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Socioeconomic and technical factors determining the adoption of hedgerows around greenhouses in southeast Spain

Belén López-Felices[1,2], *Juan Francisco Velasco-Muñoz*[1,2], *Isabel María Román-Sánchez*[1,2], *José Ángel Aznar-Sánchez*[1,2]*

[1]*Department of Economy and Business, Faculty of Economics and Business Studies, University of Almería, Almería, Spain*
[2]*Research Centre on Mediterranean Intensive Agrosystems and Agrifood Biotechnology, University of Almería, Almería, Spain*

**Corresponding author: jaznar@ual.es*

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Abstract: Pest control is one of the ecosystem services most affected by the intensification of agriculture. Pests can lead to significant losses in crop yields and jeopardise food security. In this context, installing hedgerows around greenhouses is presented as an opportunity to improve the presence of natural enemies and favour the control of pests. However, the adoption of this practice has not spread among farmers. The objective of this article is to determine the factors that affect the decision to adopt hedgerows around greenhouses by studying the case of southeast Spain. A binary logistic regression model is developed from a farmer survey of 189 farmers in the study area. The variables that are significant when explaining the installation of hedgerows are the size of the farm, the expenses, the number of methods used to combat pests, technical advice, and environmental awareness. Based on these results, action measures are proposed to promote the adoption of this practice.

Keywords: behavioural economics; biological control; logit model; non-crop vegetation; sustainability

Various ecosystem services have been negatively affected by the intensification of agricultural activity. One of the most compromised at present is the biological control of pests due to the loss of biodiversity generated by various factors, such as the simplification of the landscape, the expansion of monocultures or the excessive use of phytosanitary products (Rusch et al. 2016). Natural enemies are capable of preventing approximately half of the pests that could affect crops (Geiger et al. 2010). Therefore, this ecosystem service is fundamental to guarantee the food security of the current and future population because the annual losses of crops as a result of pests amount to between 20% and 40% globally (Sharma et al. 2017).

In this context, the development of integrated pest management (IPM) through the combination of diverse methods (biological, natural, and chemical) is presented as a good alternative to achieve economically viable pest management while minimising the possible adverse effects on both the environment and human health (Naran-

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jo et al. 2015). One of the most promising IPM techniques is conservation biological control (CBC), which seeks to favour the presence of natural enemies of pests by transforming the environment of the farm (Gontijo 2019). For this, various management practices can be used, such as providing non-crop vegetation, such as hedgerows, in the vicinity of the farms. This practice encourages the presence of natural enemies and improves their effectiveness in combating pests (Shields et al. 2019). In fact, farmlands in which homogeneous landscapes predominate have pest control levels 46% lower than those of more complex landscapes (Rusch et al. 2016). In addition, other ecosystem services, such as soil moisture conservation, weed management, pollination, nutrient cycling, or aesthetics, can also be improved by implementing this type of practice (Shields et al. 2019).

Although it has generally been considered that greenhouses offer greater protection against pests by acting as a barrier to the exterior, it must be taken into account that most greenhouses in the world have ventilation sources that connect the interior with the exterior and allow the entry of pests (Messelink et al. 2021). Therefore, installing hedgerows around greenhouses is presented as an opportunity to improve pest control. In fact, several studies have confirmed that implementing this practice has increased the auxiliary fauna in greenhouses (Rodríguez et al. 2012; Li et al. 2020). In addition to helping to control pests, the installation of hedgerows around greenhouses has other advantages, such as preventing the transfer of pests between nearby greenhouses or favouring the presence of pollinating insects (Li et al. 2020; Messelink et al. 2021). On the other hand, some studies have confirmed that the implementation of this practice is economically viable and that farmers can obtain additional economic benefits derived from the increase in the price of the harvested products by being produced in a more environmentally friendly way (Li et al. 2020; Parra et al. 2020).

Parra et al. (2020) found that the cost of installing hedgerows amounts to about EUR 405 per ha in Almeria, representing 1% of the total cost structure of a hectare of greenhouse. Adopting hedgerows can reduce phytosanitary products' use by promoting pest control. For example, adopting plants in Southeast Asian rice fields has reduced their use by 70% (Gurr et al. 2016), while non-crop vegetation has reduced the use of insecticides by an average of 34% in Beijing's eggplant greenhouse (Li et al. 2020). A study conducted in the Mediterranean region of Spain on the installation of hedgerows showed that 70% of farmers perceived a decrease in the number of phytosanitary products applied, and 80% saw an increase in auxiliary fauna (Giagnocavo et al. 2022). In addition, Li et al. (2020) estimate an increase in the selling price of the products of 0.4 EUR·kg^{-1} due to improved fruit quality and increased product value by using more environmentally friendly techniques. On the other hand, there may be other benefits derived from the provision of other ecosystem services by hedgerows, such as carbon sequestration, which is estimated to provide additional soil carbon storage of 0.15 tonnes per ha per year (Bamière et al. 2021), or enhanced pollination, which can be increased by up to 36% (Morandin et al. 2016). However, installing hedgerows can lead to a reduction in crop yields, estimated at 1.2% by Bamière et al. (2021). In any case, this practice is not very widespread among farmers who produce in greenhouses because they consider it best to maintain scarce vegetation around their farms because they believe this reduces the risk of pest infestations (Messelink et al. 2021). For this reason, it is interesting to know the factors that affect farmers' decisions about installing hedgerows around greenhouses. In general, the literature on why farmers adopt hedgerows around their farms is limited and, even so, in the case of greenhouses (Li et al. 2020; Byerly et al. 2021).

