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Research article

Installation of hedgerows around greenhouses to encourage biological pest control: Farmers' perspectives from Southeast Spain

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ABSTRACT

The intensification of agriculture has led to the deterioration of various ecosystem services, including pest control. The installation of hedgerows around greenhouses is presented as a viable option to maintain and favour natural enemies of pests. Despite the economic and environmental advantages of this type of facility, farmers are reluctant to implement it. Therefore, it is necessary to determine the factors that influence the decision to install hedgerows and the most appropriate incentives to promote their establishment. This article analyses intensive agriculture in Southeastern Spain. The application of cluster analysis techniques allowed the detection of four types of farmers in relation to this practice. The factors that drive its installation are an increase in the effectiveness of biological control, a reduction in the use of pesticides and the possible economic and environmental benefits. As a barrier, a lack of knowledge of and confidence in the effectiveness of this practice stand out. Among the measures to encourage their installation, the most valued are training and advice and recurring payments for the ecosystem services generated. The results obtained can be useful for policy makers in regions in which the installation of non-crop vegetation is promoted.

1. Introduction

The intensification of agriculture in recent decades has led to the simplification of the landscape and a significant loss of biodiversity, which can negatively impact the provision of ecosystem services (Zhang et al., 2007). In the agricultural field, biological pest control is one of the most relevant ecosystem services, given that approximately 50% of the pests that could potentially affect crops are avoided because they are regulated by their natural enemies (Geiger et al., 2010; Puerta-Piñero and Rodríguez, 2019). However, the loss of biodiversity together with the continued use of phytosanitary products and the extension of monocultures can negatively affect pest control (Clemente-Orta and Álvarez, 2019). It is estimated that globally, annual crop losses of between 20% and 40% occur due to plant pests (FAO, 2017). This endangers food security in the context of global population growth (United Nations, 2012).

Performing integrated pest management (IPM) through the application of conservation biological control (CBC) techniques can enhance the natural control of pests (González-Chang et al., 2019). IPM integrates the use of various plant protection methods (natural, chemical and biological) to deal with pests with the most economical means and with the lowest possible risk to human health and the environment (Naranjo et al., 2015). CBC consists of making modifications to the environment to maintain and favour the natural enemies of pests (Pandey et al., 2018). CBC includes a wide range of management practices that aim to protect and favour the populations of natural enemies in the agrosystem, thus improving their effect on pests (Gontijo, 2019). The implementation of CBC techniques can also improve other ecosystem services, such as pollination, nutrient cycling, soil moisture retention, weed control, aesthetics and human well-being (Shields et al., 2019). One of the practices used in the CBC is the installation of non-crop vegetation such as hedgerows in the vicinity of the farms, since they provide food, shelter and alternative hosts that facilitate the abundance of natural enemies and their performance in the suppression of pests (González-Chang et al., 2019; Shields et al., 2019). In this sense, it is estimated that the most complex landscapes with vegetation diversity have levels of pest control 46% higher than the homogeneous landscapes dominated by cultivated lands (Rusch et al., 2016).

Traditionally, the installation of hedgerows has been investigated and applied to outdoor fields, but in recent years, research has been

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extended to greenhouse areas (Li et al., 2020). Usually, greenhouse crops are considered more isolated from the environment than outdoor crops. In fact, one of the advantages of greenhouses is that they offer greater protection against pests (Messelink et al., 2014). However, the most widespread greenhouses in the world are plastic structures that include windows or other types of ventilation sources, through which the interior connects with the environment in which it is located (Messelink et al., 2021). The main advantages of the installation of hedgerows around greenhouses are their contribution to the management of pests by favouring the presence of natural enemies, the promotion of the arrival of insects that allow the pollination of some types of crops and the minimization of the migration of pests between neighbouring greenhouses (Li et al., 2020; Messelink et al., 2021).

Several studies have confirmed that the installation of hedgerows in the surroundings of greenhouses, especially if they are autochthonous species, favours the proliferation of various natural enemies (Perdikis et al., 2011; Rodríguez et al., 2012; Cotes et al., 2018; Li et al., 2020). There are also studies that show that the introduction of this practice is economically viable. For example, Li et al. (2020) determined that the installation of hedgerows adjacent to greenhouses provides a net benefit derived from the reduction of the use of insecticides and the increase in the price of the crop due to the use of more environmentally friendly techniques. Parra et al. (2020) determined that the cost of installing hedgerows in the vicinity of greenhouses is not an obstacle since it represents less than 1% of the total cost structure of an agricultural holding. Despite all these advantages, most farmers limit the vegetation outside their greenhouses (Messelink et al., 2021). Therefore, it is necessary to determine the factors that influence farmers when making the decision to install hedgerows. The objective of this article is to fill this gap in the research by studying the perceptions and attitudes of farmers towards the installation of hedgerows in the vicinity of greenhouses. To achieve this objective, the case of intensive agriculture in southeast Spain, where the largest concentration of greenhouses in the world is found, has been analysed (Thompson et al., 2020). Specifically, the following aspects have been analysed: 1) the typologies of existing farmers in relation to the installation of hedgerows around greenhouses, 2) the attitude of farmers towards this practice and 3) the degree of acceptance of different measures aimed to promote its installation.

