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# How Does Risk Management Improve Farmers' Green Production Level? Organic Fertilizer as an Example

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With increases in the frequency of various natural and social risks, effectively coping with uncertainty is necessary for the sustainable development of individuals and the society, particularly smallholder farmers with vulnerable livelihoods. Using survey data from farmers in China, we constructed a risk management capability index system for farmers at the individual, collective, and government levels to empirically analyze the impact of risk management on green production behavior through the Heckman model for two-stage sample selection. The results showed that risk management is a key factor affecting green production behavior. Membership status (membership in an organization), government subsidies, and income levels significantly promote green production levels. Moreover, risk management not only directly affects the green production level but also promotes green production behavior by expanding the scale of operation, improving the sense of responsibility, and enhancing the behavioral responsibility. Additionally, the mediating effect of these factors on farmers in the low-risk perception group was more obvious. Therefore, the risk management level of farmers should be improved at the individual, collective, and government levels to promote sustainable agriculture.

**Keywords: risk management, green production behavior, adopt decision, degree of adoption, environmental sustainability**

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## 1 INTRODUCTION

Positive outcomes for both the economy and environment are important goals of sustainable development (Isik et al., 2021) and have been widely studied. However, diverse human activities over a long time period have damaged ecosystems and led to environmental pollution and climate change, and they have caused a "metabolic fracture" in agriculture (Rehman et al., 2021). Therefore, approaches for strengthening the protection of the agricultural ecological environment are urgently needed to achieve sustainable development. Planting is the foundation of agricultural production, and environmental protection is the key aspect for ensuring the quality, safety, and environmental sustainability of agricultural products (Wan et al., 2018). China is the most populous country worldwide, and excessive input of chemical fertilizers has greatly contributed to the agricultural growth in China, which is needed to sustain the population. However, this practice has also caused various problems, such as soil acidification, environmental pollution, and quality deterioration of agricultural products (Liu et al., 2020). In the "No. 1 Central Document of China" released in 2021, the central government stressed that rural ecological revitalization and the value of agriculture in product supply and ecological conservation should be comprehensively promoted. In this context, the green production technology represented by organic fertilizers has become important in rural revitalization and for effectively promoting environmental sustainability, particularly by replacing chemical fertilizers with organic fertilizers for growing fruits, vegetables, and tea. Green tea production is a key area for promoting the environmental sustainability of agriculture at the micro level. High fertilizer consumption increases short- and long-term carbon dioxide emissions (Rehman et al., 2022). Therefore, reducing the amount of fertilizer input through factor substitution may promote environmental sustainability at the micro level.

Risk is a ubiquitous feature of the society, particularly with the intensification of global warming, and various extreme climatic conditions have aggravated the risks associated with agricultural production. In China, small farmers are the mainstay of agricultural production, and their livelihood is relatively vulnerable because of their small production scale and low-income levels (ILs). Coupled with the general lack of risk regulation measures in the society and imperfect prevention mechanism, small farmers show low-risk management capabilities (Harrison et al., 2005; Yesuf and Bluffstone, 2009), leading to multiple and frequent agricultural risks. Organic fertilizer technology has a high input cost, long investment return period, and high effect uncertainty (Xu and Zhang, 2018). To avoid risks, farmers employ traditional agricultural technologies rather than adopting the green production technology because of certain risks (despite higher returns) (Anderson, 2003). Small farmers are critical to the green transformation of agriculture, and improving their risk management capabilities can facilitate the efficient transition of small farmers to modern agriculture.

Most farmers in China have a strong risk aversion. Additionally, because of the general lack of risk regulation measures in the society and lack of effective prevention mechanisms, the livelihood of farmers is vulnerable (Harrison et al., 2005). Farmers have limited resources and often adopt inefficient and passive risk management strategies rather than confront complex agricultural risks (Jin et al., 2015; Baffoe and Matsuda, 2018), demonstrating a lack of risk management ability (ISDR, 2004). The key to achieving sustainable livelihoods involves efforts to build a risk prevention and management system (Bertola et al., 2005). Higher income levels (ILs) can enhance risk management capabilities, thereby promoting green production behaviors (GPBs) by farmers (Fang et al., 2014). Furthermore, by reducing the dependence of outputs on inputs, membership status (MS) helps to optimize the factor input structure and improve risk management capabilities (Deng et al., 2010). As an important institutional variable, government subsidies (GS) partially fund input costs, reduce the uncertainty of technology adoption, and promote green production by farmers. Although agricultural insurance is also a risk-management tool, the function of agricultural insurance in China often deviates from its original policy goals, reducing the effectiveness of risk management for farmers (Liu and Zhong, 2019). Therefore, farmers must strengthen their risk management practices through informal mechanisms at the individual level and collective organizations, as well as formal mechanisms such as by relying on the government.

