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A Probit Analysis of Factors Affecting Adoption of Improved Crop Varieties by Iranian Farmers

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ABSTRACT

Improved crop varieties are crucial for enhancing global agricultural productivity. This study investigated the factors influencing the adoption of new varieties of irrigated cereals and oilseed crops (released between 2015 and 2022) among Iranian farmers. Data were collected from 1001 respondents using a multistage sampling procedure and analyzed via descriptive statistics and a probit regression model. The results revealed that 58% of the respondents had not adopted the improved varieties introduced during this period. Probit estimates identified several significant factors affecting adoption of new varieties including education, average annual income, access to improved seeds, seed supply system, participation in training courses, communication with pioneer farmers, communication with extension agents, use of social media, attitude towards the superiority of new varieties over the old ones, relative advantage, observability, and compatibility of improved varieties with the region conditions. To enhance the adoption of new varieties,

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implementation of enlightenment programs through competent extension services—such as participatory variety selection (PVS) farms or model farms—along with effective training courses is recommended. The availability of high-quality seeds at the right time for farmers can also increase the likelihood of adopting new varieties. The significant influence of training and extension agents underscores the vital role of structured outreach and education. Furthermore, the importance of varietal compatibility with regional conditions highlights the need to consider climate adaptability in breeding programs. Understanding these adoption factors can provide relevant research institutions with valuable feedback on their released varieties and insights into barriers to widespread adoption.

Key Words: Improved varieties, Iran, Probit model, Technology adoption.

INTRODUCTION

Enhancing agricultural productivity relies on the adoption and effective use of technology. The introduction of high-yielding, drought-tolerant, and disease-resistant cultivars represents a key strategy to boost output (Damba et al., 2020). This is particularly crucial given constraints like limited water resources and production inputs, making productivity growth essential. Therefore, adopting new technologies, implementing efficient methods, and improving input productivity are vital for sustainable agricultural development.

Numerous studies confirm that technology adoption is shaped by socio-economic characteristics, institutional factors, and technology attributes. Ghimire et al. (2015) identified education, extension access, seed availability, farm size, land type, and technology-specific traits as key determinants in adopting improved rice varieties in Central Nepal. Similarly, Dhakal and Mishra (2022) found age, education, and farm size significant in Lamjung District, Nepal, while Udoh and Omonona (2008) highlighted education, extension, credit access, input availability, farm size, and yields as crucial in Nigeria. Complementing these findings, Kehinde and Adeyemo (2017) demonstrated that association membership, education, credit access, farm size, and extension contact influenced technology dis-adoption in Nigerian cocoa-based systems.

In Iran, where agriculture is characterized by small, fragmented holdings with typically low productivity, improved varieties represent a vital strategy for enhancing output. Consequently, farmers' perceptions of new varieties critically influence their adoption decisions. The specific attributes of these varieties, as evaluated by farmers, significantly impact both adoption likelihood and usage intensity (Ndeko et al., 2025). This underscores the necessity of considering farmer perceptions of technology characteristics when assessing adoption behavior (Ghimire et al., 2015).

The Agricultural Research, Education and Extension Organization (AREEO) in Iran, serves as the principal research body for the agriculture and natural resources sectors. Comprising 17 research institutes, 2 national centers, and 34 provincial research centers, AREEO has a primary mandate to develop improved cultivars for various irrigated and rainfed crops. Between 2000 and 2024, it released 108 cultivars for irrigated cereals, 52 for oilseeds, 32 for corn and forage crops (Seed and Plant Improvement Institute, 2024), and 28 for rice (Rice Research Institute of Iran, 2024).

Despite possessing an extensive and growing portfolio of agricultural knowledge and technology, AREEO has faced challenges in effectively transferring these innovations to the market. Data from its Technology Affairs Office (2020) indicate that only 308 out of approximately 1,700 developed knowledge and technology items (18 percent) had been commercialized by 2021. Confronted with funding constraints, intensified competition from imported cultivars, and the heightened imperative of food security, AREEO has been compelled to re-evaluate its strategic role. These pressures have prompted a renewed focus on optimizing research activities and enhancing the productivity of its human and financial resources.

