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Exploring the Relationship between Information-Seeking Behavior and Adoption of Biofertilizers among Onion Farmers

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Abstract: Recently, there has been increasing concern about reducing and replacing chemical fertilizers with biofertilizers to enhance soil fertility and maintain agroecosystems and sustainable agricultural production. Given that knowledge of biofertilizers is information-intensive, the lack of information-seeking behavior (ISB) might be the primary constraint for farmers adopting biofertilizers. This study aimed to analyze how ISB influences farmers' adoption of biofertilizers, using a sample of 228 onion farmers in Al-Ahsa Governorate, Saudi Arabia. The results indicate that most farmers had a moderate level of ISB. The most frequently accessed sources were mobile applications, extension institutions, and progressive farmers. The results of cluster analysis show that farmers' ISB differed significantly according to their main occupation. Among the onion farmers, 35%had adopted biofertilizers. The findings also reveal that farm size, attitude toward biofertilizers, the credibility of information sources, and the usefulness of the information positively and significantly influence farmers' adoption of biofertilizers. It was concluded that understanding the relationship between adoption and ISB could assist policymakers in focusing on knowledge diffusion when designing extension programs and advisory services to facilitate better usage of biofertilizers.

Keywords: adoption; information; behavior; biofertilizers; farmers

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1. Introduction

The production of goods and services in the knowledge-based economy is based on knowledge-intensive activities that contribute to innovative ideas, information, and practices [1]. In the era of the knowledge economy and the evolution of information communication technologies over the last 20 years, the agriculture sector has become an information-intensive industry [2,3]. Globally, agricultural information and knowledge are a source of power and the most important capital among other types of capital for improving and sustaining agricultural production [4,5]. Parmar et al. [6] noted that context-specific information is crucial to help farmers make informed decisions and reduce uncertainty. Furthermore, information opens windows for new markets for providing experiences, adopting best practices, and finding sources of financial aid [6,7]. Therefore, farmers should develop information literacy by accessing and collecting relevant information in a timely manner from varied sources to meet their needs and overcome agricultural problems [2,8]. This process of interacting with information sources is called information-seeking behavior (ISB) [9].

ISB is a fundamental human process for lifelong learning and problem-solving [10,11]. According to the conceptual framework of Wilson's model (1997) [12], information-seeking behavior is a purposive set of actions by which an individual searches for, evaluates, selects, and uses information to satisfy specific goals. Hence, this behavior requires interaction with other persons and various information sources and systems [13,14]. In agricultural production, ISB enables farmers to access reliable and timely information, get advice on how to use innovations, improve the quality of decision-making, and network with other actors in the agricultural knowledge and innovation system [3,15,16]. Consequently, inadequate information based on farmers' ISB may result in the failure to design and develop extension and advisory programs and other interventions to meet farmers' needs [17,18].

ISB is an essential component in the diffusion and adoption of agricultural innovations. The decision to adopt a particular innovation is affected by the information the farmer gains, as well as his or her knowledge and attitude toward innovation [19]. Based on Rogers's stages of adopting innovations [20], the nature of farmers' adoption of innovations is analyzed along a five-step process. In the first stage, the farmer gains knowledge about an innovation from formal sources (training, research, and extension institutions) or informal sources (neighbors, relatives, or friends) [21]. The farmer's ability to gain information is affected by their social capital and cognitive level [22,23]. The second stage is about forming an attitude about the innovation; then the farmer makes a decision, implements it, and confirms it in the last stage [20]. Additionally, adoption behavior is a function of a psychological process and a diffusion of dynamic technology from cognition to decision, which is affected by three main factors: (i) the characteristics of individuals, (ii) the characteristics and relative performance of the innovation, and (iii) the social and cultural characteristics of the community [24–27].

Biofertilizers are one of the most popular innovations applied to ensure sustainable agricultural production in recent years. Biofertilizers are described as substances containing live microorganisms (useful bacteria and fungi) that are applied to seeds, plant surfaces, or roots [28,29]. Biofertilizers are classified into three categories: nitrogen-fixing, phosphorous solubilizing and mobilizing, and micronutrient biofertilizers [30]. According toWalkiewicz, et al. [31], biofertilizers are an eco-friendly approach for the plant and soil environment. They have a significant effect on improving soil health, increasing the availability of mineral nutrients for plants, and stimulating plant growth through different mechanisms connected with microbial activity [29,32–34]. Furthermore, biofertilizers increase volatile organic compounds due to the normal metabolic activities of microorganisms which play a key role as signals in plant–microbe interactions and stimulating plant growth [35–37]. Biofertilizers not only can increase crop productivity and improve soil microbial balance, but may also have the potential to prevent plant pests and diseases by indirect competition with, or direct inhibition of, pathogens through their metabolic activities [38–42]. It has also been confirmed that biofertilizers are now widely employed as remediation agents for pesticide-contaminated soil [30,43,44]; this is important for the biological reclamation of degraded lands, including soils contaminated by industry and mining [45–47]; and for the enhancement of plant water-stress tolerance, especially in arid and semi-arid areas [48–51].