In recent years, research on sustainable development, such as green production and reducing carbon emissions, has increased. There is a long-term positive correlation between crop yield and carbon emissions; however, the crop area is significantly negatively correlated with carbon emissions (Rehman et al., 2020). Previous studies have also focused on the factors influencing farmers' green production at multiple levels, including objective capital endowments. These endowments included MS and IL capital endowment characteristics (Liu et al., 2019; Li et al., 2022), risk appetite and risk perception (RP) (Gong et al., 2016; Ahmad et al., 2021), emotions and attitudes related to the environment (Farani et al., 2021), and technology cognition (Chen et al., 2013), which greatly impact farmers' GPB. Additionally, the characteristics of property rights, social norms, and GS (Xu et al., 2014; Peng et al., 2021; Xie and Huang, 2021) are important external variables affecting the willingness of farmers to adopt green production technologies.

Research on the impact of risk factors, such as risk cognition and risk preference, on farmers' GPB has recently been conducted. However, previous studies have mostly focused on the impact of risk factors on farmers' GPB based on subjective dimensions such as RP and risk preference. Additionally, the impact of risk management (RM) on GPB from the perspective of capabilities remains unclear. Second, indicators of farmers' risk management capabilities and the impact mechanism of risk management on GPB have not been determined. Based on the survey data of 818 farmers, we constructed an indicator system of farmers' risk management at the individual, collective, and government levels and used the Heckman two-stage model to empirically test the impact of risk management on the farmers' GPB. These results can be used to propose countermeasures that can improve economic and environmental development, as well as restore agricultural production and reduce the vulnerability of farmers to natural and social risks.

## 1.1 Theoretical Background and Hypotheses

### 1.1.1 Direct Impact of Risk Management on the Green Production Behavior of Farmers

Agriculture is typically a weak industry. Compared with traditional agriculture, the green production technology exhibits some risks, such as high cost, delayed effects, and intertemporal benefits. Chinese agriculture is dominated by small-scale farmers because of limited resource endowment and lack of risk regulation measures and risk prevention mechanisms. The risk management capabilities of small farmers are mostly limited as their livelihood is vulnerable to diverse and complex agricultural risks (Cao et al., 2016). Risk or uncertainty can cause decisions on green production to deviate from those predicted by the expected utility theory. Insufficient risk management capabilities and a lack of necessary risk strategies make farmers extremely vulnerable to welfare losses (Van den Berg, 2010).

Risk management refers to the strategy used by farmers to reduce, avoid, and smooth natural and social risks and uncertainties through various measures or means. Improving risk management can facilitate rational allocation of existing resources to achieve an effective balance between benefits and risks (Krysiak, 2009), and it is an important prerequisite for farmers to achieve sustainable livelihoods. Most farmers have a strong tendency to avoid risks. Coupled with the general lack of risk regulation measures in the society and imperfect risk prevention mechanism, it is difficult to overcome livelihood risks at the individual farmer level (Holzmann and Jorgensen, 2000). Therefore, improving farmers' risk management capabilities requires efforts from farmers themselves and at the collective and government levels. Therefore, we explored the impact of farmers' risk management on their GPBs at three levels: the IL of farmers at the individual level, membership at the collective level, and GS at the government level. IL is among the main means and the most direct and critical component of household risk management (Achiba, 2018).

Farmers' IL determines their willingness to engage in green production and factor input behavior at each stage (Hayati et al., 2009). A higher IL improves living conditions and decreases income uncertainty (Kuang et al., 2020), and it increases the willingness of farmers to take risks such as purchasing green production materials. Second, MS at the collective level is an important factor affecting farmers' risk management. Through internal constraints, benefit distribution, and risk compensation mechanisms, cooperatives can reduce farmers' output dependence on factor inputs, improve risk awareness and risk management and control, help avoid and smooth agricultural production risks, and promote green production (Shah et al., 2017; Achiba, 2018). Finally, by promoting relevant technologies and establishing a subsidy system, the government has effectively alleviated information asymmetry, realized the dispersion and deep coverage of agricultural production risks, and increased farmers' awareness of green production through economic incentives (Zhao et al., 2019; Li et al., 2021). Thus, a strong level of risk management can improve the livelihood adaptability of farmers (Jezeer et al., 2019; Kuang et al.,2020) and lead to green transformation of agriculture by optimizing the allocation of household resources. Based on the aforementioned analysis, the following assumption was made.

H0. RM can promote the GPB of farmers, which is reflected in the IL, GS, and MS to promote farmers' GPB.

### 1.1.2 Indirect Impact of Risk Management on GPB of Farmers

Risk management can not only directly affect farmers' green production levels but also promote GPB by enabling expansion of the scale of operation, enhancing the sense of responsibility (SR), and improving behavioral responsibility. Green production technology requires large investments and shows a long investment return period. In addition, the current high-quality and high-price mechanism for green agricultural production is underdeveloped, and farmers face high market and natural risks. During agricultural production activities associated with natural, technological, and market risks, farmers with different levels of risk management have different preferences for gains and losses (Arbuckle et al., 2013; Van Winsen et al., 2016). Farmers with a stronger risk management ability show lower vulnerability. Farmers can expand their operation scale based on the expected development of the agricultural industry to benefit from the scale effect of the green production technology. Second, according to Maslow's hierarchy of needs theory, higher level motivational factors are pursued only after the most basic needs are satisfied. For farmers with a higher level of risk management, as their basic material needs are effectively met, they can consider higher level agricultural environmental protection and other issues (Zhao et al., 2018). A strong risk management ability can enhance ecological and social responsibilities and tend to have and maintain a healthy lifestyle to maintain food safety and the environment (Sulemana and James, 2014). Finally, farmers with higher risk management capabilities have strong behavioral responsibility, which can impact the GPB of surrounding farmers when information diffuses and is shared (Achiba, 2018), leading to the promotion of technology use. Based on the aforementioned analysis, the following assumption was made.

