frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 16 November 2023
DOI 10.3389/fsufs.2023.1286450

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OPEN ACCESS

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RECEIVED 31 August 2023
ACCEPTED 16 October 2023
PUBLISHED 16 November 2023

CITATION
Li B, Liao M and Yuan J (2023) Gap between words and action: empirical study on the consistency of farmers supporting green vegetable production practices.
Front. Sustain. Food Syst. 7:1286450.
doi: 10.3389/fsufs.2023.1286450

Gap between words and action: empirical study on the consistency of farmers supporting green vegetable production practices

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The increasing interest on the quality and safety of vegetables has focused much attention to the words (willingness) and action (behavior) of farmers toward the production of safe vegetables. However, the majority of studies typically focus on willingness or behavior, ignoring the interactions between the two. Moreover, there exists a wide gap between farmers' actual behavior and their willingness to support green production practices of vegetable. Thus, in order to explore the key factors of farmers' willingness, behavior, and their consistency to adopt green vegetable production vegetable practices, we performed bivariate probit modeling and binary logistic regression based on a survey of 452 farmers in Beijing, China. Results demonstrate the number of farmers willing to adopt green vegetable production practices to exceed those who do not by 65.5%. In particular, 73.9% of farmers adopt green vegetable production practices, while 67.5% of farmers exhibit an adoption willingness that is consistent with the adoption behavior. A positive correlation is observed between the willingness and behavior to adopt green production practices of vegetable, while the key influencing factors of the willingness, behavior, and consistency of green production practices are distinct. For example, cooperatives, neighboring farmers, and government regulation exert a significant positive impact on consistency, while family labor force, vegetable income, and the media have a significant negative impact. Moreover, cooperatives are identified as the most important influencing factor. Our work offers guidance in understanding the influencing factors of the willingness and behavior to adopt green vegetable production practices, and can provide a policy basis for governments to promote such practices.

KEYWORDS

green production practices, willingness, behavior, consistency, bivariate probit, China

1. Introduction

Vegetables provide a large amount of the vitamins and minerals necessary for a healthy lifestyle, and thus form an indispensable component in the daily diet (Cheng et al., 2016; Santarelli et al., 2018; Zhang W. et al., 2019). The healthy development of the vegetable industry can promote the adjustment of agricultural structure, optimize the diet structure of residents, increase farmers' income, and improve living standards (Wang et al., 2018; Fan et al., 2019). However, the excessive use of pesticides and chemical fertilizers during the vegetable production process (Li et al., 2016; Santarelli et al., 2018; Ha et al., 2020), the random dumping and accumulation of vegetable waste (Zhou et al., 2018), and the continuous cropping obstacles of vegetables (Mostafidi et al., 2020) have damaged the micro ecology of the production environment (Huang et al., 2006). Vegetables are also affected by pesticide residues, heavy metals, diseases, insects, and disease control microorganisms (Danelon and Salay, 2012; Rizwan et al., 2017; Mostafidi et al., 2020). These aforementioned factors result in the failure to effectively guarantee the quality and safety of vegetables.

Promoting the green development of vegetables can successfully overcome the problems of continuous cropping, the excessive application of chemical fertilizers and pesticides, and the unreasonable application of irrigation water (Li et al., 2020b). Excessive use and improper disposal of chemical inputs in agricultural production lead to a large amount of non-point source pollution and carbon emissions, which seriously affect the rural ecological environment and human physical and mental health. Agriculture green production was an effective way to solve the problem (Li et al., 2020b). It was generally considered that green vegetable production practices were a sustainable development pattern, including improved agricultural technologies and sustainable production practices. Green vegetable production practices are a step forward to sustainable agriculture. The green development of agriculture is a function of scientific and technological innovation, labor quality improvements, and the implementation of standardized production frameworks (Fan et al., 2015; Mao et al., 2019; Li et al., 2020b). In July 2018, the Ministry of Agriculture and Rural Affairs of China issued the Technical Guidelines for Agricultural Green Development to vigorously promote the green development of agriculture. Following on from this, in October 2018, on-site observations of green and efficient production technology of vegetables were held by the National Agricultural Technology Extension Service Center and performed in Wuxi, Jiangsu Province. In practice, however, the development of green agricultural production in China is at an early stage of transformation and exploration and the adoption of improved technologies and sustainable practices is limited.

Vegetables have a short growth cycle and their production is labor-intensive. Furthermore, the production behavior of farmers is crucial for the development of green vegetables. Research on farmer behavior in green agricultural production generally focus on two aspects: (1) the safe application of pesticides and chemical fertilizers; and (2) factors affecting farmers' adoption of agricultural green production technology (e.g., green fertilizer technology, integrated pest management, and water conservation technology). In terms of pesticides and chemical fertilizers applications, farmers will typically exceed the required dosages during planting in order to maximize benefits. Studies demonstrate that farmers' decision-making behavior related to the safe application of pesticides and chemical fertilizers is a function of multiple factors including the characteristics of the person in charge of production (age, education, farming experience; Schreinemachers et al., 2017; Sharifzadeh et al., 2019), farm environment (household size, farm size; Fan et al., 2015), and risk knowledge and farmers' attitudes (Bondori et al., 2018). In addition, the research identified perceived benefits as the dominant driver of farmers' safe pesticide usage, while external pressure and subjective norms play a limited role (Wang et al., 2017). Furthermore, scientific knowledge on pesticides, habitual behavior and avarice influence the pesticide use behavior, with the latter two having a negative impact (Abadi, 2018). In terms of farmers' adoption of green technology (to improve soil fertility, optimize land use and maintain long-term farm productivity at a low cost), farmers replace their traditional production modes with agricultural green technology. Previous studies have identified numerous influencing factors for the adoption of agricultural green technology: demographic and socioeconomic influences (Zhang Y. et al., 2019); social networks (Liu et al., 2019); risk preferences; and social capital (Gao et al., 2019). More specifically, the research revealed that males, younger farmers, and members of agricultural cooperatives are more likely to adopt soil testing and formulated fertilization technologies (Liu et al., 2019). The research reported normative inclinations and risk perceptions to influence water conservation behavior (Yazdanpanah et al., 2014).

Despite the extensive research on the key influencing factors of green agricultural technology adoption and safe fertilization and pesticide practices, the underlying mechanisms behind farmers' willingness and behavior to adopt green vegetable production practices remain unclear. According to the theory of planned behavior (TPB), attitude, subject norms, perceived behavioral control, and behavioral intention are key factors affecting behavior, with the latter being the most important (Ajzen, 1991). However, during decision-making, farmers typically maximize their own interests, and their production and operation behavior is based on economical and rational controls. Thus, some farmers will face inconsistencies in their willingness and behaviors. At present, relatively few studies have investigated the factors that impede or facilitate the consistency between farmer's willingness and behavior regarding green vegetable production practices.