The present study considers the implementation of biofertilizers for onion cultivation in Saudi Arabia. Onion (*Allium cepa* L.) is the second most abundant vegetable crop in Saudi Arabia after tomatoes, occupying 5200 ha (2018–2019 season) of the total cultivated area [52]. The total annual production of onions was around 70,000 tons (2018–2019 season), which made the country rank 80th among the largest onion producers in the world [52]. The quantity of onions produced is not sufficient enough to meet the demands for both domestic requirement and exports [53]. Al-Hasa Oasis in the Al-Ahsa Governorate in the eastern region is the main producing area of onions in Saudi Arabia. Seventy percent of onion production comes from smallholder farmers, mainly in the Al-Hasa Oasis. Sixty percent of small-scale farmers produced onion on a land size of 0.25–1.0 hectares. Onion production was found to be the major source of livelihood to more than 60% of farmers in the Al-Hasa Oasis [53]. Onion seeds are cultivated in nurseries from October to November, and are then transplanted to land for four months (December to the end of March) [54]. Additionally, of all the onion varieties, red onions comprise around 75% of the total production [53]. Biofertilizers provide required nutrients to enhance the growth of onions and improve the quality. According to Petrovic, et al. [55], the morphology of the onion's root system facilitates a good response to biofertilizers. This response can be observed by more N absorption and effective synthesis of more carotenoids and chlorophylls [56].

Based on the reviewed literature, there have been a variety of studies on the factors influencing the adoption of innovations and the information-seeking behavior of farmers in general, but there is limited evidence on the relationship between ISB and the adoption of onion farmers in particular. Additionally, few studies have attempted to evaluate the adoption of biofertilizers, particularly in the context of Saudi Arabia. The present study fills this research gap by gathering survey data from onion farmers in the eastern region of Saudi Arabia.

This study aimed to understand the relationship between farmers' adoption of biofertilizers and their ISB for innovations. The first objective was to analyze farmers' ISB, the second was to determine the differences in ISB according to biofertilizer adoption and farmers' socioeconomic characteristics, and the third was to understand the effect of information-seeking behavior and socioeconomic characteristics influencing farmers' adoption of biofertilizers.

2. Methodology

2.1. Survey Design

The present study employed a quantitative research approach. A cross-sectional survey design was adopted, using a questionnaire as the overarching research strategy. The study was conducted in Al-Umran district (25.2524° N, 49.4313° E), Al-Ahsa Governorate, in the eastern region of the Kingdom of Saudi Arabia (Figure 1). Al-Umran district is located in the eastern part of the Al-Ahsa Oasis, the largest oasis in the world, with a total area of 2000 ha. Thirty-seven percent of onion farmers in the study area during the 2019–2020 agricultural season depended fully on onion production, while the others cultivated other crops such as palm, onions, tomatoes, okra, eggplants, rice, and grapes [53]. The district was selected for data collection due to its fertile land and high rate of onion production in the governorate.

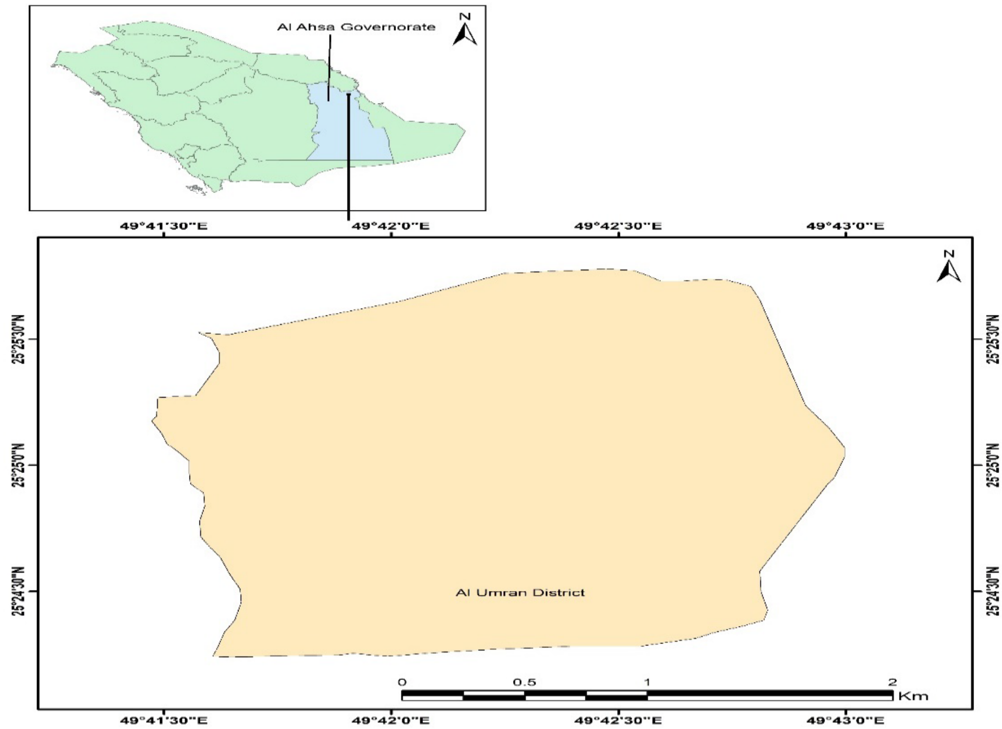

Figure 1. Map of study area. Source: Kassem, et al. [57].

2.2. Sampling Procedure

Based on the number of onions produced, five villages in the district were purposely selected: Al-Olaya, Abo Thor, Al-Remila, northern Al-Umran, and southern Al-Umran.

The study population consisted of all farmers involved in onion production during the 2019–2020 agricultural season (n = 1284). Simple random sampling was employed using Yamane's [58] sample size determination formula with a 95% confidence level and ±5% margin of error. A total of 228 respondents were determined as the total sample size for data collection.