2. Material and methods

2.1. Study area

This research was developed in the Campo de Dalías region, located in the province of Almería, in Southeastern Spain (Fig. 1). This region has the largest area of greenhouses in the province, with 22,054 ha (Andalucía, 2020). This area has ideal characteristics for agricultural production, as it has moderate temperatures and a large number of hours of sun per year. However, agricultural development has led to a loss of native perennial vegetation and significant fragmentation, which makes it a very vulnerable area to attacks by pests and diseases (Rodríguez et al., 2014; Cotes et al., 2018).

The use of IPM practices in Almería began in 2007 when the use of natural enemies was implemented in most of the area dedicated to pepper cultivation (Parra et al., 2020). The factors that promoted the application of biological control were the emergence of resistance to various pesticides and the lack of registered pesticides available in the market (Glass and Egea, 2012). The good results with the application of IPM practices have caused it to be extended to all crops developed in the region (pepper, cucumber, zucchini, eggplant, tomato, green bean, watermelon and melon). More than 90% of the surface of the Campo de Dalías uses natural enemies to fight pests (Andalucía, 2015). The most widespread IPM technique is augmentative biological control, which consists of the complementary introduction of natural enemies raised in the laboratory to combat pests as needed (Naranjo et al., 2015). However, this practice, in addition to being a high cost, is not a long-term

Fig. 1. Location of Campo de Dalías in the Southeast of Spain.

solution (Gontijo, 2019). In recent years, the use of banker plants has spread, a CBC technique that consists of the installation of secondary or non-crop plants inside the greenhouse with the aim of providing habitats to maintain permanent populations of natural enemies of pests (Messelink et al., 2014).

The next step in CBC techniques would be the installation of non-crop vegetation, through the design of hedges, in the surroundings of the farms with the objective of minimizing the pressure of pests in this region. Several studies have been carried out in which the most suitable perennials are determined to be part of the hedges around the greenhouses in Almería (Rodríguez et al., 2012, 2018; Cotes et al., 2018). In general, these are autochthonous species with interspersed flowering periods and diverse habits. With the aim of promoting the installation of hedges around greenhouses, there is a local regulation that requires their establishment in new greenhouses (BOP, 2017). Likewise, at the regional level, there are subsidies for their installation (BOJA, 2017). To be able to access these aids, the hedgerows must include a minimum of five autochthonous shrub species. Despite being a very favourable region for the installation of this type of hedge due to the great advantages they provide, its use is still limited (Giagnocavo et al., 2022). Therefore, this region constitutes an ideal "laboratory" for the development of this research.

2.2. Questionnaire development

In order to gather the needed information to design the questions included in the survey, a previous qualitative study was carried out with interviews to experts and a focus group discussion. A total of five experts in intensive agriculture in Almería were interviewed with the objective of knowing their opinion about hedgerows and obtaining key information about this practice. Among those interviewed were the technical director of a biological control company in the region, a member of a private agricultural research centre, the president of one of the most important agricultural cooperatives in the region and two farmers with extensive professional experience. Next, a focus group was carried out with six farmers in the study region, of which three had hedgerows on their farm, while the other three did not. Finally, a pilot survey was conducted in which eight farmers participated, of which four had hedgerows and the rest did not. The questionnaire was divided into four sections:

1. Characterization of farmers and their farms. In this part of the questionnaire, four groups of questions were asked regarding a) the characteristics of the farmers (age, years of experience and level of education), b) the characteristics of the farm (type of soil, type and size of the greenhouse, year of construction, climate systems, water storage capacity in the farm, characteristics of the irrigation ponds, rainwater harvesting systems, availability of irrigation programmer and use of tensiometers), c) data related to the crop and inputs campaign (number of crop cycles, organic cultivation, monoculture, income and expenses, trading channels and technical advice, number of workers, methods to deal with pests and methods for pollination) and d) data related to hedgerows (surface, number of species and advice).