The aim of this study is therefore to provide empirical evidence on the intentions of farmers toward green vegetable production practices as well as their actual behavior. In order to do this, we set the following objectives: (1) to construct a framework of influencing factors for farmers to adopt green production practices of vegetables based on TPB; (2) to investigate the disparity between the words and actions of farmers related to such the green production practices of vegetables; and (3) to determine the factors contributing to the adoption willingness, behavior, and consistency of farmers regarding the green production practices of vegetables. The findings of this study will not only contribute to understanding the barriers and drivers of the adoption of green production practices of vegetables by farmers in developing countries but can also guide the government in formulating more rational and effective policy recommendations for such practices.

The reminder of the study is structured as follows. Section 2 provides a brief introduce to green vegetable production practices. Section 3 discusses the conceptual framework and hypotheses. Section 4 presents the study sample, data, and methodology. The empirical results are detailed in Section 5, while Section 6 concludes the study. The findings and policy implications are summarized in Section 7.

2. Green vegetable production practices concepts

Actively promoting agricultural green production (AGP) is inevitable for the sustainable development of modern agriculture (Liu et al., 2020). Agricultural green production focuses on energy conservation, consumption reduction, pollution reduction, and the development of high-quality, high-efficiency, ecological and safe agricultural production methods through standardized production models (Kassie et al., 2013; Liu et al., 2020; Li et al., 2020b). Green vegetable production practices refer to the implantation of green vegetable production technical standards for the efficient use of resources, the effective protection of the ecological environment, and the improvement of vegetable quality and safety. Common features include weight loss, drug reduction and water saving, and the promotion of the sustainable vegetable production model (Figure 1). In particular, during the vegetable production process, the vegetable production environment (air, irrigation, water, and soil) should meet the environmental quality standards of green food production areas; variety selection is adapted to the local soil and climate characteristics; vegetable seed treatments include dry heat disinfection, warm soup soaking, hot water, scalding, or medicament soaking; appropriate sowing dates and methods are selected; suitable temperature, humidity and light for vegetable seedling production are implemented; green pest control, soil testing, and water-saving irrigation technologies are adopted for field management; the pesticide interval is reached at harvest; vegetable packaging conforms to the general guidelines for green food packaging; and vegetable storage and transportation follow the green food storage and transportation standards.

3. Conceptual framework and hypothesis

Initially proposed by Ajzen (1991), TPB is one of the most basic yet influential theories of cognitive behavior (Abadi, 2018; Rezaei et al., 2019a) and represents Ajzen's supplementary development of reasoned action theory. TPB believes that individual behavior is controlled and adds a factor that affects behavioral intention, perceptual behavior control (Ajzen, 1991). According to TPB, attitude, subjective norms, and perceived behavioral control are the key factors explaining behavior (Ajzen, 1991), indirectly affecting individual behavior by influencing behavioral intention. For example, when an

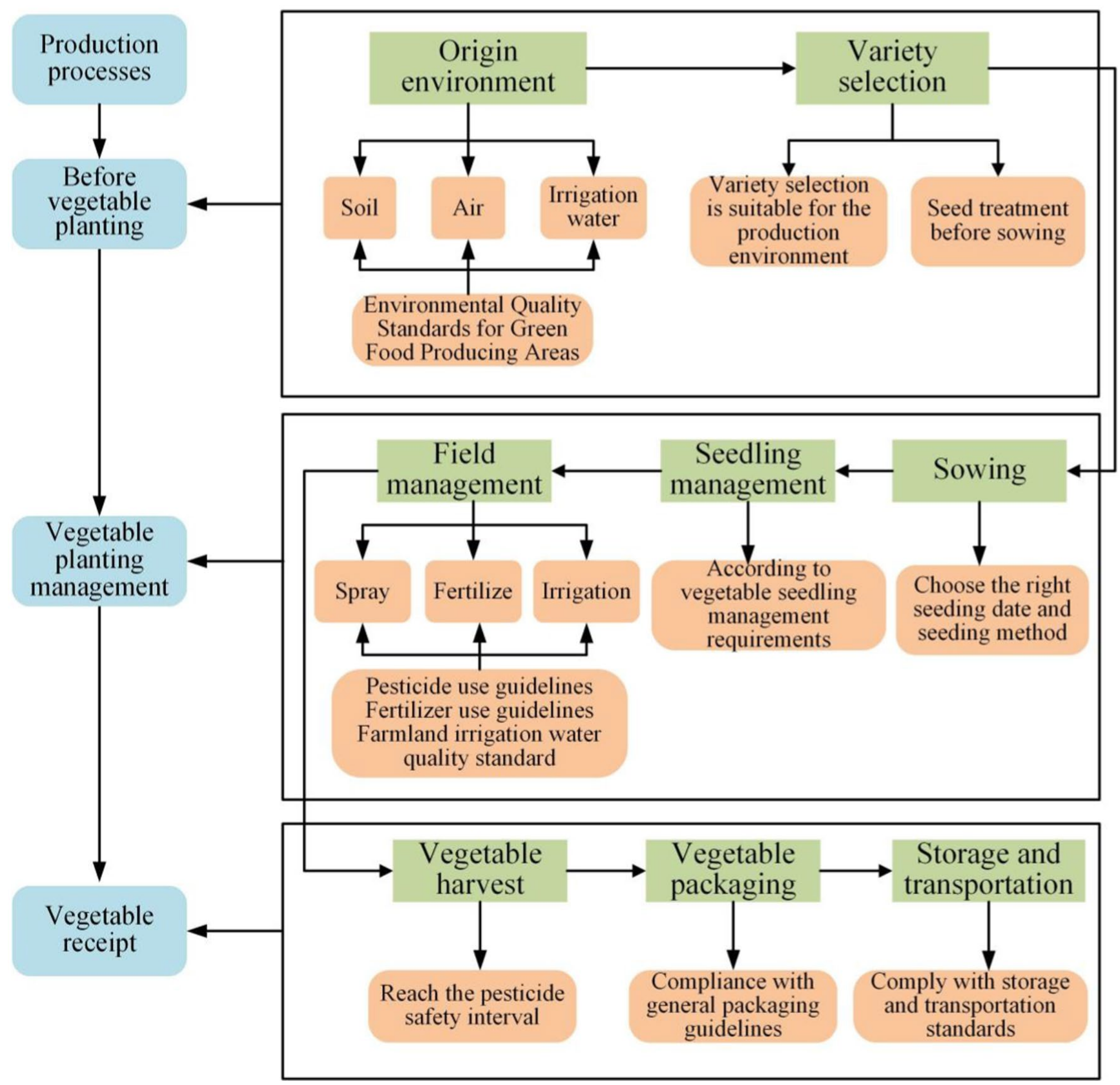

FIGURE 1
Green production practices of vegetables.

individual's attitude toward a particular behavior is positive, the subjective criteria are also positive, and the ability to control is strong. This consequently enhances the individuals' willingness to on take this behavior, increasing their probability to perform the action (Webb et al., 2013; Rezaei et al., 2019b).