H1. RM can promote farmers' GPB by expanding their business scale (BS) and enhancing their SR and behavioral responsibility (RB) (**Figure 1**).

## 2 MATERIALS AND METHODS

### 2.1 Data Sources and Sample Selection

The data were obtained from the research group's survey of farmers in Sichuan, Shaanxi, Zhejiang, and Anhui provinces in China, which was conducted from July to August 2018. These four provinces are important tea-producing areas in China, have similar climates, and have formed their own tea geographical indication brands, which are important contributors to increases in local farmers' income and local economic development. Shaanxi and Sichuan are in the Qinba Mountains, which are less developed areas in the west. Zhejiang and Anhui are in the Huangshan Mountains, which are more developed areas in the east. Analysis of the aforementioned four provinces can improve the understanding of Chinese tea production and enable comparative analysis of western and eastern tea areas.

This research was conducted using a combination of stratified and random sampling. First, eight sample counties (districts) were selected according to the popularity and distribution of tea; second, according to the economic development level of each region, three sample townships were selected, and two to three villages were randomly selected in each township. Finally, 15–25 farmers in each village were randomly selected for analysis. To ensure the validity of the data, farmers who were mainly engaged in or familiar with tea production were selected as respondents. We mainly evaluated the GPB, personal characteristics of farmers, family characteristics, risk management, external environment, and other characteristics. Finally, 818 valid questionnaires were obtained, reaching an effective rate exceeding 98%. The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of the College of Economics and Management,

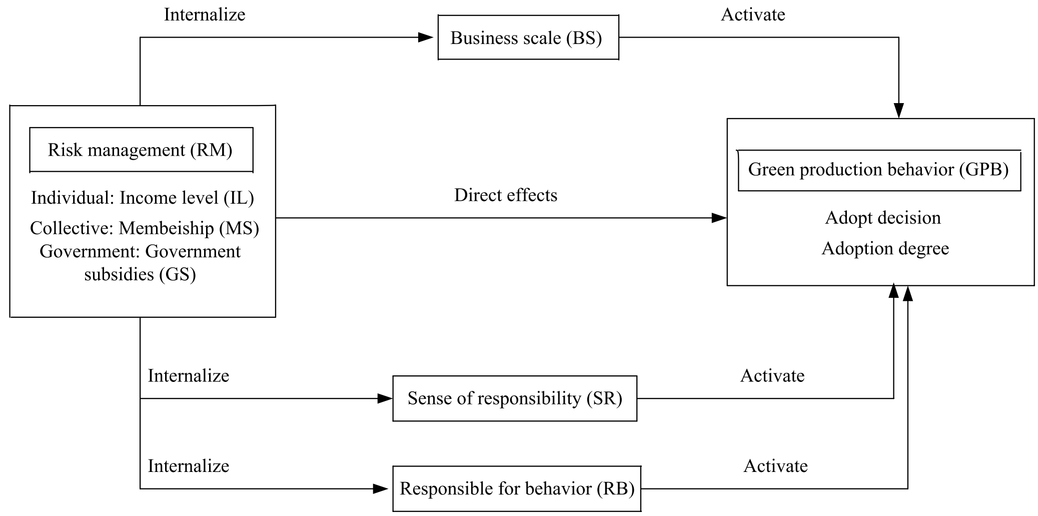


**FIGURE 1 |** Theoretical framework.

Northwest A&F University (Ref. 212/2010). The cover page of the questionnaire clearly described the objective of the survey and confidentiality of the responses. If respondents agreed, they were requested to participate in the survey. Respondents were not granted any incentives.

## 2.2 Benchmark Model

Farmers' GPB includes two stages: whether to adopt green production technology and the degree of adoption. The degree of adoption can only be observed after farmers adopt these technologies. Therefore, there is sample selection bias in the farmers' GPB. The Heckman model can effectively solve this problem. Therefore, the following Heckman model was constructed:

Stage 1: the probit model was used to estimate the variable parameters affecting the decision-making of green production for all farmers evaluated. The model is expressed as follows:

$$P(y = 1) = \Phi\left(\gamma_0 + \sum_{i=1}^{j} \gamma_i X_i\right), \tag{1}$$

where $y$ represents whether the farmer is involved in GPB; $P(y = 1)$ represents the probability that the farmer adopts green production technology, given the independent variable $X$; $\Phi(\cdot)$ represents the standard normal cumulative distribution function; $\gamma_0$ is a constant term; $j$ is the number of independent variables; $X_i$ is the $i$th independent variable affecting whether farmers adopt green production technology, including RM and control variables; and $\gamma_i$ is the parameter estimated for the independent variable $X_i$.