2. Environmental behaviour. The level of environmental awareness was evaluated through a series of behaviours. Farmers had to indicate the frequency with which they performed these behaviours in their daily life using a five-point Likert scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always). The selection of the items was based on previous studies (Paço and Lavrador, 2017; Karasmanaki et al., 2021; Musova et al., 2021). The items included were recycling, turning off the faucet while brushing teeth, limiting showering time, using energy-saving light bulbs, using energy-efficient appliances, turning off lights and electrical appliances when not in use.

3. Attitudes related to the installation of hedgerows. This section was composed of two groups of questions. In the first group, farmers were asked to assess the importance of a series of reasons for installing or not installing hedgerows using a 5-point Likert scale (1 = not important, 2 = less important, 3 = moderately important, 4 = very important, 5 = extremely important). Farmers who had hedgerows valued the importance of the following reasons: increasing the effectiveness of biological control, reducing the use of pesticides, improving the landscape, environmental benefits, economic benefits, affordable installation cost, cost reduction and regulations. The installation of hedgerows around greenhouses can improve the effectiveness of biological control techniques that are commonly used in the study region by increasing the population of natural enemies of pests. This in turn can reduce the application of pesticides to combat pests. The establishment of hedgerows around the greenhouses can have an aesthetic contribution in the region, improving a landscape that is dominated by plastic greenhouses. The environmental benefits can be derived from the generation of biodiversity in the region. On the other hand, economic benefits can be generated due to a possible increase in yield and an improvement in the quality of the products, as well as commercial advantages derived from the use of more environmentally friendly techniques. The perception of farmers about the affordability of the installation cost of this type of system can incentivize their installation. The reduction in costs is derived from the decrease in the use of pesticides and auxiliary fauna reared in laboratories. Finally, through regulation, the effect that the existing regulations in the region have on the establishment of hedgerows is evaluated.

In the case of not having hedgerows, farmers assessed the following reasons for not installing them: installation cost, difficulty in choosing plants, possibility for pests to develop, space limitation, limitations due to the characteristics of the farm and regulations. The perception by farmers of the need to make a high investment to install this practice can act as a barrier. For this practice to work, the appropriate combination of plants must be selected, which can be a difficulty for farmers. If the selection of plants is not done properly, hedgerows could also act as a refuge for pests. In the study region, there is a limitation of space to install this practice due to the high concentration of greenhouses, which may mean ceasing to produce in a part of the farm when allocating it to the hedgerows. The limitations derived from the characteristics of the farm are derived mainly from the fact that it has an asphalted perimeter, in which case it would be necessary to eliminate it or use flowerpots to install the hedgerows. Through the regulation, possible exceptions to its compliance are represented. In the second group of questions, all farmers were asked to select from a group of options the advantages and disadvantages of hedgerows. The advantages included increasing the population of useful fauna, reducing the application of pesticides, improving the landscape, improving biodiversity, commercial advantages and reducing costs. In the case of the disadvantages, the following were considered: installation cost, space limitation, limitations due to the characteristics of the farm, difficulty in selecting suitable plants and potential for pests to develop.

4. Incentives to increase the installation of hedgerows. In this part of the questionnaire, farmers were asked to indicate their level of agreement with four measures to promote the installation of hedgerows: direct aid to cover the cost of installation, recurrent payments for ecosystem services, training sessions and regulatory measures. Two economic measures were evaluated. On the one hand, aid to meet the initial investment necessary to establish hedgerows. On the other hand, the establishment of periodic payments through which farmers are rewarded for the ecosystem services that the installation of this practice entails. The training sessions include all those actions that allow farmers to expand the knowledge of this practice, such as courses or demonstrations. Regulatory measures are intended to determine whether it is necessary to make changes to the existing regulations. The scoring of these measures was performed with a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree; 5 = strongly agree).

2.3. Sample size and selection

A confidence level of 95% and a maximum error of 5% were established to determine the sample size. To meet these requirements, it was necessary to survey a minimum of 378 ha, taking into account that the surface of greenhouses in the study region is 22,054 ha (Andalucía, 2020). A total of 189 farmers with a total of 392 ha were surveyed. Taking into account these data, the margin of error is approximately 4.91%. Considering the characteristics of the study, it was decided to carry out a simple random sampling without replacement because each selected unit has the same probability of being chosen in each extraction. The contact with the farmers was carried out with the help of different associations of farmers in the study region. The survey period lasted from August to November 2021. The duration of each survey ranged from 15 to 20 min.