Given that AREEO serves as the principal entity for agricultural research in Iran, and has successfully developed and introduced a significant number of new plant varieties over the past decades, there remains limited empirical evidence on the actual drivers influencing farmers' adoption of new varieties in real-world farming conditions. Therefore, it is essential to examine the dissemination pathways of AREEO-introduced cultivars to farmers and identify the factors affecting their adoption by end-users. Research in this area will support the development of a comprehensive strategic plan to enhance the productivity of AREEO's financial and human resources. Accordingly, this study aims to model the adoption probability of newly released cereal and oilseed varieties introduced between 2015 and 2022, among farmers, focusing on cultivars developed by the AREEO. The study focuses on barley, rice, and corn in the cereal group, and rapeseed in the oilseed group.

Theoretical framework

According to Rogers (2003) characteristics of a technology influence its adoption. He proposed five characteristics including; relative advantage, complexity, compatibility, trialability, and observability that make a technology more or less readily adoptable.

Relative advantage refers to the degree to which an innovation or technology is perceived as superior to the technology it replaces (Rogers, 2003). This is typically evaluated based on economic benefits and low initial costs. Complexity refers to the extent to which an innovation is seen as difficult to learn, understand, or use (Premkumar & Roberts, 2003). High complexity-such as advanced cultivation techniques or unfamiliar seed traits, can deter adoption, particularly among smallholder farmers with limited resources or technical training. Thus, innovations with low complexity are more likely to achieve widespread acceptance in farming communities. Technology compatibility denotes how well a technology integrates with existing values, needs, and infrastructure (Prause, 2019). People are generally more inclined to adopt technologies that align with their current processes and systems (Arnold et al., 2018). Trialability is the degree to which a technology can be experimented with on a limited basis before full adoption (Venkatesh, 2001). In agriculture, trialability plays a critical role in farmers' decision-making, as the ability to test new cultivars or practices on small plots reduces perceived risks and encourages wider uptake. For instance, farmers may be more willing to adopt improved crop varieties if they can first evaluate their performance under local conditions. Finally, observability refers to the extent to which the results or benefits of a technology are visible to others. Rogers (2003) argued that these five characteristics account for at least half of the variation in technology adoption.

Attitude is another critical factor within the Technology Acceptance Model. It refers to a person’s knowledge, as well as their positive or negative feelings about an action or object (Friedrich, 2009). External variables, such as social influence and professional characteristics, also play a significant role in shaping users' attitudes. Additionally, attitudes may fluctuate based on demographic characteristics.

One of the professional characteristics examined in this study was the extent of farmers' use of social media and their digital literacy, as numerous studies have demonstrated that digital literacy can significantly increase farmers’ adoption of new farming technologies (Liu et al., 2025). Based on the aforementioned concepts, the conceptual framework for this study is illustrated in Figure 1.

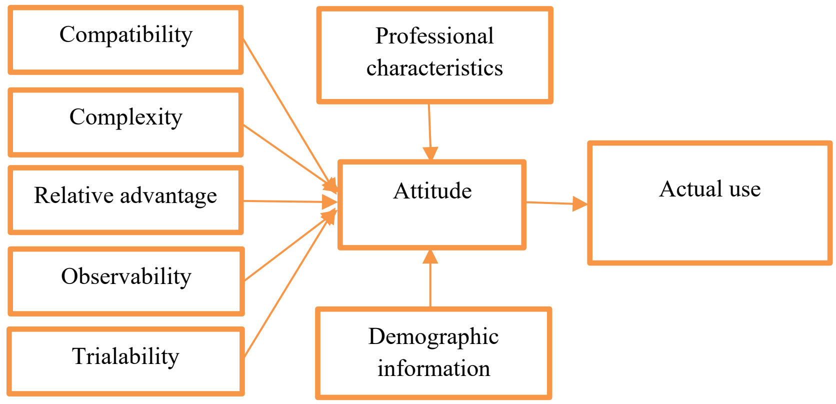

Fig. 1. The conceptual framework of the study.

MATERIALS AND METHODS

Participants and sampling procedure

A total of 10 provinces in Iran were selected for this study. Provinces with the largest cultivated areas for the crops under investigation during the 2021-2022 cropping year were chosen based on data from the Agricultural Statistical Yearbook (2021-2022). The study was conducted in selected rural districts from May to September 2023. According to the Krejcie and Morgan (1970) sampling table, the maximum sample size of 380 participants per crop was adopted. In total, 1,001 completed questionnaires were returned. A multistage sampling method was employed to select the sample, following these steps: purposive sampling to identify sampling areas within each province based on the highest cultivated areas of the studied crops; simple random sampling to select districts within the chosen sampling areas; and systematic random sampling of farmers from each selected district. Three to four districts were chosen from each province. Ultimately, a statistically representative random sample of 1,001 farmers was selected from the districts (Table 1).