Stage 2: using the degree of green production as the explained variable, based on the sample of farming households adopting green production technology, parameters for the green production technology adoption degree are estimated using OLS. At this stage, $\lambda$ (inverse Mills ratio) must be calculated to avoid sample selection bias caused by OLS estimations. The formula is as follows:

$$\lambda = \frac{\varphi\left(\gamma_0 + \sum_{i=1}^{j} \gamma_i X_i\right)}{\Phi\left(\gamma_0 + \sum_{i=1}^{j} \gamma_i X_i\right)}. \tag{2}$$

$\varphi(\cdot)$ and $\Phi(\cdot)$ represent the density functions of the standard normal distribution and its corresponding cumulative distribution function, respectively. By introducing $\lambda$ into the second-stage equation, the following equation is obtained:

$$A = \omega_0 + \sum_{i=1}^{k} \omega_i Z_i + \beta\lambda + \varepsilon, \tag{3}$$

where A represents the degree of GPB, $\omega_0$ is a constant term, k is the number of independent variables, $Z_i$ represents the $i$th independent variable affecting the degree of GPB of farmers, $\omega_i$ is the corresponding parameter to be estimated, and $\varepsilon$ is a random error term.

Moreover, we used the Sobel and bootstrap tests to test the impact of risk management on adoption of the green production technology by farmers. In the Sobel test, if the z value is greater than the critical z value based on the standard normal distribution (z = estimated value of the mediating effect/the standard error of the estimated value), there is a mediating effect; otherwise, there is no mediating effect. The bootstrap test was mainly used to obtain the estimated value of the coefficient product of the corresponding sampling by sampling N times with replacement, and the estimated value was used to construct a 95% confidence interval. If the confidence interval did not contain zero, the mediating effect was considered significant (Wen and Ye, 2014).

## 2.3 Variable Measurement

### 2.3.1 GPB

Organic fertilizer technology was evaluated as a measure of farmers' GPB, especially because the Ministry of Agriculture of

**TABLE 1 |** Variable description and descriptive statistics.

| Variable | Symbol | Definition and assignment | Mean | Std. dev |
|---|---|---|---|---|
| Green production behavior | GPB | Whether to use organic fertilizer: Yes = 1; No = 0 | 0.353 | 0.478 |
| | | Percentage of organic fertilizer application per unit area (%) | 0.167 | 0.278 |
| Government subsidies | GS | Yes = 1; No = 0 | 0.256 | 0.437 |
| Membership | MB | Yes = 1; No = 0 | 0.123 | 0.329 |
| Income level | IL | Per capita annual household income/(RMB 10,000/person) | 2.461 | 22.759 |
| Business scale | BS | Business scale/mu | 8.815 | 42.637 |
| Sense of responsibility | SR | Concerned about the safety risks of tea caused by excessive application of chemical fertilizers: 1–5 | 3.462 | 1.001 |
| Responsible for behavior | RB | Whether to persuade others to adopt green production technology: Yes = 1; No = 0 | 0.445 | 0.497 |
| Age | AG | Household head age/year | 58.206 | 10.224 |
| Educational level | EL | Education level of the head of household/year | 6.116 | 3.512 |
| Altitude | AL | Altitude/m | 434.196 | 263.170 |
| Family type | FT | Whether the family is purely farming: Yes = 1; No = 0 | 0.179 | 0.384 |
| Experience capital | EC | Experience capital/Year | 24.339 | 12.587 |
| Risk perception | RP | The proportion of yield reduction that may result from the reduction of fertilizer application: 1–5 | 4.337 | 1.606 |
| Domestic worker | DW | Are there employees in the fertilization process: Yes = 1; No = 0 | 0.047 | 0.213 |
| Organic fertilizer source | OS | Is there a source of organic fertilizer at home: Yes = 1; No = 0 | 0.142 | 0.349 |
| Neighborhood effect | NE | Whether the surrounding farmers have green production: 1–5 | 3.298 | 1.125 |
| Community outreach | CP | Does the community publicize green production technology: Yes = 1; No = 0 | 0.069 | 0.255 |
| Shaanxi | SX | Yes = 1; No = 0 | 0.355 | 0.479 |
| Sichuan | SC | Yes = 1; No = 0 | 0.253 | 0.435 |
| Anhui | AH | Yes = 1; No = 0 | 0.238 | 0.426 |

China has widely promoted the replacement of chemical fertilizers with organic fertilizers for fruits, vegetables, and tea since 2017. Organic fertilizer technology optimizes the supply structure of agricultural products and ecological environment, which has become a key path to achieving environmental sustainability development at the micro level. Additionally, the application of organic fertilizers to tea is an inevitable path to maintaining a stable Chinese strategic position as one of the largest tea exporters in world trade. Behaviors related to organic fertilizer application involve two stages: application decision and application intensity. The application decision is a 0–1 variable, whereas the application intensity is measured as the proportion of organic fertilizer application per unit area.