Agricultural Technology Adoption Theory is a multidisciplinary field combining decision theory, and innovation spread theory to explain the factors influencing farmers' adoption of new technologies (Ruzzante et al. 2021). The literature on this topic can be categorised into three paradigms: the innovation and diffusion paradigm, the economic constraints paradigm, and the adopter perception paradigm (Dissanayake et al. 2022). Although each paradigm highlights different factors that affect adoption rates and patterns, they overlap significantly. The innovation and diffusion paradigm emphasises the formation in the spread of innovation. In contrast, the economic constraints paradigm assumes that farmers aim to maximise utility and that resource inequalities impact adoption patterns. The adopter perception paradigm acknowledges subjectivity by considering the perceived need for innovation and the characteristics of the innovation as drivers of adoption behaviour. Overall, research on adopting agricultural technology assumes that farmers are rational decision-makers who seek to maximise their utility, and numerous factors influence this utility function (Ruzzante et al. 2021).

Factors influencing farmers' adoption decisions can be personal, farm, sociological and exogenous factors (Coulibaly et al. 2021). Age is one of the most common personal factors analysed in adoption studies with mixed results. On the one hand, the experience and resources

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available to older farmers can facilitate the adoption of new technologies (Mango et al. 2017). On the other hand, several studies suggest that younger farmers are more willing and educated to take the risk of incorporating new technologies (Kabir and Rainis 2015). The educational level of farmers is another of the most analysed factors that tend to affect technology adoption positively (Ruzzante et al. 2021). However, having a better income usually allows farmers to make the necessary investment, and therefore, the relationship between these variables is usually positive (Kabir and Rainis 2015). Farm characteristics can affect the adoption of technologies. The size is one of the most important factors in this area. The provision of larger farms may allow farmers to use part of the farm to incorporate or test new technologies, and larger farms tend to have higher incomes, which may facilitate the adoption of new technologies (Kabir and Rainis 2015). However, some studies show a negative relationship between these variables (Liu et al. 2018). Land tenure is also an important factor in favouring technology adoption (Coulibaly et al. 2021). Additionally, depending on the technology or practice to be adopted, other factors may influence the adoption process, such as climate, soil type, and markets.

Sociological factors include variables related to how farmers act and perceive certain actions. The evaluation of the advantages and disadvantages of the technologies to be adopted by farmers is a factor that can affect their final decision. Among these variables, environmental concerns have been a driving force in recent years for adopting practices and technologies that allow production with less harmful effects on the land (Prokopy et al. 2019). External factors include different aspects that can have an impact on the adoption of technologies, such as the availability of technical assistance and advice, the availability of information and contact with other farmers and membership in farmers' associations. Numerous studies establish that information is one of the most relevant elements when incorporating new technologies, as farmers need to be aware of the available technologies to decide to adopt them (Velasco-Muñoz et al. 2022). One of the ways to obtain such information, access to training sessions and technical advice is through membership in farmers' associations (Zhang et al. 2020). Furthermore, in this way, farmers can share their experiences using these technologies, which can greatly facilitate the extension of these technologies.

This work aims to determine the socioeconomic and technical factors influencing the decision to adopt hedgerows around greenhouses in southeast Spain, which has the highest concentration of greenhouses globally. Although it is a practice with several benefits and does not involve high costs, it is not very widespread in this area. In addition, efforts are being made to encourage the expansion of this practice through various instruments. On the one hand, establishing a regional subsidy covers around 80% of the cost of setting up hedgerows. On the other hand, a regulation has been approved that requires the establishment of green infrastructures on at least 1% of the greenhouse-free surface area of newly created farms. However, experts state that this regulation is not sufficient as it does not refer to the composition of these infrastructures, and in order to maintain adequate diversity, they should account for 15% of the farm.

MATERIAL AND METHODS

Study area. The area selected for this research was southeast Spain's Campo de Dalías region (Figure 1). This region was chosen because it has the largest area of greenhouses in the entire southeast of Spain, with around 68% of the total (Velasco-Muñoz et al. 2022). Although this area comprises different municipalities, the area was considered a whole for selecting the re-

Figure 1. Location of the Campo de Dalías in southeast Spain

× – municipalities in which the survey took place; × – municipality of El Ejido, where more surveys took place as the largest greenhouse area of Campo de Dalías is located
Source: Authors' own elaboration

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spondents, as the climatic, agronomic, and technical characteristics are similar in all of them. Moreover, the usual crops throughout the region are pepper, cucumber, courgette, aubergine, tomato, bean, watermelon, and melon. However, more farmers were surveyed in the municipality with the largest greenhouse area, El Ejido, representing 59% of the total.