Table 1. Sample size in the studied provinces.

Crops	Selected provinces	Sample size
Barley	Fars, Isfahan, Khorasan-Razavi, Khouzestan, Kerman	208
Canola	Golestan, Mazandaran, Fars, Khouzestan, Kermanshah, Hamedan	281
Corn	Khouzestan, Fars, Kermanshah	254
Rice	Mazandaran, Guilan	258

Data collection

Data were collected using a structured questionnaire that included items on socio-demographic information (age, gender, education level, etc.), agricultural characteristics (cultivated varieties, seed supply system, farm size, etc.), technological characteristics (relative advantage, complexity, compatibility, trialability, and observability), and the challenges and solutions related to the development of newly introduced cultivars. To assess technological characteristics, the technology acceptance questionnaire by Venkatesh et al. (2012) was employed. To assess attitude and actual use, the Technology Acceptance Model (TAM) questionnaire developed by Davis et al. (1989) was used. The questions used for the measurement of socio-demographic information, agricultural characteristics, as well as the challenges and strategies associated with the use of the new cultivars, was a researcher-designed questionnaire.

Initially, the questionnaire was designed electronically through the online survey software and distributed through social media network to the farmers. A total of 449 questionnaires (45%) were completed and returned electronically, while the remaining 552 questionnaires were collected through face-to-face interviews.

To establish face and content validity, the questionnaire was reviewed by a panel of experts, including breeders, agricultural researchers, and specialists in agricultural extension and education from Agricultural and Natural Resources Research and Education Centers. Based on the panel's suggestions, revisions were made to the questionnaire text. The reliability of the questionnaire was assessed using Cronbach's alpha, which yielded a value of 0.86.

Data analysis

A probit model (STATA 12.1) was employed to determine the probability of adopting newly improved varieties using plot-level data. The probit regression is the most appropriate statistical technique to predict the probability of whether or not to adopt new varieties by the farmers, particularly at the plot-level data analysis (Gauchan et al, 2012). The likelihood of farmers adopting new varieties is a non-linear function of independent variables. The Probit model establishes relation between probability values and explanatory (independent) variables and ensures the probability value between 0 and 1. In probit model, Y_i is the binary response of the farmers:

if the farmer adopts new varieties, Y_i=1, and if the farmer does not adopt the new varieties; Y_i=0.

If Y_i =1; Pr (Y_i=1) =P_i

If Yi =0; Pr (Yi=0) =1-P_i

Where P_i=E (Y=1/X) represents the conditional mean of Y given certain values of X.

The probit model uses an unobserved (latent) variable Y_i linearly related to independent variables:

$$Y_i = \beta_i X_i + \beta_0$$

Y_i: Latent dependent variable (e.g., farmer's unobserved propensity to adopt technology)

β_i: Vector of regression coefficients

X_i**:** Matrix of independent variables (e.g., education, income)

β_0**:** Error term with standard normal distribution

For each observation, the probability is:

$$P(Yi=1|Xi) = \Phi(\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k)$$

RESULTS AND DISCUSSION

Table 2 presents the descriptive variables related to the farmers examined in this study. 42% of the respondents have adopted the newly improved crop varieties and cultivated them over the past five years, while 58% remain non-adopters. Notably, although 59% of the rice varieties cultivated in the past five years were introduced between 2015 and 2022, approximately 29% of the rice varieties grown by the surveyed paddy farmers during this period were indigenous, including the Hashemi variety. Hashemi, first cultivated in 1980, is a traditional local rice variety highly regarded for its superior taste, aroma, and fragrance.

Regarding barley, approximately 52% of the varieties cultivated over the past five years were introduced in Iran after 2015. Among these, around 9% were imported, with only 2% of barley farmers growing them. In recent years, the majority of rapeseed varieties cultivated by farmers have been imported. For instance, during the 2022–2023 cropping season, all rapeseed varieties planted by the studied participants were imported. Similarly, for corn, the majority of cultivated varieties in recent years have been sourced from abroad. Over the past five years, 77.3% of the corn varieties grown by the surveyed respondents were of foreign origin.

The average age of the respondents was approximately 47 years. On average, the farmers surveyed had completed around 11 years of formal education. The mean annual income of the farmers in this study was approximately 71 million toman. The respondents had an average of 26.5 years of agricultural experience.