Theory of planned behavior is employed to understand a range of behaviors related to water-saving irrigation technology (Zhang F. et al., 2019), green fertilizer technology (Adnan et al., 2019, 2020), pesticide packaging waste disposal (Li et al., 2020a), pesticide use management (Abadi, 2018), integrated pest management (Rahman et al., 2018; Rezaei et al., 2019a), cleaner production techniques (Zhang Y. et al., 2019), as well as farmers' intention and behavior regarding water conservation (Yazdanpanah et al., 2014) and their consumption intention and behavior regarding green food (Zhu et al., 2013). These aforementioned studies have proven the success of TPB in the prediction of behavior. Furthermore, applied research on TPB has employed a variety of methods to estimate the relation between behavior and its determinants regarding agricultural technologies (Abdollahzadeh et al., 2016; Abadi, 2018; Li et al., 2020b). In the current study, we developed a conceptual framework that assumes farmers' adoption of green vegetable production to be a result of householder family and organizational characteristics, as well as the perceptions of green vegetable production, availability of information and the influence of the government and market (Figure 2).

3.1. Householder characteristics

A growing number of studies have identified multiple factors to influence technology adoption, for example, age, education, planting years, and risk. Male farmers have been reported to be more focused on agricultural production, and pay more attention to and are more likely to adopt agricultural technology compared to their female counterparts (Adnan et al., 2017; Liu et al., 2019). There is an evident negative relationship between the education level and age of farmers; the older the farmer, the lower the education level, and the less willing to accept and learn new agricultural technology, which consequently hinders farmers from adopting such technologies (Zhang et al., 2018; Barnes et al., 2019). Moreover, as a farmers' planting years increases, their accumulation of agricultural products is enhanced and they are less likely to shift from traditional production methods and planting habits, which may affect farmers' adoption of agricultural technology (Zhang et al., 2018). Farmers' risk preferences also play a role in agricultural production decisions (Liu and Huang, 2013). For example, due to uncertainties in their effects, whether farmers adopt new technologies largely depends on farmers' own risk preferences (Wang and Watanabe, 2016; Mao et al., 2019). Based on this, we hypothesized that:

> H1. Householder characteristics affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

3.2. Family characteristics

Family characteristics include the number of family members in the labor force, annual vegetable income, and vegetable planting area. Household labor is a significant predictor of farmers' agriculture green production willingness (Li et al., 2020b). However, the research implied that the labor force quantity had no significant negative impacts on farmers' adoption of low-carbon management practices (Liu et al., 2019). The research indicated farm size to have a relatively large impact on the adoption of sustainable practices (Despotović et al., 2019), while the research did not observe any significant relationship between low-carbon management decision practices and farm size (Liu et al., 2019). Therefore, the influences of labor force numbers and farm size on the adoption of agriculture technology practices remain unclear and require empirical testing. Household income is also an important factor in determining the adoption of precision agricultural technologies as it reflects the economic barrier

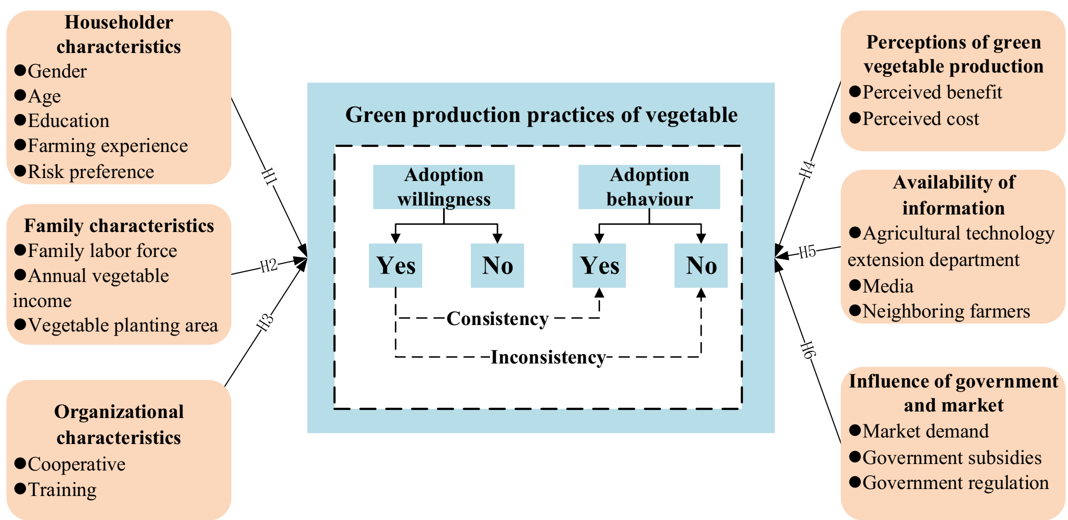

FIGURE 2
Framework of factors affecting farmers' willingness, behavior, and consistency regarding the green production practices adoption of vegetable.

to non-adopters (Barnes et al., 2019). Thus, we made the following hypothesis:

> H2. Family characteristics affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

3.3. Organizational characteristics

Organizational characteristics indicate whether farmers are members of farmer professional cooperatives and whether they participate in training. Farmer professional cooperatives play an important role in the delivery of public agricultural services, providing services such as the purchase of agricultural production materials, and the sale, processing, transportation, and storage of agricultural products, as well as technology and information related to agricultural production and operations (Spielman et al., 2010). Cooperative membership is also reported to exhibit a positive relationship with access to agricultural extension services (Abebaw and Haile, 2013). The research demonstrated that an improvement in knowledge on agriculture technology following training influenced farmers' adoption of agriculture technology (Timprasert et al., 2014). The research indicated training session attendance to have a significant positive influence on farmers' agriculture technology adoption probability (Zhang F. et al., 2019). Based on this, we hypothesized that:

> H3. Organizational characteristics affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