Agricultural activity in the area has developed due to the existence of a large number of hours of sun per year, moderate temperatures, and the availability of underground water resources. However, the expansion of agriculture in the area has had some adverse effects, one of the most important being the reduction of native perennial vegetation. This has increased the vulnerability of this region to attacks by pests and diseases (Cotes et al. 2018).

Biological control began to expand in this region in 2007 because certain crops began to show resistance to commonly used pesticides, and there were no new products registered in the market that could replace them (Parra et al. 2020). The results obtained using this technique have been so good that more than 90% of the surface of greenhouses have implemented it (Cotes et al. 2018). In most farms, augmentative biological control is used so that the natural enemies reared in laboratories are introduced into the greenhouses to deal with the pests depending on the requirements of the crop at all times (Naranjo et al. 2015). However, this technique is not as effective as pesticides and involves a high cost. Therefore, other CBC techniques are spreading, such as using banker plants based on establishing complementary plants inside the greenhouse to create spaces that continuously maintain the population of natural enemies of pests (Messelink et al. 2014).

Providing hedgerows around farms would be an additional step in using CBC techniques and could help reduce the threat posed to crops by pests. To facilitate the establishment of these hedgerows in the region, several studies have determined that native species with complementary flowering stages are the most suitable plants (Cotes et al. 2018; Rodríguez et al. 2018).

Source and data collection. For the development of this study, it was necessary to collect primary information directly from the farmers for which the survey was used as a data collection instrument. The development of the questionnaire was performed by combining two qualitative methodologies. On the one hand, in-depth interviews were conducted with a group of experts in the region's agricultural activity to collect the most relevant information on installing hedgerows around the greenhouses. Five people with different profiles were interviewed: two farmers with a long professional career, the president of one of the most important cooperatives, a researcher from a private centre and the technical director of a biological control company. The interviews provided information on the relevant variables for this study. On the other hand, to test the questionnaire, a focus group was developed in which six farmers were brought together, of which three did not have hedgerows on their farms, and the other three did. The questionnaire included personal questions (age and level of education), others related to the characteristics of the farm (holding size, season income, season expenses and organic production), others related to pest control (methods used to deal with pests, use of phytosanitary products, banker plants inside the greenhouse), external factors (technical advice and cooperative membership) and a sociological factor (environmental awareness) [see Electronic Supplementary Material (ESM)]. To determine whether farmers were environmentally aware, respondents were asked to indicate the frequency with which they had performed a series of actions in their daily lives using a five-point Likert scale in which 1 corresponds to 'never' and 5 to 'always'. The elements were selected based on those used in previous studies (Paço and Lavrador 2017; Karasmanaki et al. 2021). Items include recycling, the resumption of the bathtub while brushing teeth, the restriction of the time to shower, the use of energy-saving lights, the use of energy-efficient appliances, and the resumption of lights and electric appliances when they are not in use. These responses were then converted into a single variable where farmers were considered environmentally aware if the sum of the scores on these items was greater than the median.

Sample size and selection. The sample size was calculated as follows [Equation (1)]:

$$n = \frac{Z^2 \times p \times q \times N}{e^2 \times \left(N - 1\right) + Z^2 \times p \times q} \tag{1}$$

where: n – sample size; Z – corresponding statistic with the desired confidence value (for example, 1.96 for 95%); p – probability of having the characteristic studied (0.5); q – probability if the studied characteristic is not available (that is, $q = 1 - p$); N – total population size; e – margin of error (0.05).

The number of hectares of greenhouses in the region was considered to establish the sample size because the exact number of farmers operating in the region is unknown. Specifically, the greenhouse area of the region

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amounts to 22 054 ha (Velasco-Muñoz et al. 2022). Taking into account these values, at least 378 ha should be surveyed. Finally, 189 farmers, with a total of 392 ha, were surveyed. Different associations of farmers in the region collaborated in this study, facilitating contact with farmers. The surveys were conducted in person between August and November 2021, following the sanitary standards established at any time by the authority in relation to the COVID-19. The average duration of the surveys was between 15 and 20 min.

Model specification. The logistic regression model is a standardised statistical technique for the study of the probability of a dichotomous result, considering a series of explanatory variables that affect the result (Timprasert et al. 2014). Therefore, in this study, this model was used to analyse the factors that influence the decision to adopt or not adopt hedgerows around the greenhouses of the study region. The logistic regression model is explained below, following Gujarati and Porter (2009) and Hill et al. (2011).