About 44% of the respondents had timely access to seeds of newly introduced varieties. Additionally, 78% of the farmers sourced their required seeds from the formal seed system, and

72% were landowners. A majority of the respondents (79%) had participated in agricultural training programs, while 55% reported using social media. Farmers typically met with extension agents an average of six times per year, with an overall average of seven interactions with extension agents over the past year. The average farm size among respondents was approximately 16 hectares.

Furthermore, 76% of households reported earning additional income from off-farm employment. Regarding attitudes toward newly improved crop varieties, 51% of the respondents expressed a relatively positive or positive perception of their performance and resistance to biotic and abiotic stresses. The respondents' evaluations of the characteristics of the newly improved varieties compared to traditional ones are also presented in Table 2.

Table 2. Descriptive variables of new varieties adoption.

Variable	Description	Mean	SD
Dependent variable Adoption	1= if the respondent has cultivated the inland improved varieties introduced since 2015, 0=otherwise	0.42	0.49
Independent variables			
Demographic information			
Age	Age of the respondent (year)	47.1	9.7
Education	formal education of the respondent (year)	10.8	4.6
Average annual income	Annual income declared by the respondent (million toman)	70.9	11.2
Professional characteristics			
Agriculture experience	Respondent`s agricultural experience (year)	26.5	13.7
Access to improved seeds (Timely access to sufficient quantities of desired seed varieties)	1= if seeds are sufficiently available in local store at the appropriate time, 0=otherwise	0.44	0.49
Seed supply system	1= if the respondent supplies seeds from formal seed system, 0= informal seed systems	0.78	0.43
Farm size	Cultivated land area in the last year (ha)	16.8	23.3
Participation in training courses (over the past 5 years)	1= if the respondent attended the training courses during the past 5 years, 0=otherwise	0.79	0.48
Communication with pioneer farmers	The number of meetings with pioneer farmers in the year	7.00	2.03
Communication with extension agents	The number of meetings with extension agents in the year	5.81	2.15
Use of social media	1= merging categories 4-5 as positive responses, 0= otherwise*	0.55	0.49
Attitude towards the superiority of new varieties over the old ones	1= merging categories 4-5 as positive responses, 0= otherwise*	0.51	0.50
Technology characteristics			
Compatibility	1= merging categories 4-5 as positive responses, 0= otherwise*	0.54	0.23
Complexity	1= merging categories 4-5 as positive responses, 0= otherwise*	0.22	0.31
Relative advantage	1= merging categories 4-5 as positive responses, 0= otherwise*	0.62	0.27

Observability	1= merging categories 4-5 as positive responses, 0= otherwise*	0.42	0.25
Trialability	1= merging categories 4-5 as positive responses, 0= otherwise*	0.47	0.16

***Following Agresti (2018), Likert-scale responses were dichotomized into binary outcomes by merging categories 4-5 as positive responses.**

Table 3 presents the results of a t-test comparing the means of various characteristics between adopters and non-adopters of the new improved varieties. The analysis revealed statistically significant differences between the two groups in terms of education, access to improved seeds, seed supply system, participation in training courses, communication with extension agents, attitude towards the superiority of new varieties over the traditional ones, and the observability of the benefits of cultivating new varieties.

Although the analysis confirmed a significant difference in education levels between adopters and non-adopters, it showed no significant differences in terms of age, average annual income, agricultural experience, or farm size. Moreover, adopters exhibited a more positive attitude toward the superiority of the new varieties. The adopters also showed significantly stronger connections with extension specialists. In contrast, the perceived observability of the benefits derived from a new innovation played a more significant role in the adoption decision for non-adopters compared to adopters.

Table 3. T-test comparisons of new varieties adopters and non-adopters.

Variable	Adopters	Non-adopters	t-value	Sig.
Age (years)	49.18	49.14	0.061	0.952
Education (years)	11.55	10.28	4.352	0.000**
Average annual income (million toman)	74.02	55.17	1.833	0.074
Agriculture experience (years)	25.06	27.56	1.584	0.114
Farm size (ha)	20.70	14.74	1.921	0.061
Communication with pioneer farmers (Number per year)	9.41	6.32	1.630	0.077
Communication with extension agents (Number per year)	7.01	4.14	2.014	0.045*
Use of social media	4.01	2.98	2.012	0.032*
Attitude towards the superiority of new varieties over the old ones	0.78	0.48	2.690	0.007**
Compatibility	0.93	0.95	0.833	0.405
Complexity	0.75	0.77	1.715	0.087
Relative advantage	0.91	0.94	1.564	0.118
Observability	0.78	0.86	2.254	0.025*
Trialability	0.91	0.82	0.224	0.823