3.4. Perceptions of green vegetable production

Attitudes are defined as the degree of positive or negative assessment of a particular behavior (Despotović et al., 2019). A positive attitude and positively perceived ability of farmers consequently influences their intentions (Adnan et al., 2018). The research identified attitude to have the strongest direct influence on intentions across three social psychological models (Mastrangelo et al., 2014), while the research revealed farmers' decisions to adopt innovation to be based on beliefs and perception (Adnan et al., 2017). By applying the technology acceptance model (TAM), the research demonstrated that farmers' perception was the key barrier regarding the adoption of the technology (Adnan et al., 2019). The research indicated production, income, and costs as the principle factors influencing whether farmers consider cleaner agricultural production techniques (Zhang F. et al., 2019). In the current study, we adopt perceived benefits and perceived costs to measure farmers' perceptions of vegetable green production practices. Therefore, we hypothesized that:

> H4. Perceptions of green vegetable production affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

3.5. Availability of information

Availability of information have been reported to have a positive significant effect on behavior (Yazdanpanah et al., 2014; Adnan et al., 2018, 2019) and the mutual exchange of farmers has been identified as conducive to the diffusion of information of new technologies. In particular, the research revealed that farmers who often exchanging rice planting experiences among themselves were more likely to adopt low-carbon management practices (Liu et al., 2019). Agricultural extension services can aid in the dissemination of information related to the agricultural innovation of potential adopters, consequently enhancing the adoption of innovation (Ogunlana, 2007). Thus, the following hypotheses were established:

> H5. Availability of information affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

3.6. Influence of government and market

The market exerts pressure on the adoption of sustainable technology via customer demand, where future market demand exercises a positive and significant effect on interest (Wensing et al., 2019). The research demonstrated the impact of market incentive to be more effective than government regulation on improving the behavior of pesticide application (Zhao et al., 2018). Governmental regulations, quantified by regulatory implementation strategy, regulatory pressure, and regulatory stakeholder pressure have a positive effect on the adoption of sustainable technology (Fu et al., 2018). Government subsidies are transfer payments that can reduce the cost of adopting new agricultural technologies and have a reported positive relationship between policy subsidies and the adoption of such technologies (Zhang F. et al., 2019). Consequently, the following hypothesis has been derived:

> H6. The influence of the government and market affect farmers' adoption willingness, behavior and consistency toward green vegetable production practices.

4. Materials and methods

4.1. Study area

As a high-consuming city, Beijing have a strong demand for green, high-quality and safe vegetables. In 2019, the *per capita* consumption of vegetables and vegetable products by residents in Beijing was reported as 114.9 kg in 2019, ranking first in the *per capita* consumption of staple foods by Beijing residents. During 2000–2019, the permanent resident population of Beijing increased 13.6 to 21.5 million.

4.2. Survey instrument and data collection

Firstly, the paper constructs a framework of influencing factors affecting green vegetable production practices based on the theory of planned behavior. Secondly, based on the literature analysis and research to obtain the specific influencing factors that may affect the willingness to adopt green vegetable production practices. Finally, the research questionnaire was designed based on the possibility influencing factors obtained. In order to investigate the key factors affecting the consistency of farmers supporting vegetable green production practices, we designed a three-compontent structured questionnaire based on previous literature (Luo et al., 2014; Adnan et al., 2018, 2019; Zhang et al., 2018; Zhao et al., 2018; Zhang F. et al., 2019; Li et al., 2020b). The first component includes the basic farmer, family, and organizational characteristics (age, education, vegetable planting area, annual vegetable income, and cooperatives). The second component focuses on farmers' perceptions and adoption of green vegetable production practices, while the third component evaluates the market and government influences faced by farmers (market demand, government subsidies, and controls on green vegetable production practices). Before the formal questionnaire collection, a preliminary investigation of vegetable farmers in Beijing was conducted. After the questionnaire was collected, the questionnaire was revised and improved to ensure that the farmers clearly understood each question.

The survey was conducted in seven major vegetable production districts (Tongzhou District, Daxing District, Fangshan District, Huairou District, Miyun District, Shunyi District, and Tongzhou District) across Beijing in the northern region of the North China Plain in 2019 (Zhang et al., 2017). To ensure the authenticity and validity of the survey, and based on the approval of the Beijing Municipal Bureau of Agriculture and Rural Affairs, each district selected an exceptional agricultural technology extension worker as the investigator. The investigators were trained on the content of the survey questionnaire prior to the investigation and subsequently conducted one-on-one interviews with farmers. The stratified random sampling was used in field surveys (Hashemi et al., 2012; Zhang F. et al., 2019; Govindharaj et al., 2021). More specifically, villages from each district were selected according to the population characteristics and spatial distribution, and farmers of these villages were then selected via the simple random sampling method. The KMO value, Bartlett's test of sphericity, and Cronbach's coefficient were calculated to determine the validity and reliability of the survey. Farmers' responses are completely anonymous; Ethical standards—such as the farmers' right to withdraw from the survey at any time and the assurance that the data will only be used for scientific research—are clearly stated on the introduction page. Informed consent is explained and confirmed when farmers answer the questionnaire. A total of 452 valid questionnaires were obtained from 105 villages of the seven districts, with a questionnaire effective rate a 92.2%. The samples were evenly distributed and extensive, with a high overall representativeness.

4.3. Empirical model

Farmers' participation in green vegetable production practices is a function of multiple factors and their interactions. The possible collinearity among variables can affect the model estimation results. Therefore, we employ the variance inflation factor (VIF) as the multicollinearity statistic, where smaller VIF values indicate less collinearity between the independent variables and values exceeding 10 denote serious collinearity (He et al., 2016). The results in the current study exhibit VIF values less than 10 (Table 1), demonstrating that the degree of collinearity between the variables is within a reasonable range (Abadi, 2018).

According to the survey results, 79.2% of the household heads are males, indicating males to currently be the principle decision-makers in the production and operation of households. The majority of households engaging in vegetable planting are middle-aged and elderly individuals (30–79 years old, 53.8 average age), within rural households between 51 and 60 years old accounting for the greatest proportion of 41.8%. Farmers' education level is generally low, typically not exceeding junior high school education. Middle school education accounts for the largest proportion of the total sample, reaching 55.3%. Farmers' vegetable planting experience ranges from 2 to 60 years (17.9 years average) and farmers with 21+ years of planting account for the largest proportion of 35.4%. This highlights the extensive and rich experience of farmers in vegetable planting. The majority of households have 2–3 laborers, accounting for 69.5% of the survey sample. The degree of specialization in vegetable production is low, and vegetable farmers account for 40–60% of total household income, which is equal to 24.8% of the total sample. The planting scale varies greatly between farmers, with an average vegetable planting area of 4.8 mu. This indicates that the current rural areas are still dominated by small-scale household production (Table 2).