The adoption or not of hedgerows depends on several variables that are represented in the following Equation (2):

$$P_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{12} X_{12} \tag{2}$$

where: P_i – probability of adopting hedgerows; X_1–X_{12} – explanatory variables; β_0–β_{12} – parameter values reflecting the relative incidence of each of the explanatory variables.

This expression can also be represented as:

$$P_i = \frac{1}{1 + e^{-(Z_i)}} = \frac{e^{Z_i}}{1 + e^{Z_i}} \tag{3}$$

where: $Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{12} X_{12}$.

If P_i is the probability of adopting hedgerows, then $(1-P_i)$, the probability of not adopting hedgerows, is [Equation (4)]:

$$1 - P_i = \frac{1}{1 + e^{Z_i}} \tag{4}$$

Therefore [Equation (5)]:

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i} \tag{5}$$

If we consider the natural logarithm, we get Equation (6):

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{12} X_{12} \tag{6}$$

where: L_i – natural logarithm of the odds ratio (odds).

The multicollinearity of the independent variables was verified by calculating the correlation matrix, considering those values above 0.7 as critical (Rogério-Foguesatto and Dessimon-Machado 2022). The Hosmer and Lemeshow test was used to verify whether the model fits the data correctly. This occurs when the significance is greater than 0.05, which shows differences between the observed and expected values. Nagelkerke's R^2 was used to indicate the explanatory variable's capacity to predict the response variable (Timprasert et al. 2014). It was also found that the percentage of correct prediction was greater than 60% (Tey et al. 2014). The statistical package SPSS 28 was used to perform the data analysis. The variables studied are shown in Table 1.

Table 1. Independent variables used in the logistic regression model

Variable	Unit	Expected sign
Age (X_1)	years	–
Level of education (X_2)	years of formal education	+
Holding size (X_3)	hectares	+
Season income (X_4)	EUR·m^{-2}	+
Season expenses (X_5)	EUR·m^{-2}	–
Methods used to deal with pests (X_6)	number	+
Use of phytosanitary products (X_7)	1 if yes, 0 if no	–
Banker plants inside the greenhouse (X_8)	1 if yes, 0 if no	+
Technical advice (X_9)	1 if yes, 0 if no	+
Organic production (X_{10})	1 if yes, 0 if no	+
Cooperative membership (X_{11})	1 if yes, 0 if no	+
Environmental awareness (X_{12})	1 if yes, 0 if no	+

Source: Authors' own elaboration

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Table 2. Descriptive statistics

Variable	Min	Max	Mean	SD
Age	27.00	61.00	46.75	9.03
Level of education	1.00	18.00	10.55	3.82
Holding size	0.35	11.00	2.39	1.82
Season income	5.00	13.00	8.80	1.85
Season expenses	2.00	11.00	4.51	1.36
Methods used to deal with pests	3.00	7.00	5.60	1.02
Use of phytosanitary products	0.00	1.00	0.94	0.23
Banker plants inside greenhouses	0.00	1.00	0.51	0.47
Technical advice	0.00	1.00	0.32	0.47
Organic production	0.00	1.00	0.36	0.48
Cooperative membership	0.00	1.00	0.68	0.47
Environmental awareness	0.00	1.00	0.52	0.50

SD – standard deviation
Source: Authors' own elaboration

RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics of the surveyed farmers in southeast Spain. All variables were included in the analysis because no evidence of multicollinearity was found. Table 3 shows the results of the logistic regression. The results show an acceptable fit of the regression model: the significance of the Hosmer and Lemeshow test is 0.117, the Nagelkerke R^2 is 0.716, and the per cent correct prediction is 88.9%. The variables that have been found to be significant are the size of the farm, expenses, the number of methods used to deal with pests, technical advice, and environmental awareness.

The farm size shows a positive and significant relationship at 10% with the establishment of hedgerows. According to the odds ratio value, for each increase in the size of the farm in one hectare, the probability that hedgerows will be installed will increase by a factor of 1.701. This may be because a large number of greenhouses are concentrated in the study region. This situation makes it very difficult to expand the cultivation area, so farmers try to make the most of the land available for cultivation. In this context, the installation

Table 3. Results of the binary logistic regression

Variable	β	SE	Significance	Exp(β)
Age	–0.021	0.029	0.462	0.979
Level of education	0.005	0.067	0.941	1.005
Holding size	0.531	0.292	0.069*	1.701
Season income	0.167	0.176	0.343	1.182
Season expenses	–0.527	0.280	0.060*	0.590
Methods used to deal with pests	2.333	0.512	0.000***	10.307
Use of phytosanitary products	–1.689	1.098	0.124	0.185
Banker plants inside the greenhouse	0.638	0.690	0.355	1.892
Technical advice	2.046	0.598	0.001***	7.739
Organic production	0.311	0.605	0.607	1.365
Cooperative membership	0.202	0.644	0.754	1.224
Environmental awareness	0.140	0.605	0.067*	1.150
Constant	–12.542	3.236	0.000	0.000