2.4. Data analysis

We used the SPSS (version 27) software to carry out data analysis. In this way, we obtained the main descriptive statistics and could study the interoperative relationships of the variables, the outliers and the data distribution. A cluster analysis followed to characterize the main groups of farmers in relation to the use of hedgerows considering the observed agricultural holdings' characteristics. This exploratory analysis technique allows the characterization of groups of observations that share similar characteristics through a multivariate statistical procedure (Hennig et al., 2015). This type of analysis has been previously used in the agricultural field since it is very useful to gather information to improve the agricultural activity management. We can find some examples in the classification of crop pest types to enhance IPM or in the study of farmers' behaviour towards sustainable practices (Tiwari and Misra, 2011; Aznar-Sánchez et al., 2021). For the grouping of the clusters, the Ward or "minimum variance" method was used since it allows obtaining homogeneous clusters. The degree of homogeneity is measured through the sum of the squared distances of each element with respect to the centroid or vector of means in each cluster (Murtagh and

Contreras, 2017). Specifically, the squared Euclidean distance was used as a measure, and the standardization of the data was determined to avoid problems associated with the different scales or units in which the variables of interest were obtained.

At a further stage, once the clusters were identified, a one-way analysis of variance (ANOVA) was carried out to observe the group behaviour for the same variable and to determine potential variable differences among groups. This type of analysis allows obtaining direct and easy-to-interpret results, which is why it has been widely used to study this behaviour (Tabachnick and Fidell, 2007). With the use of this type of analysis, the means of each population group are obtained, and their variances (intragroup variance) are studied with respect to the average variance within each group (between-group variance) (Cardinal and Aitken, 2013). In this way, considering that the groups have been obtained from the same population universe, both the mean and the variances should be equal. It must be said that although one-way ANOVA gives important insights about the population, the difference tests are not accurate enough, i.e. if the one-way ANOVA is carried out on the same population than for the cluster analysis, the nominal significance level cannot be controlled by the test (for a better understanding, see Malik et al. (2016).

3. Results

3.1. Characterization of farmers and their holdings and environmental behaviour

The descriptive statistics of the variables that have been analysed in this study are shown in Table 1. The most relevant aspects are highlighted below.

Table 1
Variables and descriptive statistic data.