### 2.3.2 Risk Management

Most farmers in China have a strong tendency to avoid risks, coupled with the general lack of risk regulation measures in the society and imperfect prevention mechanisms. Relying on informal mechanisms such as individuals, as well as collective organizations, and formal mechanisms is important for farmers to construct and improve risk management and control. According to Gao and Lu (2021) and Zhu and Lu (2018), the IL at the individual level, MS at the collective level, and GS systems at the government level are used to construct a risk management indicator system for farmers. The IL was measured as the per capita income level of the family, and MS and GS were used as binary variables. The GS in this study mainly refers to the organic fertilizer subsidy. In the actual investigation, it was found that the GS for organic fertilizers for tea farmers are in the form of physical subsidies. The government distributes organic fertilizers (mostly commercial organic fertilizers) to farmers for free through village collectives or cooperatives. Therefore, government subsidies and cash family net income are independent variables.

### 2.3.3 Mediating Variables

The mediating variables included BS, SR, and responsibility for behavior (RB). The scale of operation was a continuous variable, the SR was determined on a five-level Likert scale, and the RB was a binary variable. Specifically, the SR is measured as the "consideration of the safety risks of tea caused by excessive application of chemical fertilizers" and assigned values of 1–5 according to the degree of agreement (strongly disagree–strongly agree), and "whether to persuade others to adopt the green production technology" was used to measure the SR. The RB was measured (Yu et al., 2020) and assigned a value of 1 or 0, according to the answer "yes" or "no".

### 2.3.4 Control Variables

Based on the research studies of Xie et al. (2021) and Wossen et al. (2015), we controlled the following variables: characteristics of farmers, including the age (AG) and education level (EL) of the head of the household; family characteristics, including the altitude (AL), family type (FT), experience capital (EC), BS, RP, and domestic workers (DW); and external characteristics, including the neighborhood effect (NE) and community publicizing effect (CP). The impact of the three regional variables on the estimated results was also controlled (**Table 1**).

# 3 RESULTS

## 3.1 Direct Impact of Risk Management on Farmers' Green Production Behavior

Using Stata14.0 software, the multicollinearity test showed that *Vif* values were between 1.08 and 3.82, indicating no serious

**TABLE 2** | Benchmark regression results.

| Variable | Select equation | | Result equation | |
|---|---|---|---|---|
| | Coefficient | Standard error | Coefficient | Standard error |
| GS | 0.214* | 0.125 | 0.039 | 0.034 |
| MS | 0.402** | 0.161 | 0.035 | 0.041 |
| IL | 0.085** | 0.040 | −0.001** | 0.000 |
| AG | −0.005 | 0.006 | −0.001 | 0.002 |
| EL | −0.020 | 0.016 | 0.001 | 0.005 |
| EC | 0.010** | 0.005 | −0.000 | 0.001 |
| BS | 0.026 | 0.070 | 0.046** | 0.020 |
| AL | −0.000 | 0.000 | −0.000** | 0.000 |
| FT | 0.243* | 0.144 | 0.000 | 0.040 |
| RP | 0.053 | 0.034 | −0.004 | 0.010 |
| DW | 0.571** | 0.260 | 0.085 | 0.063 |
| OS | 2.560*** | 0.235 | — — | — — |
| NE | 0.130** | 0.053 | 0.003 | 0.015 |
| CP | 0.185 | 0.196 | 0.093* | 0.053 |
| SX | 0.897*** | 0.230 | −0.172** | 0.084 |
| SC | 0.756** | 0.261 | −0.137 | 0.088 |
| AH | 0.725*** | 0.215 | −0.015 | 0.084 |
| Constant term | −2.243*** | 0.545 | 0.736*** | 0.166 |
| Mills | −0.094*** (0.029) | | | |
| N | 964 | | | |
| Wald chi$^2$ | 62.77 | | | |

****, **, and * are significant at the 1, 5, and 10% levels, respectively.*

multicollinearity in the respective variables. The inverse Mills ratios in models 1 and 2 passed the significance test, indicating sample bias in the degree of GPB of farmers, and thus, the Heckman model is suitable for use (**Table 2**).

### 3.1.1 Risk Management

As expected, GS significantly promoted the decision to use green production. An increase in GB can help reduce information asymmetry and pressure on farmers' own funds, effectively disperse the potential risks of new technology adoption, and stimulate farmers to increase their demand for GPB through economic incentives. An MS significantly promoted farmers' GPB. Through internal constraints, benefit distribution, and risk compensation mechanisms, cooperatives can reduce farmers' output dependence on factor inputs; effectively improve farmers' risk awareness, risk management, and control capabilities; help farmers avoid and smooth agricultural production risks; and promote green production. We also showed that IL significantly affects decision-making. Thus, increasing the income of farmers is the key aspect to improving the level of green production. Farmers' IL determines their willingness to engage in green production and factor input behavior at each stage (Hayati et al., 2009). A higher IL is associated with the choice of a larger number of livelihood strategies for farmers, lower living pressure and income uncertainty, and stronger resource availability and risk-taking ability. A low IL negatively impacts the degree of green production. The input cost of the green production technology is high, but the overall income of the sample farmers was low (24,610 yuan/person). If socially necessary, mechanisms for the risk, such as bottom-line assistance, are lacking; farmers will place greater emphasis on the benefits and risks of organic fertilizer investment, which is not conducive to increasing organic fertilizer investment (Huang, 2019). Thus, H0 was partially verified.