*, **, *** significant at 10, 5, and 1%, respectively; β – parameter values reflecting the relative incidence of each of the explanatory variables; SE – standard error; Exp(β) – value of the odds ratio; Hosmer and Lemeshow test: γ^2 = 12.848, df = 8, sig = 0.117; Nagelkerke R^2 = 0.716; percent correct prediction = 88.9%; number of observations = 189
Source: Authors' own elaboration

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of hedgerows could lead to a reduction in the yield obtained, which implies a high opportunity cost for farmers (Byerly et al. 2021). In this same sense, Mie Aung et al. (2020) conclude that small farms are less likely to incorporate IPM practices because their owners are concerned about the impacts that can be generated and the difficulty of carrying them out. Generally, during the surveys, farmers commented that the large concentration of greenhouses in the area means there is limited space to install hedgerows, which may mean that part of the farm may have to stop producing to install them. Therefore, farmers with a larger surface area were more open to installing hedgerows. In addition, these farmers considered that installing such systems could have commercial advantages in the medium term, given that European consumers increasingly demand more food produced using environmentally friendly techniques (Amoabeng et al. 2021). In this sense, the farmers consider that it is necessary to carry out communication and marketing campaigns to show the benefits of this practice and how it allows cleaner production.

The expenses are negatively related to installing hedgerows at a significance level of 10%. The odds ratio indicates that for each cost increase by one euro per square metre, the probability of installing hedgerows is reduced by a factor of 0.590. Farmers with higher expenses run a higher risk when incorporating new practices since they can affect the yield obtained. During the surveys, farmers facing higher costs were more reluctant to adopt hedgerows due to the risk that they would affect crop yields and thus unable to meet farm payments. On the other hand, installing hedgerows can result in cost savings by reducing the need to apply phytosanitary products. This advantage is of great interest in the current context, characterised by a growing trend in the price of these products. It should be considered that spending on phytosanitary products represents more than 5% of the annual costs of agricultural operations. In addition, the purchase of natural enemies raised in the laboratory can also be reduced with the implementation of this practice because CBC is favoured (Naranjo et al. 2015; Gontijo 2019). This can also be a great advantage in cases where natural enemies cannot be acquired in the market because some cannot be bred in the laboratory. In this sense, Timprasert et al. (2014) determine that farmers are likelier to adopt IPM practices if they reduce the pest control cost. According to farmers' comments, they are not opposed to their adoption but request more evidence on the benefits of installing them and quantifying the cost savings they can bring. However, no studies quantify this saving in the region, so more research on this practice is needed to provide farmers with this information.

The number of methods used to deal with pests shows a positive and significant relationship at 1% with the installation of hedgerows. The odds ratio for this variable indicates that using an additional method to deal with pests increases the probability of installing hedgerows by a factor of 10.307. In the region, various methods are used to deal with pests, such as phytosanitary products, the use of biological control, and the installation of hormonal attractants or anti-insect meshes. Farmers' receptivity to incorporating various methods to combat pests can help them choose the installation of hedgerows around greenhouses. In this sense, Prokopy et al. (2019) indicate that better farmers' adoption of better management practices has a positive attitude towards them and if they have previously adopted other sustainable practices. During the surveys, the farmers who had hedgerows said that the incorporation of these had been gradual, so at first, they began to incorporate laboratory-bred auxiliary fauna and other techniques, but that these techniques were not totally effective when a pest attacked suddenly. However, incorporating hedgerows creates a habitat for the auxiliary fauna that serves to prevent and be prepared for when there are more severe pests. They also point out that it is important to incorporate different techniques little by little, as they require a period of adaptation and learning, thus reducing the risk of yield losses in the harvest.

The availability of technical advice on this practice shows a positive and significant relationship at 1% with installing hedgerows around greenhouses. The odds ratio for this variable indicates that the availability of advice increases the probability of installing hedgerows by 7.739 compared to not being advised. This is not surprising considering that it is a new practice in the region and, therefore, it is necessary to transmit information about it. In this regard, Timprasert et al. (2014) established that access to extension and counselling services is positively related to vegetable producers' adoption of IPM techniques in Thailand. Kabir and Rainis (2015) indicate that this is also one of the determinants in the case of vegetable farming in Bangladesh. Access to useful information is an essential factor when incorporating IPM practices (Tey et al. 2014). Therefore, promoting the transmission of the experiences of farmers who develop a new practice is necessary since this is usually the best way to promote its adoption (Liu et al. 2018; Mazhar et al. 2021). Advice is often available to farmers in the area from various

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sources (cooperatives, supply companies, farmers' associations). However, this advice is more focused on commercial aspects. Therefore, farmers who had chosen to implement hedgerows referred to the importance of advice on hedgerows. Firstly, it is necessary for farmers to know that it is possible to improve biological control by implementing this practice. Secondly, experts are required to advise on the best species to incorporate depending on the farm's location and the crops to be grown. Finally, technicians are required to accompany farmers during the first stage to check that the hedgerows are actually working and to avoid possible problems and yield losses. Farmers who had been using hedgerows for some time were quite satisfied with them, commenting that, as they were native species, the maintenance required was minimal and, in addition, they had noticed an improvement in biodiversity that had enabled them to control pests better. It is true, however, that some of them indicated that they would like to see an accurate quantification of the growth of auxiliary fauna and the reduction in the application of phytosanitary products that this entails.