2.3. Survey Data Collection

The survey was performed between December 2020 and February 2021. Face-to-face interviews were conducted using structured questionnaires. The questionnaire was developed based on previous studies in the field of ISB [18,57,59–61]. The developed instrument focused on collecting data on the socioeconomic characteristics, the adoption of biofertilizers, and ISB of farmers.

Farmers' ISB was measured based on 4 variables: the number of information sources they were exposed to, the frequency of use of the information on the farm, the credibility, and the usefulness of the information. Farmers were asked to determine the frequency with which they used each source (16 sources) according to a 5-point Likert scale (5 = daily, 4 = weekly, 3 = monthly, 2 = seasonally, 1 = yearly, 0 = never). The respondents were also asked to determine the credibility and usefulness of information by the Likert scale (ranging from 5 = very high to 1 = very low). For each information source, the overall scores for the variables of ISB (accessibility, credibility, and usefulness) were summed to determine the relative importance of each source. In cluster analysis, the overall scores for the variables of ISB were summed for all information sources and converted into percentages. Farmers' ISB was classified as high if it was at a level higher than 75% (mean > 3.75), moderate if it was between 50 and 75% (mean 2.50–3.75), and low if it was less than 50% (mean < 2.50). The data collection tool was first prepared in Arabic and then translated into English. A panel of 5 experts at King Saud University in the fields of agricultural extension and mass communication were selected to examine the suitability of the tool to the study's purpose and the relevance of the content. The questionnaire was pre-tested on 15 farmers in the study area before data collection to assess whether the intent of the questions was understood and ensure that they were readable.

2.4. Data Analysis

SPSS v. 25.0 (IBM Corp, Armonk, NY, USA) was used to analyze the survey data. Percentages, means, and standard deviations were calculated to describe the variables. Cluster analysis was used to define groups of farmers with similar ISB. To compare clusters of farmers' ISB according to socioeconomic characteristics, the Kruskal–Wallis test was performed. Additionally, Dunn's test for multiple comparisons was applied to determine which specific means were significant compared to the others. Based on the dichotomous decision of "adopt" or "not adopt" (dependent variable), a binary logit model was used to analyze the determinants of farmers' adoption [62]. The response to farmers' adoption of biofertilizers in onion production can be written as follows:

$$Y_i = \begin{cases} 1\, if\ a\ farmer\ has\ adopted\ biofertilizers \\ 0\, if\ a\ farmer\ has\ not\ adopted\ biofertilizers \end{cases} \tag{1}$$

Supposing Pi is the probability of being adopted and $1 - Pi$ is the probability of not being adopted:

$$Pi = \frac{1}{1 + e^{-Zi}} \tag{2}$$

$$1 - Pi = \frac{1}{1 + e^{Zi}} \tag{3}$$

The equation for the binary logit model is as follows [63]:

$$\frac{Pi}{1 - Pi} = e^{\beta i Xi + ui} \tag{4}$$

$$ln\left(\frac{Pi}{1-Pi}\right) = \beta iXi + ui, \ldots = 1,2,3, \ldots n \quad (5)$$

where ln is the odds ratio, Xi is the set of independent variables, βi is coefficient of independent variables, and ui is an error term.

This study employed the following binary logit equation to determine the factors affecting farmers' adoption of biofertilizers in onion production:

$$ln\left(\frac{Pi}{1-Pi}\right) = \beta 0 + \beta 1\ AGE + \beta 2\ EDU + \beta 3\ OCCU + \beta 4\ EXP + \beta 5\ FSIZE + \beta 6\ FINCO + \beta 7\ MCOOP + \beta 8\ BTRAIN + \beta 9\ BATTIT + \beta 10\ NSOUR + \beta 11\ ACCESS + \beta 12\ CRED + \beta 13\ USEFUL + ui \quad (6)$$

Table 1 presents the definitions of variables in the adoption model. The impact on onion farmers' decision-making regarding biofertilizers was predicted based on the previous literature on farmers' behavior toward adopting agriculture technology.

Table 1. Variable settings and descriptions in adoption model.

Variable (Symbol)	Definition and Assignment	Sign
Age (AGE)	Years of age	−
Education level (EDUC)	Education status of farmer;dummy variable (1 if farmer had formal education, 0 otherwise)	+
Main occupation (OCCU)	Main occupation status of farmer; dummy variable (1 if agriculture, 0 otherwise)	+
Experience of onion planting (EXP)	Years of experience cultivating onions	+
Onion farm size (FSIZE)	Cultivated area owned, in hectares	+
Percentage of family income from onion (FINCO)	Percentage of total family income from onions in 2019	+
Membership in agricultural cooperatives (MCOOP)	Dichotomous variable (No = 0, Yes = 1)	+
Biofertilizer training experience (BTRAIN)	Dichotomous variable (No = 0, Yes = 1)	+
Attitude toward biofertilizers (BATTIT)	Categorical variable (apply immediately = 3, apply when good results appear = 2, apply when most others apply = 1)	−
Number of sources (NSOUR)	Number of information sources farmer was exposed to; continuous variable	+
Accessibility (ACCESS)	Frequency of access to information sources; continuous variable	+
Credibility (CRED)	Trustworthiness of information obtained from sources; continuous variable	+
Usefulness (USEFUL)	Quality of information obtained from sources; continuous variable	+
	Dependent variable	
Adoption of biofertilizers	Dichotomous variable (No = 0, Yes = 1)	

(+/−) indicates positive or negative relationship with dependent variable.