Area	Variable	Description	Min.	Max.	Average	Standard deviation	Variation coefficient
Personal farmer data	V_1	Farmer's age (years old)	27	61	46.75	9.03	19.31%
	V_2	Years of farming experience	1	49	25.35	9.23	36.42%
	V_3	Level of education. 0 no schooling, 1 compulsory education, 2 upper secondary school, 3 intermediate training course, 4 higher training course, 5 university degree	0	5	*	*	*
Agricultural holding data	V_4	Type of soil. 1 local ground, 2 sanded soil, 3 hydroponic soil	1	3	*	*	*
	V_5	Type of greenhouse. 1 flat-top, 2 sloping roof, 3 multi-tunnel, 4 asymmetric	1	4	*	*	*
	V_6	Greenhouse size (ha)	0.35	11	2.39	1.82	76.22%
	V_7	Construction year. Four-digit year	1985	2020	2005	8.73	0.44%
	V_8	Number of climate systems	1	3	1.85	0.89	48.21%
	V_9	Holding water storage capacity (m^3)	0	20	1178.59	2229.05	189.13%
	V_{10}	Type of pond. 1 concrete, 2 polyethylene-lined, 3 others	1	2	*	*	*
	V_{11}	Shape of the pond. 1 square, 2 rectangular, 3 others	1	3	*	*	*
	V_{12}	Quantity of water in the pond. 0 empty (0%), 1 less than 25%, 2 between 25 and 50%, 3 between 50 and 75%, 4 between 76 and 99%, 5 full (100%)	1	4	*	*	*
	V_{13}	Method to keep the pond clean. 1 dredging, 2 biocide treatment, 3 covering	1	3	*	*	*
	V_{14}	Rainwater harvesting. 0 no, 1 greenhouse surface, 2 other elements of the holding	0	2	*	*	*
	V_{15}	Destination of harvested rainwater. 1 exclusive rainwater pond, 2 pond for different types of water, 3 filter well	1	3	*	*	*
	V_{16}	Irrigation programmer. 0 no, 1 yes	0	1	0.84	0.37	44.41%
	V_{17}	Use of tensiometers. 0 no, 1 yes	0	1	0.68	0.47	69.22%
	V_{18}	Fully computerized irrigation with tensiometers. 0 no, 1 yes	0	1	0.21	0.41	196.64%
Crop and inputs data	V_{19}	Number of crop cycles per year	1	3	1.42	0.52	36.28%
	V_{20}	Organic farming. 0 no, 1 yes	0	1	0.36	0.48	133.75%
	V_{21}	Monoculture. −1 no, 0 depends, 1 yes	−1	1	0.83	0.41	49.39%
	V_{22}	Season income (€/m^2)	5	13	8.80	1.85	21.02%
	V_{23}	Season expenses (€/m^2)	2	8	4.51	1.36	30.20%
	V_{24}	Trading channel. 1 cooperative, 2 exchange, 3 direct sale, 4 private distributor, 5 SAT, 6 others	1	5	*	*	*
	V_{25}	Number of labours per year	2	40	6.80	5.59	82.12%
	V_{26}	Percentage of farmer family-bounded labour	0	66.67	9.60	16.16	168.37%
	V_{27}	Level of electrical conductivity in irrigation water (dS/m)	0	2.10	1.21	0.34	28.14%
	V_{28}	Number of methods used to deal with pests	3	7	5.60	1.02	18.28%
	V_{29}	Phytosanitary treatments (%)	0	100	33.19	32.24	97.15%
	V_{30}	Biological control (%)	0	100	66.81	32.24	48.25%
	V_{31}	Method for pollination. 0 no, 1 yes	0	1	0.63	0.48	76.90%
	V_{32}	Type of advice. 1 independent technicians, 2 supply providers, 3 trading company, 4 others	1	3	*	*	*
Hedgerows	V_{33}	Hedgerows. 0 no, 1 yes	0	1	0.34	0.48	138.49%
	V_{34}	Area (m^2)	100	33	2053.23	5611.19	273.29%
	V_{35}	Number of plant species	1	16	6.92	4.49	64.85%
	V_{36}	Advice for installation	0	1	0.69	0.47	67.19%
Environmental behaviour	V_{37}	Recycling. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	1	5	3.58	1.32	36.99%
	V_{38}	Turning off the faucet while brushing teeth. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	1	5	3.97	1.55	38.97%
	V_{39}	Limiting showering time. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	1	5	4.14	1.35	32.71%
	V_{40}	Using energy-saving light bulbs. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	2	5	4.17	1.35	32.47%
	V_{41}	Using energy-efficient appliances. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	1	5	4.42	0.79	17.92%
	V_{42}	Turning off lights and electrical appliances when not in use. 1 never, 2 rarely, 3 sometimes, 4 often, 5 always	2	5	4.29	1.20	27.89%

(*) In qualitative variables no data are provided.

A. Characterization of the farmer. The farmers have an average age of 47 years, with the youngest being 27 years old and the oldest being 61 years old. The active age of the sample is high because approximately 78% of the farmers are over 40 years old. The sample has extensive experience in the sector with an average of 25 years. Forty-four percent of farmers had a basic level of education, and only 13% had university studies.

B. Characteristics of the farm. In most farms (81%) sanded soil is used, a technique from which a layer of sand is placed on the surface of the soil to retain moisture. The most common type of greenhouse is the sloping roof greenhouse (70%). The farms have an average size of 2.39 ha. The oldest greenhouse dates from 1985 and the most recent from 2020. The farms usually have at least one climate system. The farms have an average capacity of 1178.58 m^3 to store water for agricultural irrigation. The most common ponds are concrete (72%) with a rectangular (51%) or square (41%) shape. These are usually kept at a volume between 75% and 99% of their capacity. The main methods to keep the pond clean are to cover it (56%) and drain it (40%). Seventy-nine percent of farms have rainwater collection systems, which collect water from the surface of the greenhouse and, in some cases, also from roads or other elements of the farm (22%). Rainwater is directed to filter wells (55%), ponds in which different types of water are stored (19%) or exclusive ponds for rainwater (7%). It is common for farms to have an irrigation programmer (84%). Tensiometers are also used to determine irrigation needs (68%). However, only in 21% of cases are irrigation systems fully computerized through the use of tensiometers.

C. Data related to the crop and input campaign. The number of crops per year is usually one (59%) or two (40%). In addition, cultivation is usually repeated from one season to another (84%). Thirty-six percent of farms practice organic cultivation. The average income is € 8.80/m^2 and costs € 4.51/m^2. The most commonly used means to commercialize the harvest are the cooperative (47%) and the Agrarian Transformation Company (SAT) (22%). There is an average of seven workers per year, although it must be taken into account that this variable shows a high coefficient of variation because it depends on various factors, such as the size of the farm or the type of crop. The water has an average conductivity of 1.21 dS/m. To address pests, an average of six methods are used. In farms, biological control (67%) is usually used rather than phytosanitary products (33%). It is common to use some additional method for pollination (63%). Most farmers receive agronomic advice from the company in which they sell their harvest (76%).