Environmental awareness is positively related and at a significance level of 10% to installing hedgerows. According to the odds ratio, farmers who are aware adopt this practice 1.150 times more than those who are not. Those farmers who know the environmental effects of their activity are more likely to change their usual way of managing the farm and incorporate possible practices and actions that are more respectful and responsible (Prokopy et al. 2019). Farmers with hedgerows performed more frequently than the actions measured in this study showing their higher level of environmental awareness. In addition, these are generally younger farmers who are more knowledgeable about environmental issues and are concerned about ensuring the sustainability of this economic activity. Thus, communicating with farmers about the environmental effects of their activity is essential to increase their level of awareness and promote the use of more sustainable practices. Therefore, it is necessary to communicate to farmers in the region the main environmental benefits of this practice – improvement of biodiversity and enhancement of biological control of pests.

The following recommendations are proposed to policymakers to intervene and improve the adoption of hedgerows by farmers. First, financial support for farmers with the smallest farms would be necessary. Small farmers often face challenges in adopting sustainable methods or new technology due to the opportunity cost of reducing their production on limited land. Therefore, financial assistance could alleviate the burden of income loss. In this respect, it would be necessary to extend the aid available to cover the cost of installing hedgerows and make them more accessible to farmers. On the other hand, different types of economic incentives could be considered, such as tax exemptions or recurrent subsidies for the ecosystem services generated by the implementation of this practice (Piñeiro et al. 2020). Secondly, quantifying the cost savings associated with implementing hedgerows is crucial to convince farmers to adopt them, especially those with higher expenses. A cost-benefit analysis can help farmers understand the long-term financial benefits, such as reduced input costs, increased productivity, or improved pest control. Such an analysis can provide information on the potential risks and trade-offs associated with adopting hedgerows. Overall, quantifying cost savings is essential to promote their adoption and reap their long-term benefits for both farmers and the environment.

Thirdly, adopting diverse methods of dealing with pests needs to be encouraged, as this makes farmers more familiar with incorporating various technologies and practices and more willing to take the risk involved. To achieve this, technical advice on this issue is essential, especially in the case of a novel practice such as hedgerows. In this sense, in addition to technicians, demonstration days in which other farmers who have successfully implemented technology and practices are involved are the most effective tool because they enable farmers themselves to exchange experiences (Velasco-Muñoz et al. 2022). For hedgerows, workshops are needed to show how hedgerows work, their economic feasibility, and the benefits they generate both at the agricultural level and at the area's environmental level. Finally, improving farmers' attitudes and environmental awareness is crucial for promoting sustainable agriculture practices such as installing hedgerows. More aware farmers are more likely to be aware of the benefits of adopting hedgerows, such as improved biodiversity, pollination, or pest control. In addition, they are also more likely to see the long-term benefits of reduced application of pesticides or commercial advantages. Various ways to raise farmers' awareness of these aspects include education programs, advertising campaigns, or on-farm demonstrations (Ardoin et al. 2020).

CONCLUSION

The objective of this work was to analyse the factors that determine farmers' decisions about installing hedgerows around greenhouses to favour the presence

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of natural enemies that help combat pests. To this end, the case of agriculture in southeast Spain has been analysed. The results have provided helpful information on how to increase the adoption of this practice. Thus, the size of the farm, the expenses, the number of methods used to deal with pests, technical advice and environmental awareness are statistically significant when explaining the adoption of hedgerows around greenhouses by farmers. However, age, educational level, income, use of phytosanitary products, use of banker plants, organic production, and belonging to a cooperative were not significant.

These results are relevant for policymakers because they show what can be the areas of action to increase the installation of hedgerows around greenhouses. First, it would be interesting to financially support farmers who have the smallest farms because they are the ones who have the greatest difficulties in incorporating this practice due to the opportunity cost of not producing in part of their farm. Second, it is necessary to quantify the cost savings that implementing this practice can entail, given that farmers with higher expenses are more reluctant to install them. Third, it is necessary to encourage the adoption of various methods to deal with pests, for which it is essential that farmers have technical advice on this issue and, especially, on installing hedgerows since it is a novel practice. Finally, developing plans to improve farmers' attitudes and environmental awareness would be very appropriate since the more aware farmers are more willing to adopt the hedgerows.