3. Results

3.1. Socioeconomic Characteristics of Farmers

The socioeconomic characteristics of the respondents are summarized in Table 2. The results indicate that the average age of the farmers was 52.72 years. Nearly 65% of them were between 41 and 60 years old, and 22.4% were over 60 years old. More than one-third of the farmers (36.4%) had an intermediate education, and very few had a higher education (7.5%). Among the sample, agriculture was the main occupation for 30.3%, more than half (53.9%) were involved in agriculture and other occupations, and 15.8% considered off-farm activities as their main occupation. Among the respondents, 53.1% had less than 11 years of experience with planting onions and only 6.1% had more than 20 years of experience; the average experience with onion planting was 10.95 years. The respondents were characterized as small-scale farmers, with an average onion farm size of 1.09 ha. The largest onion cultivation area was 7 ha. However, less than half the farmers (45.2%) had less than 1 hectare of onions, 36% had more than 2 hectares, and 18.86% had 1–2 hectares. As to onion income as a percentage of total family income, in the largest group (50.9%), onion income accounted for less than 25% of total income. For only 8.8% of farmers, it accounted for more than 75% of total family income. Around half of the respondents (50.4%) were members of the local agricultural cooperation. In terms of biofertilizer training experience, the results show that 68%of the respondents had not received any training. In addition, a small proportion of respondents (18.9%) claimed that they would use biofertilizers immediately, whereas 49.1% claimed that they would apply it when positive results appeared, and 32% would use it when most farmers had applied it. Regarding adoption by the entire survey sample, 81 farmers (35.5%) had adopted biofertilizers for their onion farms, while the other 147 (64.5%) had not.

Table 2. Descriptive summary of farmers' characteristics.

Farmers' Characteristics	Number of Farmers = 228	
	Frequency	%
Age (min. = 21, max. = 80, mean = 52.72, SD = 10.59)		
Younger than 41 years	30	13.1
41–60 years	147	64.5
Older than 60 years	51	22.4
Education level		
Primary school or below	64	28.1
Intermediate	83	36.4
Secondary	64	28.1
University	17	7.5
Main occupation		
Agriculture	69	30.3
Non-agriculture	36	15.8
Agriculture and business	57	25.0
Agriculture and employment	66	28.9
Experience with onion planting (min. = 2, max. = 28, mean = 10.95, SD = 5.50)		
Less than 11 years	121	53.1
11–20 years	93	40.8
More than 20 years	14	6.1
Onion farm size (min. = 0.1, max. = 7, mean = 1.93, SD = 1.42)		
Less than 1 hectare	103	45.1
1–2 hectares	43	18.9
More than 2 hectares	82	36.0
Percentage of family income from onion (min. = 10, max. = 85, mean = 35.93, SD = 19.71)		
Less than 25%	116	50.9
25–50%	58	25.4
51–75%	34	14.9
More than 75%	20	8.8

Table 2. *Cont.*

Farmers' Characteristics	Number of Farmers = 228	
	Frequency	**%**
Membership in agricultural cooperative		
Yes	115	50.4
No	113	49.6
Biofertilizer training experience		
Yes	73	32
No	155	68
Attitude toward biofertilizers		
Apply immediately	43	18.9
Apply when good results appear	112	49.1
Apply when all others applied	73	32
Adoption of biofertilizers		
Adopters	81	35.5
Non-adopters	147	64.5

3.2. Farmers' ISB

3.2.1. Types of Information Accessed

Figure 2 presents the types of information accessed by onion farmers to meet their needs. The findings demonstrate that information related to disease and pest control ranked first, with an average of 4.12. Post-harvest information ranked second, with an average of 4.07, and information on marketing ranked third (3.92). Information on biofertilizers ranked sixth, with an average of 3.37. This reflects that the respondents had a moderate level of access to information related to biofertilizers. To conclude, access was frequent for four types of information, moderate for fivetypes, and low for six types.