According to TPB, individual behavior is not only determined by behavioral intentions, but is also restricted by actual control conditions (e.g., personal power, opportunity, and resources). Therefore, adoption willingness and adoption behavior are usually related and can be considered as discrete binary variables to be modeled by probit or logistic frameworks, respectively (Timprasert et al., 2014). However, correlations between the disturbance items of the different models can result in model estimation bias. In order to overcome this, in the current study, we applied the bivariate probit model, which allows correlations between the disturbance terms of different equations, thereby improving efficiency (Li et al., 2021). More specifically, the bivariate probit model analyzes the factors affecting farmers' willingness and behavior to adopt green vegetable production practices as follows:

TABLE 1 The VIF values for individual variables.

Variable	VIF value	Variable	VIF value
Gender	1.07	Training	1.24
Age	1.8	Perceived benefit	1.56
Education	1.31	Perceived cost	1.6
Farming experience	1.74	Agricultural technology extension department	2.55
Risk preference	1.28	Media	2.62
Family labor force	1.22	Neighboring farmers	2.49
Annual vegetable income	1.33	Market demand	1.48
Vegetable planting area	1.38	Government subsidies	1.13
Cooperative	1.23		

TABLE 2 Variable definitions.

Variable	Definition	Mean	S.D.
Householder characteristics			
Gender	1 = male, 0 = female	0.79	0.41
Age	Years	53.83	9.39
Education	1 = primary school and below; 2 = middle school; 3 = high school; 4 = junior college; and 5 = undergraduate and above	2.37	0.81
Farming experience	Years	17.95	11.15
Risk preference	1 = risk aversion; 2 = neutrality; 3 = risk appetite	1.89	0.67
Family characteristics			
Family labor force	Number of family members	2.36	0.95
Annual vegetable income	Percentage of farm income to total income: 1 = 20% and below; 2 = 21–40%; 3 = 41–60%; 4 = 61–80%; 5 = 81%, and above.	3.08	1.41
Vegetable planting area	Mu	4.76	6.13
Organizational characteristics			
Cooperative	1 = farmer is a member of a farmer's cooperative; 0 = otherwise	0.52	0.50
Training	1 = farmer attended agricultural technology training; 0 = otherwise	3.03	1.00
Perceptions of green vegetable production			
Perceived benefit	Green vegetable production increases benefit: 1 = strongly disagree to 5 = strongly agree	4.31	0.73
Perceived cost	Green vegetable production increases costs: 1 = strongly disagree to 5 = strongly agree	4.09	0.88
Availability of information			
Agricultural technology extension department	Influence of agricultural technology extension department: 1 = minimal influence to 5 = great influence	3.66	1.00
Media	Influence of media: 1 = minimal influence to 5 = great influence	3.62	1.03
Neighboring farmers	Influence of neighboring farmers: 1 = minimal influence to 5 = great influence	3.50	1.05
Influence of government and market			
Market demand	Influence of market demand: 1 = minimal influence to 5 = great influence	3.05	0.94
Government subsidies	1 = yes; 0 = no	0.42	0.49
Government regulation	Strictness: 1 = not strict to 5 = very strict	3.60	0.93

$$\begin{cases} Y_w^* = X_w\beta_w + \varepsilon_w \\ Y_b^* = X_b\beta_b + \varepsilon_b \end{cases}, \quad (1)$$

where Y_w^* and Y_b^* represent the unobservable latent variables of farmers' willingness and behavior to adopt green vegetable production practices; X_w and X_b are the factors influencing farmers' willingness and behavior to adopt green vegetable production practices; and β_w and β_b are coefficients to be determined, where the disturbance term (β_w, β_b) obeys a two-dimensional joint normal distribution with an expectation of 0, variance of 1 and correlation coefficient is ρ:

$$\begin{pmatrix} \varepsilon_w \\ \varepsilon_b \end{pmatrix} \sim \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right\}. \quad (2)$$

Observable variables Y_w and Y_b represent farmers' behavior to and willingness to adopt green vegetable production practices and are determined as follows:

$$Y_w = \begin{cases} 1, Y_w^* > 0 \\ 0, Y_w^* \leq 0 \end{cases}, \quad (3)$$

,

$$Y_b = \begin{cases} 1, Y_b^* > 0 \\ 0, Y_b^* \leq 0 \end{cases}, \quad (4)$$

where $Y_w^* > 0$ denotes that farmers are willing to adopt green production practices of vegetable; and $Y_b^* > 0$ denotes that farmers adopt green production practices of vegetable. The bivariate probit model parameters are estimated using the full information maximum likelihood procedure. Assuming that ρ is significant: if $\rho = 0$, β_w and β_b are not related and this model is equivalent to two separate probit models; if $\rho > 0$, the willingness has a positive effect on the adoption behavior; and if $\rho < 0$, the willingness has a hindering effect on the adoption behavior.

5. Results

5.1. Farmers' adoption willingness and behavior of green vegetable production practices

Figure 3 presents the results of farmers' green vegetable production adoption willingness, adoption behavior, and consistency.

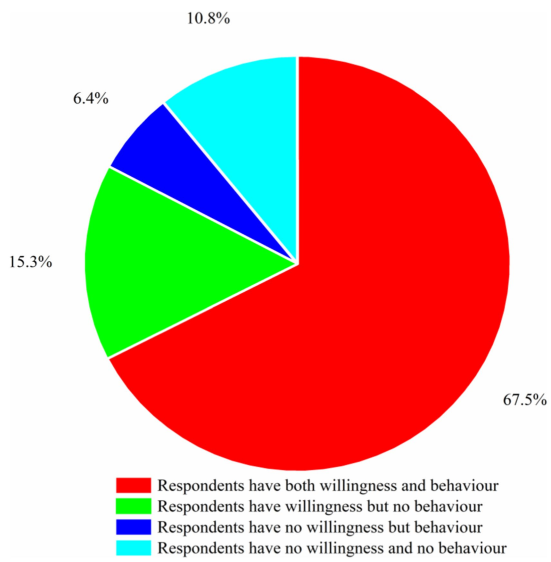

FIGURE 3
Willingness and behavior of farmers to support the development of green vegetable production practices.