**, Significant at 1%; *, Significant at 5%.

The Variance Inflation Factor (VIF) was calculated to assess multicollinearity among the independent variables. The initial results indicated a high degree of multicollinearity between "agricultural experience" and "farm size" (VIF>10), suggesting that these variables provide overlapping information to the model. To mitigate this issue, and ensure the robustness and reliability of the parameter estimates, "farm size" was consequently excluded from the final specification. The VIF values for the remaining variables, as presented in Table 4, are all well below the common threshold of 10, with the highest being 5.03, confirming that severe multicollinearity is no longer a concern in the final model and the parameter estimates are reliable. The multicollinearity diagnostics for the regression predictors are summarized in table 4.

Table 4. The results of multicollinearity test.

Variables	VIF	Variables	VIF
Age	1.20	Use of social media	3.35
Education	1.35	Attitude	5.00
Average annual income	1.45	Compatibility	4.81
Agriculture experience	1.81	Complexity	3.80
Access to improved seeds	3.84	Relative advantage	3.50
Seed supply system	4.27	Observability	3.40
Participation in training courses	5.03	Trialability	3.61
Communication with pioneer farmers	4.15	Mean VIF	2.82
Communication with extension agents	3.98		

Based on the fitted probit model, the marginal effects of the key variables are calculated and interpreted as follows:

The results indicate that the variable attitude, with a marginal effect of 12.48%, has the strongest impact on the adoption of improved crop varieties. This suggests that changing farmers' attitudes towards new varieties yields the highest return in increasing adoption rates. Following this, compatibility with a marginal effect of 10.53% and relative advantage with a marginal effect of 9.25% rank next. Participation in training courses and access to improved seeds also have significant effects, at 8.35% and 6.28%, respectively. Conversely, age and complexity show significant negative effects. The results are presented in Table 5.

Table 5 also presents the results of the estimated probit regression model, which identifies several factors that significantly influence the likelihood of adopting new varieties.

Out of the 16 estimated coefficients, 11 are statistically significant. The coefficients for the following variables are significant at the 0.01 percent level: education, access to improved seeds, communication with pioneer farmers, use of social media, attitude towards the superiority of new varieties over the old ones, compatibility, and relative advantage. The coefficients for average annual income, seed supply system, communication with extension agents, and observability is significant at the 0.05 level.

Education emerged as a key determinant in adoption decisions. The findings indicate that as the level of education increases, so does the probability of adopting new varieties. This suggests that farmers with higher education levels are better able to process and understand information, thereby increasing their inclination to adopt these technologies. This observation is consistent with previous studies (Ghimire et al., 2015, Dhakal and Mishra, 2022, Udoh and Omonona, 2008, and Kehinde and Adeyemo, 2017).

Additionally, the availability of seeds in sufficient quantities and at the appropriate time significantly enhances adoption rates. Local availability of seeds facilitates the purchase and cultivation of improved varieties. Moreover, the source of seed supply plays an important role; seeds obtained from formal systems, which typically adhere to strict quality control measures, are more likely to encourage adoption than those from informal sources (Biemond, 2013). This result aligns with earlier findings by Ghimire et al. (2015) and Udoh and Omonona (2008).

Furthermore, effective communication with pioneer farmers and extension services is shown to significantly promote adoption, underscoring the role of these information channels in technology dissemination. These results are consistent with research conducted by Ghimire et al. (2015), Dhakal and Mishra (2022), Udoh and Omonona (2008), and Kehinde and Adeyemo (2017).

The analysis also reveals that the use of social media positively influences the adoption of new varieties. Social media platforms offer considerable convenience by providing timely and detailed agricultural information, including the features, advantages, potential drawbacks, economic efficiency, and costs associated with new technologies, thereby aiding farmers in making informed decisions. Finally, a positive attitude towards the new varieties is associated with higher adoption rates. Adopters exhibit a significantly more favorable perception of these technologies compared to non-adopters, a finding that aligns with behavioral theories positing a direct link between positive attitudes and behavioral actions (Oli et al., 2025).

The pseudo-R^2 of 0.4 indicates that the independent variables in the model collectively explain approximately 40% of the variation in farmers' adoption of the new varieties. This is considered a reasonably good level of explanatory power in behavioral and social science research, as adoption decisions are influenced by a wide array of complex factors, not all of which can be captured in a single model.

Table 5. Probit Regression Results: Coefficient Estimates and Marginal Effects.