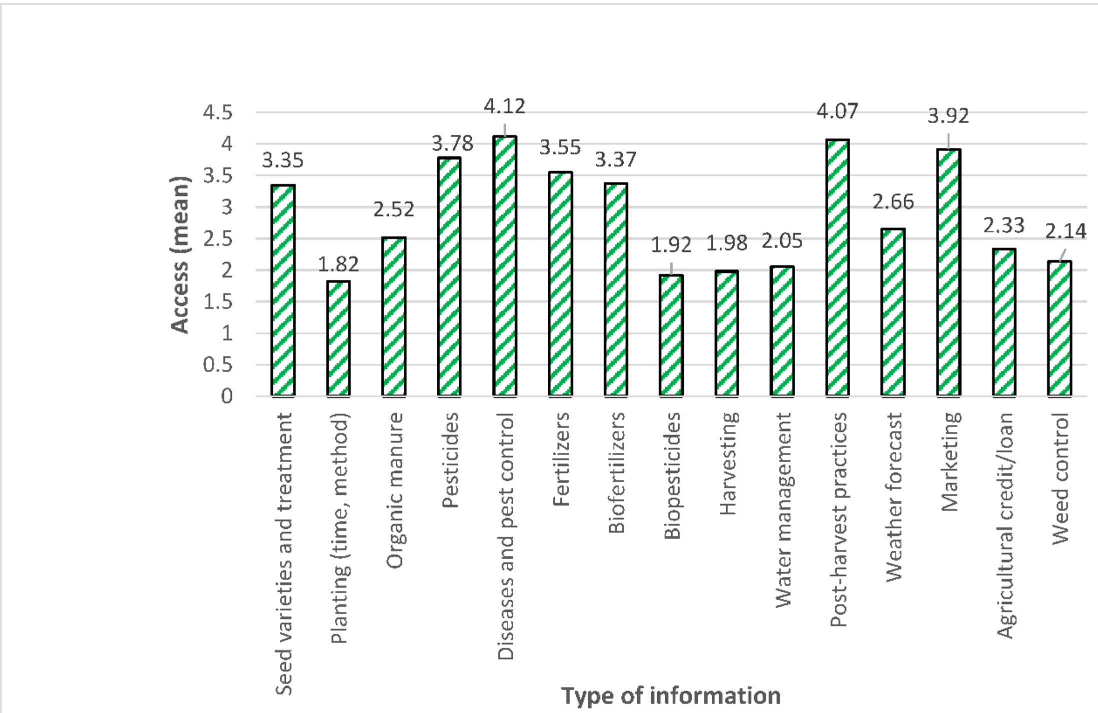

Figure 2. Types of information accessed by farmers.

3.2.2. Information Sources

Figure 3 presents the distribution of information sources according to accessibility, credibility, and usefulness of information delivered from the farmers' perspective; it can be observed that the means of the three variables ranged between low and moderate levels for all sources. The findings show that the most frequently accessed source was mobile applications, with a mean of 3.52, followed by extension institutions (3.42), and progressive farmers (3.42). In terms of the credibility of information, the sources can be ranked in descending order as follows: progressive farms (3.18), mobile applications (3.15), and input suppliers (3.11). In the same vein, only four sources (mobile applications, input suppliers, research centers, extension institutions) were ranked as having a moderate level of usefulness (mean 2.5–3.75), while the other sources were ranked lower. This finding reflects a moderate level of farmers' ISB. Furthermore, it was observed that the levels of accessibility, credibility, and usefulness varied for each source and between sources.

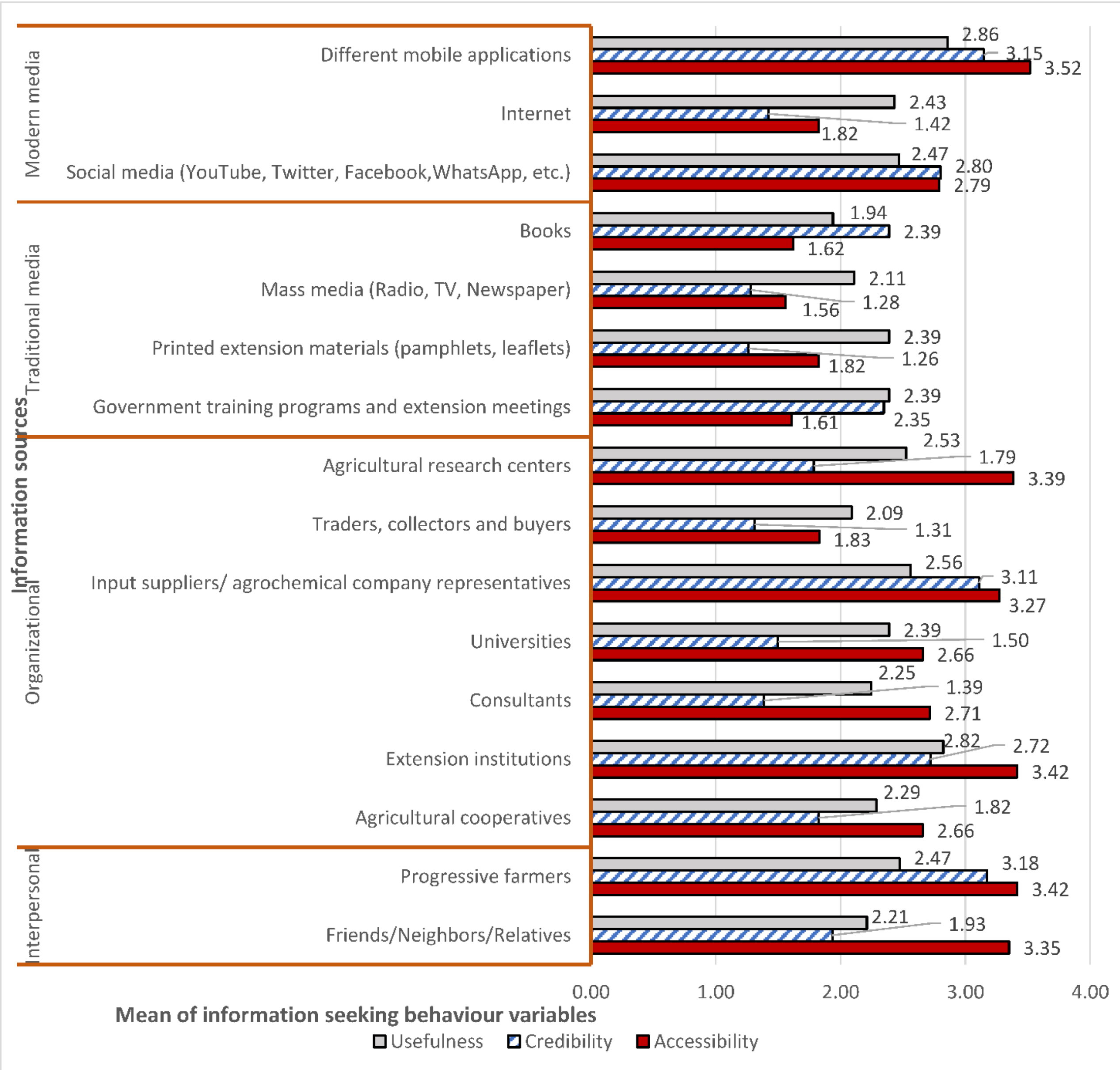

Figure 3. Farmers' information-seeking behavior with various information sources.

