations

Combing all the findings, this paper puts forward the following feasible recommendations.

Firstly, improve farmers' ability to obtain information. Increase the construction of rural information infrastructure, build a diversified authoritative information dissemination and exchange platform, and provide more information on agricultural policies, new agricultural technologies, prices of agricultural products, etc., so as to improve the convenience and timeliness of farmers' access to information. Second, strengthen agricultural technology promotion and training to improve farmers' cognitive levels. On the one hand, dispatch technical specialists or invite agricultural technology experts and scholars to explain in the field and use other ways to let farmers fully understand the positive effects of green production behaviors. Additionally, introduce the establishment of green agricultural demonstration bases to attract farmers to experience advanced green production technology and to enhance farmers' green benefits cognition. Third, formulate relevant policies to mobilize farmers to learn new technologies. Improve the government subsidy mechanism in addition to ensuring the implementation of subsidies for farmers to adopt green production behaviors, and for the adoption of more types of new technologies for farmers to give tax relief, technical guidance, and other incentives to reduce the cost to farmers to adopt new technologies; encourage farmers to learn new technologies and improve the adoption rate of green production behaviors.

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