Future research should focus on installing hedgerows in the study region to analyse the opportunity cost of allocating land for this practice, its effectiveness in reducing the use of phytosanitary products, and its impact on commercial production. It should be noted that this study was conducted in southeast Spain, and the specific characteristics of this region may influence farmers' attitudes and perceptions about hedgerows. Therefore, the findings of this study may have limited applicability to other regions or agricultural systems. To promote the adoption of hedgerows in other greenhouse agriculture areas and address the loss of biodiversity that threatens pest control and agricultural sustainability, it is necessary to replicate this study in other geographical areas and consider other variables that may affect farmers' willingness to adopt this practice. Additionally, future research should analyse the impact of proposed measures to encourage the adoption of hedgerows. Overall, the lessons learned from this study can promote sustainable agriculture practices in greenhouse agriculture areas.

REFERENCES

Amoabeng B.W., Stevenson P.C., Mochiah M.B., Asare K.P., Gurr G.M. (2021): Economic analysis of habitat manipulation in Brassica pest management: Wild plant species suppress cabbage webworm. Crop Protection, 150: 105788.

Ardoin N.M., Bowers A.W., Gaillard E. (2020): Environmental education outcomes for conservation: A systematic review. Biological Conservation, 241: 108224.

Bamière L., Jayet P.A., Kahindo S., Martin E. (2021): Carbon sequestration in French agricultural soils: A spatial economic evaluation. Agricultural Economics (United Kingdom), 52: 301–316.

Byerly H., Kross S.M., Niles M.T., Fisher B. (2021): Applications of behavioral science to biodiversity management in agricultural landscapes: Conceptual mapping and a California case study. Environmental Monitoring and Assessment, 193: 1–16.

Cotes B., González M., Benítez E., De Mas E., Clemente-Orta G., Campos M., Rodríguez E. (2018): Spider communities and biological control in native habitats surrounding greenhouses. Insects, 9: 33.

Coulibaly T.P., Du J., Diakité D. (2021): Sustainable agricultural practices adoption. Agriculture (Poľnohospodárstvo), 67: 166–176.

Dissanayake C.A.K., Jayathilake W., Wickramasuriya H.V.A., Dissanayake U., Kopiyawattage K.P.P., Wasala W.M.C.B. (2022): Theories and models of technology adoption in agricultural sector. Human Behavior and Emerging Technologies: 22: 9258317.

Geiger F., Bengtsson J., Berendse F., Weisser W.W., Emmerson M., Morales M.B., Ceryngier P., Liira J., Tscharntke T., Winqvist C., Eggers S., Bommarco R., Pärt T., Bretagnolle V., Plantegenest M., Clement L.W., Dennis C., Palmer C., Oñate J.J., Inchausti P. (2010): Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology, 11: 97–105.

Giagnocavo C., De Cara-García M., González M., Juan M., Marín-Guirao J.I., Mehrabi S., Rodríguez E., Van der Blom J., Crisol-Martínez E. (2022): Reconnecting farmers with nature through agroecological transitions: Interacting niches and experimentation and the role of agricultural knowledge and innovation systems. Agriculture, 12: 137.

Gontijo L.M. (2019): Engineering natural enemy shelters to enhance conservation biological control in field crops. Biological Control, 130: 155–163.

Gujarati D.A.N., Porter D.C. (2009): Basic Econometrics. 5th Ed. Irwin, McGraw-Hill: 922.

Gurr G.M., Lu Z., Zheng X., Xu H., Zhu P., Chen G., Yao X., Cheng J., Zhu Z., Catindig J.L., Villareal S., Van Chien H.,

https://doi.org/10.17221/49/2023-AGRICECON

Cuong L.Q., Channoo C., Chengwattana N., Lan L.P., Hai L.H., Chaiwong J., Nicol H.I., Heong K.L. (2016): Multi-country evidence that crop diversification promotes ecological intensification of agriculture. Nature Plants, 2: 1–4.

Hill R.C., Griffiths W.E., Lim G.C. (2011): Principles of Econometrics. 4th Ed. New York, John Wiley & Sons: 784.

Kabir M.H., Rainis R. (2015): Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an approach to sustainable agricultural development. Environment, Development and Sustainability, 17: 1413–1429.

Karasmanaki E., Dimopoulou P., Vryzas Z., Karipidis P., Tsantopoulos G. (2021): Is the environmental behavior of farmers affecting their pesticide practices? A case study from Greece. Sustainability, 13: 1452.

Li S., Jaworski C.C., Hatt S., Zhang F., Desneux N., Wang S. (2020): Flower strips adjacent to greenhouses help reduce pest populations and insecticide applications inside organic commercial greenhouses. Journal of Pest Science, 94: 679–689.

Liu T., Bruins R.J.F., Heberling M.T. (2018): Factors influencing farmers' adoption of best management practices: A review and synthesis. Sustainability, 10: 432.

Mango N., Makate C., Tamene L., Mponela P., Ndengu G. (2017): Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. International Soil and Water Conservation Research, 5: 122–129.