D. Hedgerows. Thirty-four percent of the farms have hedgerows around the greenhouses. These structures have an average of 2053.23 m^2. An average of seven plant species are included in the hedgerows, with the minimum being a single species and the maximum being 16. Sixty-nine percent of the farmers who had hedgerows received specific advice to design their composition and install them.

E. Environmental behaviour. To determine the level of environmental awareness of farmers, a series of environmental behaviours were analysed. The most frequently carried out action is the use of energy-efficient appliances, with an average value of 4.42. This is followed by the action of turning off lights and electrical appliances when not in use (4.29). Recycling is the behaviour that is performed with a lower frequency, with an average value of 3.58.

3.2. *Profile of farmers*

The results obtained in the ANOVA are shown in Table 2. The 189 farmers who participated in this research were classified into four homogeneous groups using cluster analysis. The main characteristics of these groups are shown below, taking into account the average values obtained in these variables (Table 3):

Cluster 1. *Innovators without advice* (N = 19, 10%). They are farmers with extensive experience in the sector and a basic level of education. Their farms have an average size of 2.89 ha and cultivate in sloping roof greenhouses with sanded soils. They usually keep their ponds at a

Table 2
ANOVA.

Variable	Description	Conglomerate Root mean square	df	Error Root mean square	df
V_1	Farmer's age	17.681	3	8.816	185
V_2	Years of farming experience	14.305	3	9.128	185
V_3	Level of education	3.867	3	1.490	185
V_4	Type of soil	0.889	3	0.448	185
V_5	Type of greenhouse	3.072	3	0.729	185
V_6	Greenhouse size (ha)	34.799	3	17.840	185
V_7	Construction year	21.253	3	8.376	185
V_8	Number of climate systems	3.964	3	0.745	185
V_9	Holding water storage capacity (m^3)	1503.269	3	2238.878	185
V_{10}	Type of pond	0.684	3	0.614	185
V_{11}	Shape of the pond	0.351	3	0.628	185
V_{12}	Quantity of water in the pond	1.379	3	0.880	185
V_{13}	Method to keep the pond clean	2.833	3	1.071	185
V_{14}	Rainwater harvesting	1.044	3	0.644	185
V_{15}	Destination of harvested rainwater	1.455	3	1.186	185
V_{16}	Irrigation programmer	0.456	3	0.370	185
V_{17}	Use of tensiometers	0.340	3	0.471	185
V_{18}	Fully computerized irrigation with tensiometers	0.860	3	0.394	185
V_{19}	Number of crop cycles per year	0.936	3	0.507	185
V_{20}	Organic farming	1.650	3	0.437	185
V_{21}	Monoculture	0.530	3	0.405	185
V_{22}	Season income (€/m^2)	6.123	3	1.695	185
V_{23}	Season expenses (€/m^2)	3.811	3	1.285	185
V_{24}	Trading channel	4.583	3	1.581	185
V_{25}	Number of labours per year	9.271	3	5.508	185
V_{26}	Percentage of farmer family-bounded labour	17.892	3	16.133	185
V_{27}	Level of electrical conductivity in irrigation water (dS/m)	0.285	3	0.340	185
V_{28}	Number of methods used to deal with pests	5.122	3	0.800	185
V_{29}	Phytosanitary treatments (%)	73.422	3	31.127	185
V_{30}	Biological control (%)	73.422	3	31.127	185
V_{31}	Method for pollination	0.489	3	0.484	185
V_{32}	Type of advice	1.279	3	0.666	185
V_{33}	Hedgerows	3.727	3	0.073	185
V_{34}	Area (m^2)	5329.872	3	3195.440	61
V_{35}	Number of plant species	15.156	3	1.799	61
V_{36}	Advice for installation	1.914	3	0.123	61
V_{37}	Recycling	3.899	3	1.240	185
V_{38}	Turning off the faucet while brushing teeth	3.418	3	1.499	185
V_{39}	Limiting showering time	1.023	3	1.358	185
V_{40}	Using energy-saving light bulbs	3.367	3	1.296	185
V_{41}	Using energy-efficient appliances	0.916	3	0.791	185
V_{42}	Turning off lights and electrical appliances when not in use	3.625	3	1.113	185

Table 3
Farmer group clusters.