Variable	Estimate	Std. error	z-score	Marginal Effect	Interpretation of Marginal Effect
Age	-0.02	0.01	-1.302	-0.0041	A one-year increase in age decreases the probability of adopting improved seeds by 0.41 percentage points.
Education	0.15	0.05	3.001**	0.0325	Attaining one additional level of education increases the probability of adoption by 3.25 percentage points.
Average annual income	0.20	0.08	2.50*	0.0412	A one-level increase in income category increases the probability of adoption by 4.12 percentage points.
Agriculture experience	0.03	0.02	1.50	0.0128	A one-level increase in agricultural experience increases the probability of adoption by 1.28 percentage points.
Access to improved seeds	0.30	0.10	3.00**	0.0628	Switching from local to improved seeds increases the probability of adoption by 6.28 percentage points.
Seed supply system	0.25	0.09	2.37*	0.0908	The use of seeds from formal sources increases the adoption probability by 9.08 percentage points.
Participation in training courses	0.40	0.15	1.67	0.0135	Participation in training classes increases the probability of adoption by 1.35 percentage points.
Communication with pioneer farmers	0.20	0.08	5.50**	0.0403	A one-unit increase in connection with progressive farmers increases the probability of adoption by 4.03 percentage points.
Communication with extension agents	0.18	0.07	2.51*	0.0368	A one-unit increase in connection with agricultural experts increases the probability of adoption by 3.68 percentage points.
Use of social media	0.42	0.06	3.06**	0.0512	The use of social media increases the probability of adoption by 5.12 percentage points.
Attitude towards the superiority of new varieties over the old ones	0.60	0.15	4.00**	0.1248	A one-unit increase in a positive attitude increases the probability of adoption by 12.48 percentage points.
Compatibility	0.50	0.14	3.57**	0.1053	A one-unit increase in perceived compatibility increases the probability of adoption by 10.53 percentage points.
Complexity	-0.30	0.10	-1.55	-0.0612	A one-unit increase in perceived complexity decreases the probability of adoption by 6.12 percentage points.
Relative advantage	0.45	0.12	3.75**	0.0925	A one-unit increase in perceived comparative advantage increases the probability of adoption by 9.25 percentage points.
Observability	0.20	0.08	2.51*	0.0421	A one-unit increase in perceived observability increases the probability of adoption by 4.21 percentage points.
Trialability	0.25	0.09	1.78	0.0518	A one-unit increase in perceived trialability increases the probability of adoption by 5.18 percentage points.
Constant	-1.38	0.18	-5.11		

Log likelihood= -622.061; Pseudo R-squared= 0.420; *: significant at the 0.05 level, **: significant at the 0.01 level.

Barriers to the timely cultivation of newly introduced cultivars include inadequate knowledge and information about the new varieties, limited access to their seeds, and incompatibility with the region's climatic conditions. In response, the most favored solution among respondents was the implementation of PVS (participatory variety selection) farms or model farms, which would effectively demonstrate the quality and yield potential of the new varieties (Table 6).

Table 6. The most important challenges of adoption the new introduced varieties from the respondents' point of view.

Challenges	Mean*	SD.	CV.	Rank
Inadequate knowledge and information about the new introduced varieties	3.87	0.12	0.03	1
Lack of access to the seed of the new varieties	3.98	0.24	0.06	2
Incompatibility of some new introduced varieties with the climatic conditions of the region	4.58	0.82	0.18	3
Lower economic and profitable advantage of some of the new varieties compared to the old ones	4.03	0.93	0.23	4
Absence of experts next to the farmers to answer their questions and problems when planting a new variety	3.50	0.91	0.26	5
Lack of availability of the possibility of new cultivars trial cultivation by the farmers	3.52	0.99	0.28	6
Potential solutions				
Implementation of PVS (participatory variety selection) farms or model farms to display the quality and quantity of new varieties	4.15	0.11	0.02	1
Holding training courses	4.02	0.17	0.04	2
Availability of seeds in sufficient quantity and at the right time	3.89	0.21	0.05	3

1: very low, 5: very high.

DISCUSSION

Improved crop varieties play a crucial role in enhancing agricultural efficiency by increasing yields, improving resistance to biotic and abiotic stresses, and optimizing resource use. This study examined the factors influencing the adoption of new varieties among Iranian farmers using a probit model. The findings highlighted significant differences between adopters and non-adopters in terms of education, access to improved seeds, seed supply systems, participation in training courses, communication with extension agents, attitudes toward the superiority of new varieties over traditional ones, and observability of the benefits of cultivating new varieties.