### 3.1.2 Control Variables

EC significantly affects decisions related to GPB, indicating that longer planting years are associated with a better understanding of the inter-period agricultural technology. BS significantly promoted the GPB of farmers. A larger tea planting scale reduces the cost per unit area of the green production technology. AL does not promote GPB because a higher altitude increases the difficulty of organic fertilizer application. FT and DW significantly affected decisions related to GPB because the family's farming and hired labor increase the agricultural labor force. In addition, the NE and CP significantly affected GPB, indicating the importance of the village environment in GPB.

## 3.2 Indirect Impact of Risk Management on Farmers' Green Production Behavior

To determine the impact of GS on farmers' GPB, the Sobel test was performed. BS, SR, and RB showed significant effects and satisfied the assumption that the confidence interval did not contain zero (**Table 3**). These results showed that GS influence farmers' GPB, and BS, SR, and RB have significant mediating effects. Additionally, the mediating effects of BS, SR, and RB were significant in the effect of MS on farmers' GPB. Thus, GS and MS improve farmers' risk management ability by expanding the operation scale, enhancing SR and environmental sentiment, and promoting technology diffusion. For the effects of IL on farmers' GPB, the SR and BR did not pass the Sobel test and did not meet the assumption that the confidence interval does not

**TABLE 3** | Mediation test results.

| Path I: impact of RM on MV | Coefficient | Path II: influence of MV on GPB | Coefficient | Mediating effect coefficient | Sobel test (z-value) | Bootstrap confidence interval | Proportion of the mediation effect/% |
|---|---|---|---|---|---|---|---|
| GS→BS | 0.346***(0.065) | BS→GPB | 0.035** (0.017) | 0.012* (0.006) | Z: 1.878 | [0.002,0.033] | 10.78 |
| GS→SR | 0.183** (0.076) | SR→GPB | 0.044** (0.015) | 0.008* (0.004) | Z: 1.874 | [0.007,0.036] | 7.29 |
| GS→RB | 0.082** (0.038) | RB→GPB | 0.095** (0.029) | 0.007* (0.004) | Z: 1.778 | [0.004,0.032] | 6.91 |
| MS→BS | 0.502***(0.087) | BS→GPB | 0.033* (0.017) | 0.016* (0.009) | Z: 1.809 | [0.001,0.056] | 10.30 |
| MS→SR | 0.263** (0.101) | SR→GPB | 0.043** (0.014) | 0.011* (0.005) | Z: 1.938 | [0.005,0.041] | 5.95 |
| MS→RB | 0.160** (0.051) | RB→GPB | 0.091** (0.030) | 0.014** (0.006) | Z: 2.180 | [0.007,0.044] | 8.92 |
| IL→BS | 0.006***(0.001) | BS→GPB | 0.043** (0.017) | 0.001** (0.000) | Z: 2.220 | [−0.005,0.006] | 44.34 |
| IL→SR | 0.001 (0.001) | SR→ GPB | 0.048*** (0.015) | 0.000 (0.000) | Z: 0.551 | [−0.002,0.002] | 6.12 |
| IL→RB | 0.000 (0.001) | RB→GPB | 0.102*** (0.030) | 0.000 (0.000) | Z: 0.188 | [−0.001,0.001] | 2.17 |

*The standard errors are in brackets, and the estimation results of the other control variables are omitted.*

**TABLE 4** | Subsample mediation effect test of government subsidies.

| Category | Path | Mediating effect coefficient salience | Sobel test (Z value) | Bootstrap confidence interval | Proportion of the mediation effect/% |
|---|---|---|---|---|---|
| Low-risk perception | GS→BS→GPB | 0.032** (0.013) | Z: 2.485 | [0.005,0.060] | 21.42 |
| High-risk perception | GS→BS→GPB | 0.010 (0.007) | Z: 1.299 | [−0.005,0.026] | 13.70 |
| Low-risk perception | GS→SR→GPB | 0.021* (0.011) | Z: 1.963 | [0.002,0.052] | 17.73 |
| High-risk perception | GS→SR→GPB | 0.009 (0.006) | Z: 1.507 | [−0.002,0.021] | 15.11 |
| Low-risk perception | GS→RB→GPB | 0.024** (0.011) | Z: 2.142 | [0.002,0.047] | 20.71 |
| High-risk perception | GS→RB→GPB | 0.010 (0.006) | Z: 1.561 | [−0.003,0.024] | 15.69 |

contain zero. Although the MS passed the Sobel test, it violated the assumption that the confidence interval contained zero, indicating that the mediating effects of BS, SR, and RB were not significant in the effects of IL on farmers' GPB. The per capita income of farmers in the sample area is low, limiting the expansion of the BS and improvement in responsibility awareness, leading to less responsible behaviors. Thus, H1 was partially verified.