Among the 452 surveyed households, there is an evident distinction between the proportion of sample farmers with a willingness to adopt green production practices and those who do not, with the former exceeding the latter by 65.5%. A total of 334 farmers (73.9%) adopt green production practices during the vegetable production process, which is 47.8% higher than those who do not adopt such practices. Furthermore, 67.5% of farmers exhibit the same willingness and behavior to adopt green vegetable production practices, while 15.3% demonstrate distinct trends in willingness and behavior. Thus, the consistency of farmers' willingness and behavior to adopt green vegetable production requires further study.

5.2. Econometric model estimation results

Farmers' adoption willingness and behavior to green vegetable production practices were estimated with Stata (v.15.0, StataCorp) using the bivariate probit model. The bivariate probit model results indicate a reasonably good fit between the model and data, with a Wald chi-square value of 196.57 (significant at the 1% level). Moreover, the value of ρ is 0.272, which is significant at the 5% level. This indicates that the willingness of farmers to adopt green vegetable production practices has a positive impact on the adoption behavior. The results demonstrate the effectiveness of the bivariate probit model developed in this study (Table 3).

TABLE 3 Estimation results of the farmers' willingness and behavior to adopt green vegetable production practices.

Variable	Adoption willingness	Adoption behavior
	Coef.	Coef.
Householder characteristics		
Gender	0.258 (0.229)	−0.173 (0.199)
Age	0.023 (0.013)*	−0.004 (0.010)
Education	0.293 (0.158)*	−0.175 (0.099)*
Farming experience	−0.015 (0.011)	−0.018 (0.008)**
Risk preference	0.109 (0.142)	0.153 (0.132)
Family characteristics		
Family labor force	−0.276 (0.095)***	−0.249 (0.082) ***
Annual vegetable income	−0.235 (0.085)***	−0.237 (0.062) ***
Vegetable planting area	0.102 (0.048)**	0.072 (0.030) ***
Organizational characteristics		
Cooperative	−0.367 (0.187)**	0.544 (0.172) ***
Training	0.231 (0.107)**	0.153 (0.091) *
Perceptions of green vegetable production		
Perceived benefit	0.051 (0.172)	0.255 (0.123) **
Perceived cost	−0.474 (0.145)***	−0.381 (0.112) ***
Availability of information		
Agricultural technology extension department	0.253 (0.147)*	0.036 (0.132)
Media	−0.079 (0.128)	−0.155 (0.118)
Neighboring farmers	−0.065 (0.148)	0.284 (0.114) **
Influence of government and market		
Market demand	0.318 (0.099)***	0.182 (0.101) *
Government subsidies	0.538 (0.191)***	0.498 (0.161) ***
Government regulation	0.339 (0.114)***	0.540 (0.100) ***
Constant	−1.441 (1.234)	−0.857 (0.884)
N	452	
ρ	0.272(0.115)**	
Wald chi²	196.57	
Prob > chi²	0	
Log pseudolikelihood	−307.787	

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively.
Standard errors are in parenthesis.

6. Discussion

6.1. Bivariate probit model regression analysis of the willingness and adoption variables

6.1.1. Householder characteristics

Age is observed to have a significant positive effect on farmers' adoption willingness toward green vegetable production practices, and the value of coefficient is 0.023. This is likely to be attributed to the positive relationship between rural information infrastructure development in Beijing and the opportunities and channels for information acquisition. Thus, a more developed rural information infrastructure results in more farmers receiving information about green vegetable production practices, which increases their understanding of such practices and their willingness to try them. Education also exerts a positive impact on farmers' adoption willingness; the value of coefficient is 0.293. Yet its influence on farmers' adoption behavior toward green vegetable production practices is negative, the value of coefficient is −0.175. This indicates that the higher the education level, the less likely farmers are to adopt green vegetable production practices. A greater educational level increases the ability of farmers to obtain, process, and use information relevant to the adoption of new technologies. However, when farmers are uncertain about the benefits of new agricultural technologies and models, they will be more careful about selecting them. Farming experience has a significant negative influence on farmers' adoption behavior toward green vegetable production practices. This suggests that farmers with many years of planting experience are more reluctant to adopt green vegetable production practices. This may be attributed to the richer vegetable production experience of farmers with longer planting years, who rely on their own experience in the vegetable planting process rather than adopting advanced agricultural production techniques (Zhang et al., 2018).

6.1.2. Family characteristics

Family labor force is observed to have a significant negative effect on farmers' adoption willingness and behavior in supporting green vegetable production practices, and the values of coefficient are −0.276 and −0.249, respectively. The research highlights the important role of the family labor force in determining the adoption of eco-friendly agricultural production as it reflects the human capital barrier to non-adopters (Zhang et al., 2018). Annual vegetable income exerts a significant negative impact on farmers' adoption willingness and behavior toward green vegetable production practices, and the values of coefficient are −0.235 and −0.237, respectively. It shows that farmers with higher annual vegetable incomes are less likely to adopt such practice. Household income is crucial in determining the adoption of precision agricultural technology as it reflects the economic barrier to non-adopters (Barnes et al., 2019). Farmers of higher farm incomes have been reported to be less likely to face risks from the adoption of agriculture technology (Zhang F. et al., 2019). Vegetable planting area is observed to have a significant effect (at the 5% level) on farmers' adoption willingness and behavior toward green vegetable production practices, the values of coefficient are 0.102 and 0.072, respectively. The larger the vegetable planting scale, the greater the benefits of scale, the lower the cost per unit area of vegetable planting, and the greater the possibility of adopting green production practices (Li et al., 2020a,b).

6.1.3. Organizational characteristics

Our results identify cooperatives as a key factor in farmers' adoption behavior toward green vegetable production practices, the value of coefficient is 0.554. Cooperatives can provide farmers with support and services in green vegetable production technology, market information, sales channels, etc., and can help reduce the risk of green vegetable production and planting, thus increasing farmers' initiative to adopt green vegetable production. The research suggested the role of cooperatives in accelerating the adoption of agricultural technologies by smallholder farmers in Ethiopia (Abebaw and Haile, 2013). Furthermore, farmers who are more integrated with farmers' groups and are in contact with non-government organizations are more likely to adopt such technologies. Training exhibits a significant positive effect on farmers' adoption willingness and behavior toward green vegetable production practices, and the values of coefficient are 0.231 and 0.153, respectively. More specifically, farmers who receive training on agricultural technology are more likely to adopt vegetable green production practices. Previous research has demonstrated training to be a significant determinant of technology adoption in agriculture (Mwalupaso et al., 2019), with farmers who have received technical training identified as being more prone to adopt low-carbon management practices (Liu et al., 2019).