3.2.3. Clusters of Information-Seeking Behavior

Farmers' information-seeking was identified using cluster analysis based on the number of sources they were exposed to, accessibility, credibility, and usefulness, as shown in Table 3. The results show that the average number of sources accessed by the respondents was 7.44 and sources were accessed seasonally, with a mean of 2.59. The mean values of perceived trust in the information delivered ranged from one to four, with an overall average of 2.18, indicating a moderate level of credibility from the farmers' perspective. Additionally, the average level of usefulness reached 2.48, indicating a moderate level of perceived benefit from the information delivered.

Table 3. Descriptive statistics for four variables used in farmers' information-seeking behavior clusters.

Variable	Min.	Max.	Mean	Standard Deviation
Number of sources	3	13	7.44	2.00
Accessibility	1	4	2.59	0.42
Credibility	1	4	2.18	0.57
Usefulness	1	4	2.48	0.64

Based on the results of cluster analysis by the *k*-means method, farmers' ISB could be classified into three categories, as shown in Table 4. Cluster I, the smallest group (24.56%), was exposed to the highest number of sources (10.37 on average, 64.81% of the maximum score); had a frequency of access of 2.75 (55% of the maximum score); had a moderate level of credibility regarding the information delivered, with a mean score of 2.17; and received moderate benefit from the information, with a mean score of 2.25. Cluster II represented the largest percentage among all groups (50.44%), explored fewer information sources (44.43% of the maximum score), exhibited less frequent access (52.20%), had the highest level of perceived credibility of the information delivered (45.20%), and had the highest level of perceived usefulness, with a mean score of 2.52. On the other hand, cluster III represented 25% of the sample, was exposed to the fewest sources of information (32.62%), had the least frequent access (47.80%), had the lowest level of perceived credibility (39.20%), and had a moderate level of perceived usefulness (2.26 on average, 45.20% of the maximum score). The ANOVA results also revealed that ISB clusters differed significantly for all the variables ($p < 0.01$).

Table 4. Behavior of information-seeking clusters identified from cluster analysis.

Clusters	Number of Farmers (%)	Number of Sources		Accessibility		Credibility		Usefulness	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cluster I	56 (24.56%)	10.37	1.25	2.75	0.38	2.17	0.51	2.25	0.74
Cluster II	115 (50.44%)	7.11	0.39	2.61	0.37	2.26	0.61	2.52	0.58
Cluster III	57 (25.0%)	5.22	0.80	2.39	0.49	1.96	0.52	2.26	0.61
F		363.1 **		68.31 **		193.78 **		277.83 **	

SD (standard deviation) ** Statistically significant at 1%.

3.3. Differences among BehaviorClusters According to Socioeconomic Characteristics

The Kruskal–Wallis test was conducted to examine the differences among behavior clusters according to socioeconomic characteristics, as presented in Table 5. Significant differences (chi square = 6.77, $p < 0.05$) were found among the three clusters according to main occupation. The results of Dunn's test showed that the mean value of cluster III significantly differed at $p < 0.05$ from the group means of cluster I. On the other hand, no significant differences were found among clusters and their level of adopting biofertilizers, at $p < 0.05$. In the same vein, there were no significant differences among clusters at a 0.05 probability level regarding age, education level, experience with onion planting, farm size, family income from onion, membership in agricultural cooperatives, biofertilizer training experience, and attitude toward biofertilizers.

Table 5. Differences among clusters of information-seeking behavior according to farmers' socioeconomic characteristics.

Variables	Cluster I	Cluster II	Cluster III	Kruskal-Wallis Test		Dunn's Test			
				χ^2	*p*-Value	Mean Difference		Std. Error	*p*-Value
Age	53.32	52.39	52.81	0.68	0.71				
Education level	0.41	0.36	0.28	2.17	0.33				
						I–II	−11.31	8.55	0.18
Main occupation	0.19	0.29	0.42	6.77 *	0.03	I–III	−25.61 *	9.87	0.03
						II–III	−14.29	8.50	0.09
Experience with onion planting	11.30	10.93	10.63	0.79	0.67				
Onion farm size	2.13	1.88	1.84	1.93	0.38				
Percentage of family income from onion	36.71	35.51	36.05	0.71	0.70				
Membership in agricultural cooperative	0.55	0.51	0.44	1.55	0.46				
Biofertilizer training experience	0.39	0.33	0.23	3.62	0.16				
Attitude toward biofertilizers	1.83	1.85	1.92	0.54	0.76				
Adoption of biofertilizers	0.27	0.36	0.44	3.58	0.17				

* Significant at 0.05 level.

3.4. Factors Influencing the Adoption of Biofertilizers

A binary logistic regression model was used to predict farmers' adoption of biofertilizers using socioeconomic characteristics and ISB variables as predictors, as shown in Table 6. A test of the full model against a constant-only model was statistically significant, indicating that the predictors as a set reliably distinguished between adopters and non-adopters of biofertilizers (chi-square = 87.36, $p < 0.01$, df = 13). A Nagelkerke's R^2 value of 0.482 indicates a moderately strong relationship between dependent and explanatory variables. Prediction success overall was 79.1% (89% for non-adopters and 61.3% for adopters). The findings indicate that onion farm size ($p = 0.001$), attitude toward biofertilizers ($p = 0.00$), number of sources ($p = 0.007$), and credibility of information delivered ($p = 0.014$) were the main variables that had a significant influence on the adoption of biofertilizers in the study area. The other explanatory variables included in the model were not significant predictors of biofertilizer adoption.