## 3.3 Subsample Mediation Analysis

Farmers with different risk preference levels use varying risk management measures (van Winsen et al., 2016). As the impact of farmers' risk management on GPBs may differ at different RP levels, the mediating effect was further subsampled. Because the high-quality and high-price mechanism of green production is underdeveloped, farmers' RP of green production technology is mainly reflected in their perception of yield risk. Therefore, we used production RP as the grouping basis with the average production RP as the boundary, as well as lower and higher than the average as low-RP and high-RP, respectively. In the low-RP group, BS, SR, and RB significantly mediated the effects of GS on farmers' GPB, whereas the results in the high-RP group were not significant (**Table 4**). This result may lead to the development of strategies that can increase farmers' investment levels in green production in the context of their strong risk aversion.

In the low-RP group, BS, SR, and RB significantly mediated the effects of MS on farmers' GPB, whereas the results in the high-RP group were not significant. As shown in **Table 5**, there were significant differences in RP in the effects of risk management on farmers' GPB in terms of BS, SR, and behavior, and the impact of the low-RP group was more significant. This is because farmers in the low-RP group have a lower degree of loss aversion and can evaluate the potential risks of adopting the green production technology (van Winsen et al., 2016). Therefore, under certain risk management capabilities, farmers are more inclined to adopt the green production technology and avoid irrational behaviors.

# 4 DISCUSSION

Excessive application of chemical fertilizers has greatly contributed to the growth of agriculture in China but has also led to soil acidification, environmental pollution in production areas, and decreased quality of agricultural products. The

**TABLE 5 |** Subsample mediation test of membership status.

| Category | Path | Mediating effect coefficient salience | Sobel test (Z-value) | Bootstrap test confidence interval | Proportion of the mediation effect/% |
|---|---|---|---|---|---|
| Low-risk perception | MS→BS→GPB | 0.047** (0.018) | Z: 2.519 | [0.005,0.089] | 18.15 |
| High-risk perception | MS→BS→GPB | 0.016 (0.014) | Z: 1.128 | [−0.013,0.047] | 12.05 |
| Low-risk perception | MS→SR→GPB | 0.027** (0.013) | Z: 2.017 | [0.002,0.053] | 12.71 |
| High-risk perception | MS→SR→GPB | 0.007 (0.006) | Z: 1.077 | [−0.006,0.020] | 5.99 |
| Low-risk perception | MS→RB→GPB | 0.036** (0.015) | Z: 2.342 | [0.007,0.065] | 17.07 |
| High-risk perception | MS→RB→GPB | 0.014 (0.009) | Z: 1.584 | [−0.004,0.033] | 12.02 |

**TABLE 6 |** Heterogeneity analysis.

| Variable | Below scale | | Above scale | | Low altitude | | High altitude | |
|---|---|---|---|---|---|---|---|---|
| | Select equation | Result equation | Select equation | Result equation | Select equation | Result equation | Select equation | Result equation |
| GS | 0.142 (0.130) | 0.043* (0.026) | −0.024 (0.263) | 0.028 (0.056) | 0.023 (0.179) | 0.058 (0.035) | 0.315** (0.150) | 0.043 (0.031) |
| MS | 0.314* (0.185) | 0.081** (0.036) | 0.558* (0.289) | 0.138** (0.062) | 0.251 (0.245) | 0.024 (0.051) | 0.479** (0.196) | 0.133*** (0.039) |
| IL | 0.102** (0.049) | 0.014* (0.008) | 0.046 (0.058) | −0.001 (0.000) | 0.016 (0.062) | 0.011 (0.011) | 0.075 (0.052) | −0.001** (0.000) |
| CV | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 665 | 665 | 153 | 153 | 375 | — — | 443 | — — |
| LR $chi^2$ | 98.53 | — — | 41.60 | — — | 37.18 | — — | 45.28 | — — |
| Pseudo $R^2$ | 0.115 | — — | 0.205 | — — | 0.088 | — — | 0.075 | — — |
| Log likelihood | −380.196 | — — | −80.732 | — — | −192.561 | — — | −281.245 | — — |

environment is the foundation of agricultural production, and improving the quality of the production area is important for the sustainable development of agriculture. Organic fertilizer technology has recently become the main green production technology in China because of its ability to improve soil properties and restore the environment. However, this technology is also expensive, and its effects on investment are unclear.

With global warming, agricultural production has been impacted by an increasing number of natural disasters. In addition, the large social risks represented by diseases such as COVID-19 profoundly and continuously affect agricultural production and peoples' lives. In China, small farmers with small land scales and low ILs are the mainstay of agricultural production. When external shocks are large, farmers tend to adopt traditional methods of unsustainable investment in agricultural production because they lack risk management capabilities. Thus, from the perspective of risk governance, improving risk management is a key factor in promoting the use of modern agriculture by small farmers.