6.1.4. Perceptions of green vegetable production

The correlation between perceived benefit and farmers' adoption behavior toward green vegetable production practices is positive and statistically significant at the 5% level, the value of coefficient is 0.255. This indicates that farmers who recognize that green vegetable production practices can increase income and protect the environment are more likely to participate in green vegetable production. The greater the concerns of farmers about agro-products quality and environmental issues, the stronger their willingness to adopt eco-friendly agricultural production (Zhang et al., 2018). Furthermore, the research revealed quality and environmental improvements to have a positive effect on farmers' long-term adoption intentions of cleaner production technology (Zhang Y. et al., 2019). Perceived cost has a significant negative impact on farmers' adoption willingness and behavior toward green vegetable production practices, and the values of coefficient are −0.474 and −0.381, respectively. Farmers first aim to rationally and economically maximize their interests in agricultural production. Agricultural product prices and production costs have an important impact on farmers' production decisions and behavior. The diffusion of sustainable technology can accelerate following the reduction in agricultural profit via declining output prices, resulting in many farmers facing difficulties in buying external inputs. The research demonstrated lower pest management costs to have a significant positive effect on the adoption of integrated pest management (Timprasert et al., 2014).

6.1.5. Availability of information

Agricultural technology extension services are observed to exert a positive impact on farmers' willingness to adopt green vegetable production practices; the value of coefficient is 0.253. Previous work reveals that access to extension services increases the likelihood of adopting improved maize varieties (Khonje et al., 2015). Moreover, the research indicates that access to extension support is the major influencing factor of farmer's adoption of integrated pest management practices (Timprasert et al., 2014). Our results demonstrate the variable neighboring farmers to have a significant positive impact on the farmers' behavior of green vegetable production practices. The demonstration effect of neighboring friends in the surrounding villages will encourage farmers to participate in green vegetable production practices; the value of coefficient is 0.284. The mutual exchange of farmers is conducive to the diffusion of information related to new technologies (Liu et al., 2019). Monitoring and imitating the choice of others to adopt a different technology has an important influence on the dissemination of modern technologies between smallholders in developing countries (Adenle et al., 2019). The research demonstrated the positive influence of communication through diverse information channels on farmers' intentions to convert from conventional to organic farming (Zeweld et al., 2017).

6.1.6. Influence of government and market

Market demand has a significant effect on farmers' adoption willingness and behavior toward green vegetable production practices at the 1% significance level, and the values of coefficient are 0.318 and

0.182, respectively. This indicates the important influence of market demand on farmers' adoption of green vegetable production practices. The research demonstrated that future market demand exerts a significant positive effect on farmers' interests in novel practices that protect the bioeconomy (Wensing et al., 2019). Government subsidies are observed to have a significant positive effect (at the 1% level) on farmers' adoption willingness and behavior toward green vegetable production practices, and the values of coefficient are 0.538 and 0.498, respectively. This implies that farmers obtaining government subsidies are more likely to adopt new agricultural technologies compared to those with no government subsidies. The research suggested that the lack of agricultural clean production subsidies paid directly to most farmers slows down the adoption of agricultural clean production (Luo et al., 2014). The government should provide farmers with incentives for the application of cleaner production technologies (Zhang Y. et al., 2019). Government regulation has a significant positive effect on farmers' adoption willingness and behavior toward green vegetable production practices at the 1% significance level, and the values of coefficient are 0.339 and 0.540, respectively. Government regulation can assist in the construction of adequate market norms, compresses the adverse selection spaces, and allow a price premium to farmers who focus on the quality and safety of agricultural products (Zhao et al., 2018; Piñeiro et al., 2020).

6.2. How to motivate farmers to adopt supportive actions

The survey results indicate inconsistencies between the words and actions of 21.7% of farmers, of which 15.3% of farmers are willing to adopt green vegetable production practices yet have not taken any action. More specifically, the gap between words and actions is generally a result of farmers who are willing to adopt the new practices but have not demonstrated the behavior. In the actual development of green vegetable production practices, the policy focus of the agricultural government sector should be on how to promote this part of the farmers to adopt practical behavior. Therefore, in the current study, we select the surveyed farmers who demonstrated inconsistencies between willingness and behavior for further analysis. The factors affecting the consistency of farmers supporting green vegetable production practices were evaluated using the binary logistic model via Stata15.0 (Table 4). The binary logistic model exhibited a good fit with the data, with log likelihood and LR chi2 values of −139.911 and 77.83, respectively, at the 1% significance level.

Table 4 reveals that farmers are more likely to exhibit consistency if they join a cooperative; if there is an enhanced exchange between neighbors about green production practices; and if the government strengthens the green vegetable production supervision of farmers. Cooperatives are observed to exert the greatest contribution in narrowing the gap between words and actions; the value of coefficient is 1.666. The average marginal effect indicates that compared with non-cooperative farmers, the consistency of the willingness and behavior of cooperative members increases by 19.7%. This may be attributed to the important information platform provided by cooperatives to farmers. This allows farmers to obtain a wider information network, thus improving farmers' understanding of green vegetable production practices and encouraging their adoption (Abebaw and Haile, 2013; Barnes et al., 2019). Neighboring farmers

TABLE 4 Estimation results of the consistency of farmers supporting green vegetable production practices.

Variable	Consistency	
	Coefficient	Marginal effects
Householder characteristics		
Gender	−0.357(0.432)	−0.042(0.051)
Age	0.000(0.022)	0.000(0.003)
Education	−0.148(0.244)	−0.017(0.029)
Farming experience	−0.019(0.018)	−0.002(0.002)
Risk preference	−0.061(0.273)	−0.007(0.032)
Family characteristics		
Family labor force	−0.374(0.180) **	−0.044(0.021) **
Annual vegetable income	−0.221(0.124) *	−0.026(0.014) *
Vegetable planting area	0.070(0.053)	0.008(0.006)
Organizational characteristics		
Cooperative	1.666(0.373) ***	0.197(0.041) ***
Training	−0.080(0.171)	−0.009(0.020)
Perceptions of green vegetable production		
Perceived benefit	0.200(0.266)	0.024(0.031)
Perceived cost	−0.208(0.249)	−0.025(0.029)
Availability of information		
Agricultural technology extension department	−0.233(0.227)	−0.028(0.027)
Media	−0.465(0.234) **	−0.055(0.027) **
Neighboring farmers	0.887(0.233) ***	0.105(0.026) ***
Influence of government and market		
Market demand	0.064(0.202)	0.008(0.024)
Government subsidies	0.306(0.323)	0.036(0.038)
Government regulation	0.830(0.204) ***	0.098(0.022) ***
Constant	−0.212(1.989)	—
N	374	
Pseudo R^2	0.218	
LR chi^2	77.83	
Prob > chi^2	0	
Log likelihood	−139.911	