Table 6. Factors influencing adoption of biofertilizers.

Variable	Coefficients	Odds Ratio	Std. Err.	z	*p* > z
Constant	−5.555	0.004	1.810	9.418	0.002
Age	0.019	1.020	0.019	1.018	0.313
Education level	0.005	1.005	0.414	0.000	0.990
Main occupation	−0.197	0.821	0.281	0.491	0.484
Experience with onion planting	−0.004	0.996	0.044	0.008	0.929
Onion farm size	0.582 **	1.790	0.173	11.371	0.001
Percentage of family income from onion	0.013	1.013	0.012	1.069	0.301
Membership in agricultural cooperative	0.680	1.973	0.479	2.014	0.156
Biofertilizer training experience	−0.466	0.627	0.414	1.270	0.260
Attitude toward biofertilizers					
Apply when good results appear	−1.719 **	0.123	0.478	12.949	0.00
Apply when most others apply	−2.097 **	0.179	0.528	15.748	0.00
Number of sources	0.271 **	0.762	0.101	7.253	0.007
Accessibility	0.570	1.768	0.570	0.998	0.318
Credibility	1.136 **	3.113	0.461	6.072	0.014
Usefulness	−0.371	0.690	0.341	1.180	0.277
	chi-square (13) = 87.36 **				
	Nagelkerke's R^2 = 0.482				

** Statistically significant at 1%.

4. Discussion

This study analyzed ISB to explore the number and type of information sources accessed, the frequency of access, and the credibility and usefulness of information. This behavior was examined in relation to farmers' adoption of biofertilizers in the study area. The insights from this examination will enrich the existing literature on the adoption of innovations, which is mainly based on studying the effects of innovation characteristics and personal attributes on adoption. From a theoretical point of view, farmers with strong ISB are more likely to adopt innovations. This study assessed how onion farmers with different socioeconomic characteristics and behaviors adopt biofertilizers in the study area. This approach provides a series of guidelines to design agricultural advisory services and improve decision-making to meet farmers' needs.

4.1. Farmers' Information Seeking Behavior

The results of the study show that the category of farmers with a moderate level of ISB was the largest. This may be attributed to the lack of extension services in the study area to increase awareness of agricultural innovations. Additionally, given that the majority of respondents were either illiterate or had only finished intermediate education, these farmers may be unwilling to read, understand, and interpret the various agricultural recommendations [47,49]. Hence, governments in developing countries should pay attention to, and invest in, enhancing the quality of informal education provided by extension and advisory services and adult literacy [18]. In this regard, Kassem [59] argued that extension services could support farmers' information behavior with two approaches: developing different delivery and content strategies for agricultural advisory programs, and acting as a broker between the various actors in the agricultural value chain. This role would enable farmers with low information behavior to access needed and timely information and accelerate the rate of adoption of innovations [64].

4.2. Farmers' Adoption Level of Biofertilizers

A low level of biofertilizer adoption was observed among onion farmers in the study area. A probable explanation for this finding might be that farmers have insufficient knowledge of biofertilizers, and thus, searching for information about them is not a priority. This interpretation was confirmed by the study results, which showed that the majority of respondents did not receive training on biofertilizers. They have a neutral attitude toward biofertilizers and good access to information related to post-harvest, marketing, and disease and pest control. In the same context, several studies conducted in India summarized the constraints that farmers face in adopting biofertilizers, including a lack of awareness regarding their use and benefits, a lack of supply centers in rural areas, and the absence of timely guidance from extension services [65–72].

To overcome the challenges of adoption and promote the production of quality biofertilizers, Atieno, et al. [73] and Raimi, et al. [74] noted an urgent need for procedures such as conducting adequate biofertilizer research, implementing effective regulatory frameworks and quality control management, providing adequate and effective extension programs, conducting agromarket development, and providing biofertilizers on the market at an affordable price. The findings are consistent with previous studies that reported low or medium levels of farmers' adoption of biofertilizers [75–81].

4.3. Factors Influencing Adoption of Biofertilizers

The findings confirm that farm size had a positive and significant effect on the adoption of biofertilizers by onion farmers in the study area. For each unit increase in farm size, the odds of a farmer adopting biofertilizers were 1.790, suggesting that those with larger farms were more likely to adopt biofertilizers, probably due to the scale efficiency that allows farmers to learn and apply new technologies and gain more income [82]. These reasons encourage farmers who own and manage more resources to purchase high-quality production inputs and take risks by adopting innovations [83]. In other words, having a larger farm will accelerate the adoption of biofertilizers, whereas having a smaller farm may discourage farmers from adopting biofertilizers in Saudi Arabia. These findings are in line with previous studies that reported that farm size had a positive influence on the adoption of biofertilizers [66,75,79,80,84].