The observed significant differences are rooted in established socioeconomic and psychological theories of technology adoption. For example, higher education levels among adopters suggest a greater cognitive ability to understand, process, and evaluate the complex information associated with new agricultural technologies. Education reduces perceived uncertainty and equips farmers with the skills to manage new practices effectively.

Access to Improved Seeds and Seed Supply Systems are fundamental prerequisites for adoption. The results of this research confirms that non-adopters often face structural barriers, such as physical unavailability, unreliable markets, or higher costs. A formal seed supply system guarantees access to certified, high-quality seeds, significantly lowering a major adoption barrier.

Training provides procedural knowledge and hands-on skills that theoretical knowledge alone cannot. It builds farmers' self-efficacy, making them feel confident in their ability to successfully implement the new technology, thereby reducing perceived risk.

Extension agents act as trusted, formal sources of information. Their guidance is crucial for overcoming technical challenges and validating the benefits of the innovation. Stronger links with extension services mean adopters have better access to expert knowledge and troubleshooting support.

Attitude towards the Superiority of New Varieties reflects the core concept of "Relative Advantage" from Diffusion of Innovation theory. Adopters hold a stronger belief that the new seeds offer tangible benefits (e.g., higher yield, better drought resistance, improved quality) compared to traditional varieties. A positive attitude is a powerful mental precursor to the decision to adopt.

And finally, although innovations whose results are easily visible and measurable are adopted more rapidly, farmers who fall into the non-adopter category are generally characterized by conservative and risk-averse behavior. Thus, exposure to the observable results of innovation in neighboring plots provides compelling, credible evidence and reduces perceived uncertainty, making the innovation more socially acceptable.

The probit analysis further confirmed that education level, average annual income, access to improved seeds, seed supply system, communication with pioneer farmers and extension agents, use of social media, attitude towards the superiority of new varieties over the old ones, compatibility, relative advantage, and observability were key determinants of adoption the new introduced varieties by farmers.

Among the technological characteristics assessed, compatibility emerged as a critical factor influencing adoption. Although Iran’s plant breeding programs are designed around climatic conditions, the impacts of climate change have compromised the effectiveness and genetic progress achieved by the current breeding systems. Rising and fluctuating temperatures have contributed to reduced crop yields and destabilized production. In addition, the evolving climate has altered pest and disease dynamics, posing further challenges to food production. To address these issues, next-generation breeding approaches—such as genomic selection and genomic editing—offer promising avenues by incorporating new germplasm and technological advances to develop climate-resilient crops. However, successful implementation of these approaches requires the integration of multidisciplinary tools, techniques, and platforms into the analytical process.

The probit analysis also confirms that relative advantage and observability were pivotal factors influencing farmers' adoption of the newly introduced varieties. The significance of relative advantage indicates that farmers were more likely to adopt the varieties if they perceived a clear superiority over existing options, such as higher yield, greater drought tolerance, or improved profitability. Concurrently, the importance of observability signifies that the tangible results of these advantages needed to be visibly apparent to farmers, for instance, by witnessing successful outcomes in demonstration plots or neighbors' fields. The interaction of these two factors underscores that adoption is driven not only by the potential for economic gain but also by the ability to reduce uncertainty through the direct observation of positive outcomes in real-world conditions, thereby building confidence in the innovation.

Given the significant role of extension agents, a greater emphasis on information dissemination and the implementation of participatory plant selection programs are recommended to facilitate the introduction of new varieties and enhance their adoption rates among farmers.

To address these challenges, next-generation breeding approaches such as genomic selection, genomic editing, and marker-assisted selection (MAS) must be leveraged to accelerate the development of climate-smart crops. These advanced breeding techniques enable the identification of desirable traits, enhancing crop adaptability and resistance to extreme weather conditions. However, their successful implementation requires an integrated approach that combines biotechnology, agronomy, and precision agriculture to optimize breeding outcomes.

Beyond breeding innovations, strengthening agricultural extension services is essential for bridging the knowledge gap and increasing adoption rates. Given the significant role of extension agents in technology dissemination, policymakers should focus on enhancing farmer training programs, establishing participatory variety selection (PVS) farms, and promoting demonstration plots to showcase the performance of new varieties under real farming conditions. Additionally, digital tools and social media platforms can be further utilized to facilitate knowledge sharing and increase farmers' exposure to modern agricultural innovations.