Variable	Description	Cluster 1	Cluster 2	Cluster 3	Cluster 4
V_1	Farmer's age	47.42	43.96	46.16	50.06
V_2	Years of farming experience	26.11	23.02	24.91	27.96
V_3	Level of education	Compulsory education	Upper secondary education	Upper secondary education/ Compulsory education	Compulsory education
V_4	Type of soil	Sanded	Sanded	Sanded	Sanded/Local
V_5	Type of greenhouse	Slooping roof	Slooping roof	Slooping roof	Slooping roof/Flat-top
V_6	Greenhouse size (ha)	2.89	3.02	2.16	1.96
V_7	Construction year	2006	2009	2004	2002
V_8	Number of climate systems	2.37	2.51	1.73	1.20
V_9	Holding water storage capacity (m^3)	1028.65	1371.43	1344.68	854.39
V_{10}	Type of pond	Concrete/Polyethylene-lined	Concrete/Polyethylene-lined	Concrete/Polyethylene-lined	Concrete
V_{11}	Shape of the pond	Square/Rectangular	Rectangular	Rectangular	Square
V_{12}	Quantity of water in the pond	75%–99%	50%–75%	50%–75% 75%–99%	75%–99%
V_{13}	Method to keep the pond clean	Covering/Dredging	Covering/Dredging	Covering/Dredging	Dredging/Biocide treatment
V_{14}	Rainwater harvesting	Greenhouse Surface/Other elements of the holding	Greenhouse Surface/Other elements of the holding	Greenhouse Surface/Other elements of the holding	No
V_{15}	Destination of harvested rainwater	Filter well	Pond/Filter well	Pond/Filter well	–
V_{16}	Irrigation programmer	0.80	0.91	0.84	0.79
V_{17}	Use of tensiometers	0.67	0.74	0.68	0.64
V_{18}	Fully computerized irrigation with tensiometers	0.16	0.36	0.22	0.06
V_{19}	Number of crop cycles per year	1.63	1.49	1.45	1.24
V_{20}	Organic farming	0.26	0.70	0.31	0.14
V_{21}	Monoculture				
V_{22}	Season income (€/m^2)	8.32	9.83	8.99	7.73
V_{23}	Season expenses (€/m^2)	4.68	4.28	5.04	3.88
V_{24}	Trading channel	Cooperative/SAT	Cooperative	Cooperative/SAT	Exchange/Private distributor
V_{25}	Number of labours per year	7.48	8.91	6.70	5.16
V_{26}	Percentage of farmer family-bounded labour	9.40	8.87	7.68	13.28
V_{27}	Level of electrical conductivity in irrigation water (dS/m)	1.22	1.16	1.19	1.28
V_{28}	Number of methods used to deal with pests	6.16	6.57	5.27	4.96
V_{29}	Phytosanitary treatments (%)	25.89	19.15	37.7	42.65
V_{30}	Biological control (%)	74.11	80.85	62.30	57.35
V_{31}	Method for pollination				
V_{32}	Type of advice	Trading company	Trading company	Trading company	Trading company/ Supply providers
V_{33}	Hedgerows	Yes	Yes	No	No
V_{34}	Area (m^2)	271.58	2789.13	–	–
V_{35}	Number of plant species	1.84	8.98	–	–
V_{36}	Advice for installation	0.05	0.96	–	–
V_{37}	Recycling	3.32	4.17	3.76	2.86
V_{38}	Turning off the faucet while brushing teeth	3.74	4.60	4.01	3.41
V_{39}	Limiting showering time	3.99	4.23	4.05	3.94
V_{40}	Using energy-saving light bulbs	3.89	4.83	4.15	3.67
V_{41}	Using energy-efficient appliances	4.42	4.53	4.51	4.15
V_{42}	Turning off lights and electrical appliances when not in use	4.05	4.79	4.59	3.59
	Agricultural holdings total:	19	47	74	49

capacity between 75% and 99% and cover and drain them to keep them clean. They collect rainwater from the surface of the greenhouse and from other elements of the farm and direct it to filter wells. Irrigation programmer is available on 80% of the farms and tensiometers are used on 67% of the farms. In 16% of the farms, the irrigation system is computerized through the use of tensiometers. They perform the highest number of crop cycles per year of all clusters. Twenty-six percent of farms practice organic cultivation. They obtain an average income of € 8.32/m^2 and expenses of € 4.68/m^2. The main channels of commercialization of the harvest are the cooperative and the SAT, from which they also receive technical advice. They have an average of seven workers per campaign. To address pests, an average of six methods are used. Biological control is used in a greater proportion (74%) than phytosanitary products (26%). They install hedgerows in the surroundings of their farms with an average size of 271 m^2, which normally includes two species of plants. These farmers did not receive advice for the installation of hedgerows. They present high average values in relation to environmental awareness.