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively.
Standard errors are in parenthesis.
Coefficients in Marginal Effects column represent the average marginal effects.

positively affect the consistency of farmers supporting green production practices of vegetables, with an impact coefficient and marginal effect of 0.887 and 0.105, respectively. Moreover, the contribution of neighboring farmers come second to cooperatives in reducing the gap between words and actions, reaching 10.5%. As a dominant rural social group, the mutual influence among farmers cannot be neglected, with neighbors exerting a great influence on each other, particularly for the adoption of new technologies (Liu et al., 2019). The intensity of government supervision has a significant positive impact on the consistency of farmers supporting green vegetable production practices. This indicates that the consistency of farmers' green vegetable production behavior willingness and behavior increases significantly with the government's supervision of green vegetable production. The research demonstrated input controls to have a significant positive influence on farmers' willingness to adopt eco-friendly agricultural production (Zhang et al., 2018).

Annual vegetable income is observed to exert a significant negative effect on the consistency of farmers supporting green vegetable production practices, the value of coefficient is −0.221. Farmers with a high proportion of vegetable income are more dependent on agricultural income and are more concern with the effects of new technologies. In particular, farmers with a high proportion of agricultural income are more cautious in adopting new technologies with unclear economic benefits (Barnes et al., 2019; Zhang Y. et al., 2019). Family labor has a significant negative effect on the consistency of farmers supporting green vegetable production practices, the value of coefficient is −0.374; as the family labor force increases, the probability of consistency between their words and actions decreases by 4.4%.

7. Conclusion and policy implications

7.1. Conclusion

The practice of green vegetable production is conducive to the health of consumers, producers, and the environment. It is also highly efficient for operators and promotes the sustainable development of vegetables. Investigating the decision-making behavior of farmers for green vegetable production practices can enhance the effectiveness of green vegetable practices. This study constructs a framework of factors affecting farmers' decision-making behaviors to green vegetable production practices. More specifically, we analyze the willingness and behavior of 452 farmers in Beijing, using bivariate probit and logistic models to explore the dominant influencing factors of farmers' adoption willingness, behavior, and consistency regarding green production practices of vegetable. These findings and conclusions can be generalized to the adoption of green vegetable production practices by rural farmers in similar first-tier cities such as Shanghai and Guangzhou. There are some potential limitations in extrapolating these findings to broader populations. First-tier city farmers and second-tier city farmers have different, for example, the area of arable land, income, consumer demand for green vegetables, and government policies on green vegetables are very different. Second-tier and even third-tier cities can be investigated as comparative studies in a follow-up study.

The following key conclusions were determined:

1. The majority of farmers are willing to adopt green vegetable production practices (82.7%). This greatly exceeds the proportion of farmers unwilling to adopt such practices. Moreover, the proportion of farmers adopting green vegetable production practices is 47.8% higher than that of non-practicing farmers, with 18.5% of these farmers exhibiting inconsistencies between their words and actions.
2. The willingness to adopt green vegetable production practices promotes the adoption behavior, yet the influencing factors of the adoption willingness and behavior are distinct. Age, farming experience, perceived benefits, the agricultural technology extension department, and neighboring behavior are the dominant factors resulting in variations between the adoption willingness and behavior. Vegetable planting area, training, market demand, government subsidies, and government regulation have a positive influence on farmer's adoption willingness and behavior for supporting green vegetable production practices, while family labor force, annual vegetable income, and perceived cost exert negative effects.
3. Results revealed that the larger the vegetable planting area, the higher the probability of consistency between the willingness and behavior of farmers, while family labor force and annual vegetable income have a negative impact on consistency. Cooperative membership exerts a significant positive impact on consistency, with the probability of farmers' words and actions being consistent increasing by 19.7% upon joining a cooperative. The stronger the influence of the exemplary norms of neighboring behavior, the higher the consistency between willingness and behavior. The media and strict government control exert a negative and significant positive effect, respectively, on the consistency between willingness and behavior.

7.2. Policy implications

Based on our conclusions, we propose several initiatives in order to enhance farmers' willingness and behavior to adopt green production practices of vegetable; and effectively promote the transformation of vegetable green production. These initiatives are described in the following.

1. Promote and advocate the concept and model of green vegetable production practices to farmers through media (e.g., TV and publicity boards) to further deepen farmers' basic understanding of green vegetable production practices.
2. Develop the channels used to obtain information on green vegetable production practices such that farmers can efficiently obtain new technical information; and support the exchanges and interactions between farmers, relatives, friends, neighbors and villagers so as to promote the sharing and learning of green production experiences among farmers, particularly through social networks.
3. Cooperatives has a positive and significant impact on farmers' adoption behavior toward green vegetable production practices. Enhance the role of rural cooperatives in the promotion and innovation of green technology for vegetables; employ cooperatives to regulate farmers' scattered planting; and strengthen the role of cooperatives in production, sales, market information, brand creation, personnel training, and inputs (e.g., pesticides, seeds, and fertilizers) in management.
4. Government regulation are observed to have a significant positive effect on farmers' adoption willingness and behavior toward green vegetable production practices. Intensify the supervision of the vegetable green production practices process and standardize the use of input products. The government should have an active role in the process of ensuring vegetable quality and safety supervision and inspection, strengthening

the investigation, collection, and special rectification of banned pesticides and counterfeit pesticides, and ensure the safety and reliability of vegetable inputs.

5. Government subsidies are observed to have a significant positive effect on farmers' adoption willingness and behavior toward green vegetable production practices. Improve the policy environment for farmers' green production of vegetables; increase financial subsidies for the promotion of green vegetable production technologies and high-quality varieties; continuously reduce farmers' green production costs through policy incentives; and guide and standardize farmers' green production practices of vegetable.

In this study, we focus specifically on influencing factors of farmers' willingness, behavior, and consistency in adopting green vegetable production practices for food security. It is necessary to deepen the research and comparative analysis of the production of other green agricultural production practices so as to reveal the differences in the influence factors of the adoption of the production of different green agricultural production practices. The data of this study are mainly based on the data of farmers in Beijing, and it is necessary to deepen the research and comparative analysis in other regions to reveal the differences in different regions. Factors influencing farmers' adoption of different types and number of green vegetable production technology are also important for future studies.

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

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

BL: Writing – original draft. ML: Writing – review & editing. JY: Supervision, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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.

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