Another critical aspect to consider is the role of seed systems in determining adoption success. The results of this study confirmed that timely access to quality seeds is a fundamental prerequisite for technology uptake. Strengthening formal seed production and distribution networks, while improving the regulation of informal seed markets, can ensure that farmers have reliable access to high-quality seeds at the right time. Furthermore, partnerships between research institutions, seed companies, and governmental organizations can help streamline seed delivery mechanisms and improve varietal turnover rates.

Finally, future research should explore the long-term socioeconomic impacts of adopting new varieties, particularly in terms of profitability, sustainability, and food security. Investigating farmers' risk perceptions and market-related barriers could provide deeper insights into adoption constraints and help design more effective interventions. Moreover, assessing the role of farmer cooperatives and collective action in facilitating technology diffusion could offer new strategies for improving adoption rates.

The findings of this study underscore the importance of multiple factors—including education, seed availability, extension services, and social media—in influencing the adoption of new varieties. While breeding advancements are necessary to develop climate-adaptive crops, ensuring their successful adoption requires an integrated approach that addresses access to improved seeds, knowledge dissemination, and farmer engagement. By strengthening seed systems, leveraging digital tools, and expanding participatory breeding programs, policymakers and agricultural stakeholders can enhance the adoption of improved varieties, ultimately contributing to greater agricultural productivity and resilience in Iran.

The primary limitation of this study stems from its reliance on self-reported survey data collected from farmers in selected counties. This methodological approach may introduce response biases, particularly social desirability bias that could lead to inflated adoption rate reporting. Building on these findings, we propose the following directions for future research:

- Conduct panel studies to track adoption dynamics over time and assess causal effects of interventions (e.g., training programs).
- Use quasi-experimental designs to evaluate policy impacts on improved varieties adoption.
- Investigate how climate-smart varieties perform under local conditions and how farmers perceive their adaptability.

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تحلیل پروبیت عوامل مؤثر بر پذیرش ارقام اصلاح شده توسط بهره برداران در ایران

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چکیده

ارقام اصلاح شده گیاهی در ارتقاء بهره وری کشاورزی در سطح جهان از اهمیت حیاتی برخوردارند. این مطالعه به بررسی عوامل مؤثر بر پذیرش ارقام جدید غلات آبی و دانه‌های روغنی (معرفی‌شده بین سال‌های 2015-2022) در بین بهره برداران در ایران پرداخته است. داده‌ها از 1001 پاسخگو با استفاده از روش نمونه‌گیری چندمرحله‌ای جمع‌آوری و با استفاده از آمار توصیفی و مدل رگرسیون پروبیت تجزیه و تحلیل شد. نتایج نشان داد که 58 درصد از پاسخ‌دهندگان، ارقام معرفی‌شده در این بازه زمانی را پذیرش نکرده‌اند. برآوردهای مدل پروبیت، چندین عامل مهم مؤثر بر پذیرش ارقام جدید را شناسایی کرده اند که عبارتند از: سطح تحصیلات، میانگین درآمد سالانه، دسترسی به بذر اصلاح شده، نظام تأمین بذر، مشارکت در دوره‌های آموزشی، ارتباط با کشاورزان پیشرو، ارتباط با مروجان ترویجی، استفاده از رسانه‌های اجتماعی، نگرش نسبت به برتری ارقام جدید نسبت به ارقام قدیمی، مزیت نسبی، قابلیت مشاهده نتایج و سازگاری ارقام اصلاح شده با شرایط منطقه. به منظور افزایش میزان پذیرش ارقام جدید، اجرای برنامه‌های ترویجی از طریق خدمات ترویجی کارآمد - نظیر مزارع انتخاب مشارکتی ارقام (PVS) یا مزارع الگویی - همراه با دوره‌های آموزشی مؤثر پیشنهاد می‌شود. در دسترس بودن بذر باکیفیت در زمان مناسب برای کشاورزان نیز می‌تواند احتمال پذیرش ارقام جدید را افزایش دهد. تأثیر معنادار آموزش و عوامل

ترویجی، نقش حیاتی برنامه‌های ساختاریافته اطلاع‌رسانی و آموزش را تأیید می‌کند. افزون بر این، اهمیت سازگاری رقم با شرایط منطقه‌ای، لزوم توجه به سازگاری اقلیمی در برنامه‌های به نژادی را برجسته می‌سازد. درک عوامل موثر بر پذیرش می‌تواند بازخورد ارزشمندی در مورد ارقام عرضه‌شده و همچنین بینشی درباره موانع پذیرش گسترده آنها در اختیار نهادهای تحقیقاتی ذیربط قرار دهد.