Neutral and negative attitudes toward biofertilizers were the main factors that negatively and significantly affected the adoption of biofertilizers in the study area. Farmers who had a neutral attitude were less likely to adopt biofertilizers by about 88% (odds ratio = 0.123). Likewise, farmers who had a negative attitude were less likely to adopt biofertilizers by about 82% (odds ratio = 0.179). The findings suggest that attitude was the main prerequisite for onion farmers to adopt biofertilizers in the study area. As noted by AlSaleh and Thakur [85], one's attitude toward innovation is the cognitive process that represents one's positive or negative feeling about adopting an innovation. Attitudes toward innovations are hypothesized to be influenced by internal beliefs, including past experience, perceived benefits, perceived difficulty, compatibility, and enhanced value. These beliefs may hinder farmers from reading, understanding, and acquiring sufficient knowledge about innovations [86,87]. Consequently, if not addressed at a high priority level, a negative attitude toward biofertilizers is more likely to hinder onion farmers in the study area from adopting biofertilizers. These findings suggest that policies and interventions should be targeted toward improving the distribution of biofertilizers by raising awareness about their advantages in sustainable agricultural production and enhancing the government's primary role in facilitating collaboration among actors in the agricultural innovation system [65]. The results of this study are in agreement with previous studies showing that attitude toward biofertilizers was the main variable determining their adoption [76,77,88].

The results show that accessing a number of information sources significantly and positively affected the adoption of biofertilizers in the study area. For a unit increase in the variable access to information sources, the odds of a farmer adopting biofertilizers were 0.762, suggesting that those who had more access to information sources were more likely to adopt biofertilizers. A possible explanation for this result might be that access to information sources offsets knowledge constraints, thus enabling farmers to purchase ecologically friendly and cost-effective inputs such as biofertilizers which increase agricultural production and enhance the quality of onions. These findings are in agreement with previous studies conducted in Egypt that reported that exposure to information sources was a significant positive predictor of biofertilizer adoption [76,77].

The credibility of the information obtained from sources had a positive and significant influence on the adoption of biofertilizers in the study area. For a unit increase in the variable credibility of information, the odds of a farmer adopting biofertilizers were 3.113, suggesting that those who trust the information delivered were more likely to adopt biofertilizers. This result reflects that the trustworthiness of information sources is a critical factor in seeking such sources and forming a positive attitude toward innovations among farmers [59,64]. A possible explanation for this result is that farmers give preference to reliable sources to get information and follow their recommendations. Practically, it was observed during field data collection that farmers, particularly those with low information behavior, prefer interpersonal communication with other farmers, particularly progressive farmers, and relatives or neighbors, as reliable sources of information. For this reason, interventions should be undertaken to strengthen the trust between farmers and public or private information sources by maintaining transparency around the advantages and disadvantages of innovation, collaborating among stakeholders, fostering open communication between farmers and service providers, and taking responsibility to adopt innovations [89]. The results of this study are in line with previous studies reporting a positive influence of the credibility of information channels on the adoption of various agricultural innovations in general [18,64].

The current study has some limitations. First, the surveyed sample only included farmers from one geographical area. Selecting farmers from one governorate did not allow us to survey participants from different farming contexts or cultural backgrounds. Therefore, the results cannot be generalized to other governorates or other countries. Second, the investigation of farmers' ISB was in keeping with what they believed to be true. This could have biased the findings on their actual ISB. Finally, this study did not address the extent of biofertilizer adoption practices in terms of types of biofertilizers, sources of purchases, methods of application, quantity used per hectare, time of application, and precautions followed during usage and storage. This failure to determine such practices prevented us from explaining the varied levels of adoption among farmers.

5. Conclusions

This paper provides insight into the impact of ISB on the adoption of biofertilizers, using survey data from Saudi onion farmers. It contributes to the literature by filling a gap in the body of knowledge regarding how ISB may influence a farmer's choice to adopt or not adopt biofertilizers. Furthermore, this is the first empirical study to attempt an exploration of this topic in Saudi Arabia. We conceptualized ISB by analyzing four variables: the number of information channels accessed, the frequency of access, and the credibility and usefulness of the information delivered. Our results clearly show the different levels of ISB among farmers in the study area. It was concluded that ISB could motivate farmers to adopt biofertilizers if they accessed the information from various sources that they trusted. The results also reveal that a larger farm size and a positive attitude toward biofertilizers tend to increase the likelihood that farmers will adopt biofertilizers. The findings of our study have four important implications regarding how to successfully target low information behavior and promote the adoption of biofertilizers. First, to increase the use of biofertilizers, our study suggests making information on them more continuously available to farmers so that they can access it when they have a need for such information. Using social media platforms might be an efficient way to increase the intensity of information exposure with the least information cost for farmers, thus enhancing the knowledge and adoption of biofertilizers. Similarly, public extension services could consider introducing a participatory extension approach to information communication technologies, such as farmer field schools to help farmers access, learn, and share relevant information. Second, improving the reliability and timely delivery of information could positively affect farmers' attitudes toward biofertilizers. Third, we found that the most common and trusted information channels were progressive farmers within their community, as well as input dealers. These sources can be leveraged to promote the practice of using biofertilizers, such as the types of biofertilizers, proper application techniques, and precautions to be taken during their use. Lastly, the advantages of using biofertilizers should be aligned with the information that farmers need the most in the fields of disease and pest control, marketing, and post-harvest. At present, farmers' need for information is strong, and they are open to information about the practice of using biofertilizer and how they are related to preventing plant pests and diseases, and enhancing the quality of crops, promoting competitiveness, and targeting new markets. Empirical research on the impact of ISB on biofertilizer adoption in different countries is suggested. Furthermore, analyzing how the adoption of biofertilizers may be influenced by the quality of the information delivered, the types of biofertilizers, and application practices would be an interesting topic to examine.

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