Mazhar R., Ghafoor A., Xuehao B., Wei Z. (2021): Fostering sustainable agriculture: Do institutional factors impact the adoption of multiple climate-smart agricultural practices among new entry organic farmers in Pakistan? Journal of Cleaner Production, 283: 124620.

Messelink G.J., Bennison J., Alomar O., Ingegno B.L., Tavella L., Shipp L., Palevsky E., Wäckers F.L. (2014): Approaches to conserving natural enemy populations in greenhouse crops: Current methods and future prospects. BioControl, 59: 377–393.

Messelink G.J., Lambion J., Janssen A., Van Rijn P.C.J. (2021): Biodiversity in and around greenhouses: Benefits and potential risks for pest management. Insects, 12: 933.

Mie Aung Z.M., Arunrat N., Sereenonchai S., Yuttitham M., Stewart T.N., Chaowiwat W. (2020): Farmers' Knowledge, Attitude and Practice on Integrated Pest Management in Kalaw Region, Myanmar. 2020 International Conference and Utility Exhibition on Energy, Environment and Climate Change, ICUE: 1–7.

Morandin L.A., Long R.F., Kremen C. (2016): Pest control and pollination cost-benefit analysis of hedgerow restoration in a simplified agricultural landscape. Journal of Economic Entomology, 109: 1020–1027.

Naranjo S.E., Ellsworth P.C., Frisvold G.B. (2015): Economic value of biological control in integrated pest management of managed plant systems. Annual Review of Entomology, 60: 621–645.

Paço A., Lavrador T. (2017): Environmental knowledge and attitudes and behaviours towards energy consumption. Journal of Environmental Management, 197: 384–392.

Parra S., Rodríguez E., González M. (2020): What is the cost of increasing biodiversity in the environment of the Almeria greenhouses, southeast of Spain? Acta Horticulturae, 1268: 193–197.

Piñeiro V., Arias J., Dürr J., Elverdin P., Ibáñez A.M., Kinengyere A., Opazo C.M., Owoo N., Page J.R., Prager S.D., Torero M. (2020): A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. Nature Sustainability, 3: 809–820.

Prokopy L.S., Floress K., Arbuckle J.G., Church S.P., Eanes F.R., Gao Y., Gramig B.M., Ranjan P., Singh A.S. (2019): Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. Journal of Soil and Water Conservation, 74: 520–534.

Rodríguez E., Schwarzer V., Van der Blom J., Cabello T., González M. (2012): The selection of native insectary plants for landscaping in greenhouse areas of SE Spain. Landscape Management for Functional Biodiversity, 75: 73–76.

Rodríguez E., González M., Paredes D., Campos M., Benítez E. (2018): Selecting native perennial plants for ecological intensification in Mediterranean greenhouse horticulture. Bulletin of Entomological Research, 108: 694–704.

Rogério-Foguesatto C., Dessimon-Machado J.A. (2022): Adoption of sustainable agricultural practices in Brazil: understanding the influence of socioeconomic and psychological factors. Journal of Agribusiness in Developing and Emerging Economies, 12: 204–222.

Rusch A., Chaplin-Kramer R., Gardiner M.M., Hawro V., Holland J., Landis D., Thies C., Tscharntke T., Weisser W.W., Winqvist C., Woltz M., Bommarco R. (2016): Agricultural landscape simplification reduces natural pest control: A quantitative synthesis. Agriculture, Ecosystems & Environment, 221: 198–204.

Ruzzante S., Labarta R., Bilton A. (2021): Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. World Development, 146: 105599.

Sharma S., Kooner R., Arora R. (2017): Insect pests and crop losses. In: Arora R., Sandhu S. (eds.): Breeding Insect Resistant Crops for Sustainable Agriculture. Singapore, Springer: 45–66.

Shields M.W., Johnson A.C., Pandey S., Cullen R., González-Chang M., Wratten S.D., Gurr G.M. (2019): History, cur-

https://doi.org/10.17221/49/2023-AGRICECON

rent situation and challenges for conservation biological control. Biological Control, 131: 25–35.

Tey Y.S., Li E., Bruwer J., Abdullah A.M., Brindal M., Radam A., Ismail M.M., Darham S. (2014): The relative importance of factors influencing the adoption of sustainable agricultural practices: A factor approach for Malaysian vegetable farmers. Sustainability Science, 9: 17–29.

Timprasert S., Datta A., Ranamukhaarachchi S.L. (2014): Factors determining adoption of integrated pest management by vegetable growers in Nakhon Ratchasima Province, Thailand. Crop Protection, 62: 32–39.

Velasco-Muñoz J.F., Aznar-Sánchez J.A., López-Felices B., Balacco G. (2022): Adopting sustainable water management practices in agriculture based on stakeholder preferences. Agricultural Economics – Czech, 68: 317–326.

Zhang S., Sun Z., Ma W., Valentinov V. (2020): The effect of cooperative membership on agricultural technology adoption in Sichuan, China. China Economic Review, 62: 101334.

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