Most previous studies focused on the factors influencing green production from a subjective perspective, such as by evaluating the RP, whereas the impact on farmers' green production from the perspective of ability has not been widely examined. Additionally, farmers' risk management capability systems and their impact on green production are unclear. We constructed an indicator system for farmer household risk management from three dimensions—individual, collective, and government—and empirically evaluated the impact mechanism of risk management on farmers' GPB. Risk management is a key variable affecting farmers' GPB. Specifically, MS, GS, and ILs significantly promote farmers' decision to adopt green production technology. Analysis of the effects of MS and GS on farmers' GPB showed that BS, SR, and RB have significant mediating effects. Thus, risk management can directly affect and promote the GPB of farmers by expanding the scale of operation and improving farmers' SR and BR. Therefore, the level of green production can be improved by increasing GS for green production. GS can also guide farmers to join cooperatives. In addition, the IL in the sample area was relatively low, preventing farmers from adopting the green production technology. Therefore, improving farmers' ILs is important for promoting green production.

We further analyzed the heterogeneity of the impact of risk management on farmers' GPB; the results are shown in **Table 6**. The MS and IL of farmers below the designated size significantly promoted the decision to adopt green production, whereas IL did not significantly affect the decision to adopt green production technology for farmers above the designated size. GS, MS, and IL significantly promoted the adoption of green production technology by farmers below a designated size, whereas only MS significantly promoted the adoption of green production technology by farmers above the designated size. Therefore, risk management has a greater impact on small-scale farmers than on large-scale farmers. Currently, small farmers are the main source of agricultural production in China and show strong livelihood vulnerability. Therefore, guiding these farmers to join cooperatives, increasing GS, and increasing their individual income to improve their risk management capabilities can improve green production levels. In addition, according to heterogeneity analysis of altitude, risk management did not significantly affect the GPB of farmers in low-altitude areas but significantly promoted the GPB of farmers in high-altitude areas. High-altitude tea farms have fewer pests and diseases and produce high-quality tea leaves compared to low-altitude tea farms. Organic fertilizers tend to show greater volatilization in high-altitude areas than in low-altitude areas; therefore, farmers in high-altitude areas improve the level of green production through GS and by joining cooperatives. Our conclusions provide insight for promoting ecological restoration and improving the environmental quality of agricultural production areas under the background of frequent risks and low vulnerability of farmers.

## 5 CONCLUSION

Risk and uncertainty are prominent phenomena in today's society, particularly for small farmers. Farmers often adopt risk-averse strategies when facing new technology adoption, which has certain vulnerabilities (ISDR, 2004). We examined the impact of risk management on farmers' GPB by building a risk management capability system that considers the individual, collective, and governmental levels. Our empirical results revealed that risk management is a key variable affecting farmers' GPB. MS, GS, and ILs significantly promoted decision-making related to farmers' GPB. However, the IL of the sample area is relatively low, limiting the ability of the farmers to protect the quality of agricultural land. These data can help the government improve the risk management ability of farmers at a practical level and reduce resistance to the diffusion of green production technology. Additionally, the MS, SR, and BR significantly mediated the effects of MS and GS on farmers' GPB. These mediating effects were more obvious in the low-risk group than in the high-risk group. The policy implication of these results is that to avoid adverse impacts of risk preference on farmers' adoption of green production technologies, farmers can improve their risk management capabilities and reduce their risk aversion.

Our results have several policy implications. First, we focused on improving farmers' risk management capabilities at multiple levels. At the individual level, farmers should actively participate in agricultural and non-agricultural training, strengthen technical learning, and continuously improve their individual skills. At the collective level, it is necessary to increase support for local cooperatives, guide and attract more farmers to become members of cooperatives, and demonstrate the driving effects of cooperatives. The government should strengthen the level and scope of GS for farmers' organic fertilizers and other green production factors, particularly for farmers in mountainous areas to obtain and purchase these fertilizers. Moreover, it is necessary to raise the market access threshold and mechanism of green production of high-quality tea at a suitable price and to increase the income of farmers involved in the tea business. Through support from local enterprises, non-agricultural opportunities for farmers will increase. Second, for farmers with strong local risk management capabilities, the government should further promote the transfer of farmland and provide relevant policy assistance to help expand their BS. Technical training and publicity for farmers with strong risk management capabilities should be emphasized to guide them to enhance their sense of social responsibility and behavior and ultimately promote the diffusion of green production technologies. Third, the intensity and frequency of technical training in the green production technology should be increased, and farmers should assess the risks of GPB to improve their green production levels. In particular, the government should aid small-scale farmers and farmers involved in green tea production in high-altitude areas.

There were some limitations to this study. We evaluated short-term farmer survey data, preventing analysis of dynamic changes in the GPB of each farmer at different times. In our further studies, we will focus on improving the resilience of farmers in the context of risk shocks and the impact of risks on production and life. Additionally, time series data will be expanded based on cross-sectional data to enhance the robustness and reliability of the measurement results.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the College of Economics and Management, Northwest A&F University (Ref.212/2010). The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

XW: conceptualization, writing—original draft, and methodology; YM: review and editing; HL: investigation, resources, supervision, and project administration; CX: validation and project administration.

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