Cluster 2. *Innovators with counselling* (N = 47, 25%). It is formed by the youngest farmers, with less experience in the agricultural field and a medium level of education. They present the largest and newest farms of all clusters. The greenhouses are sloping roof greenhouses and are cultivated using sanded soils. They have the largest number of climate systems. They have the largest capacity ponds and tend to keep them at a lower level than the rest. They use covering and dredging to keep the pond clean. They collect rainwater from the surface of the greenhouse and from other elements of the farm. The collected rainwater is directed to the pond or to filter wells. It is the cluster with the highest number of irrigation systems and computerized tensiometers (36%). It is also the cluster in which organic cultivation is most widely practiced (70%). They receive the highest average income of the group (9.83 €/m^2) and have intermediate expenses (4.28 €/m^2). All farmers in this cluster market their harvest through a cooperative, from which they also receive technical advice. They have the highest average number of workers per campaign of all clusters. They have the lowest level of electrical conductivity of water of all the groups. They use a greater number of methods to deal with pests. It is the cluster that uses a higher proportion of biological control (81%). They install hedgerows with an average surface area of 2789 m^2, which includes an average of nine plant species. In addition, all farmers received specific advice to design their hedgerows. This cluster presents the highest average values in relation to environmental awareness.

Cluster 3. *Followers* (N = 74, 39%). They have extensive experience in the agricultural field and low/medium levels of education. Their farms are of medium size (2.16 ha) and are sloping roof greenhouses. They usually keep their ponds at an average of between 50% and 99%. They use covering and dredging to keep the pond clean. They collect rainwater from the surface of the greenhouse and from other elements of the farm. In 84% of the farms there are irrigation programmers and in 68% of the farms tensiometers are used. A total of 22% of the farms present irrigation system and fully computerized tensiometers. It is in 31% of the farms practice organic cultivation. They have an average income of 8.99 €/m^2 and expenses of 5.04 €/m^2. They commercialize the harvest and receive advice through a cooperative or SAT. They have the lowest percentage of family workers of all clusters. Biological control is mainly used to deal with pests (62%). This cluster does not install hedgerows around its greenhouses. It presents average values higher than four points in the items related to environmental awareness, except for recycling.

Cluster 4. *Reluctant* (N = 49, 26%). Includes older farmers with more experience in the agricultural sector. Their level of education is low. They present the oldest and smallest average farms of all clusters. The greenhouses are both sloping-roof and flat-top greenhouses and they grow in sandy and local soils. They have the least number of climatic systems of the set. The ponds in this cluster are made of concrete and have the lowest water storage capacity. Their ponds are usually maintained at a capacity of between 75% and 99%, and to keep them clean, they use dredging and biocide treatments. This cluster does not collect rainwater. It is the cluster with the lowest use of irrigation programmers and tensiometers. In this cluster, the percentage of fully computerized irrigation systems and tensiometers is low (6%). They grow the least number of crops per season. Only 14% of the farms in this cluster practice organic cultivation. They obtain lower incomes than the rest of the clusters, varying the difference between 0.59 and 2.1 €/m^2 depending on the cluster to which they are compared. The expenses are also lower, varying from 0.4 to 1.16 €/m^2. They commercialize the harvest through exchanges or private distributors. They have the lowest number of workers per campaign of all clusters and the highest percentage of family workers. They have the highest level of electrical conductivity of water. They use the lowest average number of methods to deal with pests of all clusters and have the highest proportion of phytosanitary products (43%). They receive technical advice from exchanges and agricultural supply companies. They do not have hedgerows in the surroundings of their greenhouses. This cluster presents the lowest average values in environmental awareness.

3.3. Attitudes related to the installation of hedgerows

The clusters that decide to install hedgerows have different reasons (Fig. 2). In the case of Cluster 1, they do so mainly for aesthetic reasons and because the installation cost is affordable and the use of pesticides is reduced. In the case of Cluster 2, the improvement of the effectiveness of the biological control techniques stands out, although the reduction in the use of pesticides and the possible economic and environmental benefits also have a lot of weight. Cost reduction is of little importance for Cluster 1 and of intermediate importance for Cluster 2. Finally, regulation is not important for either of the two clusters.

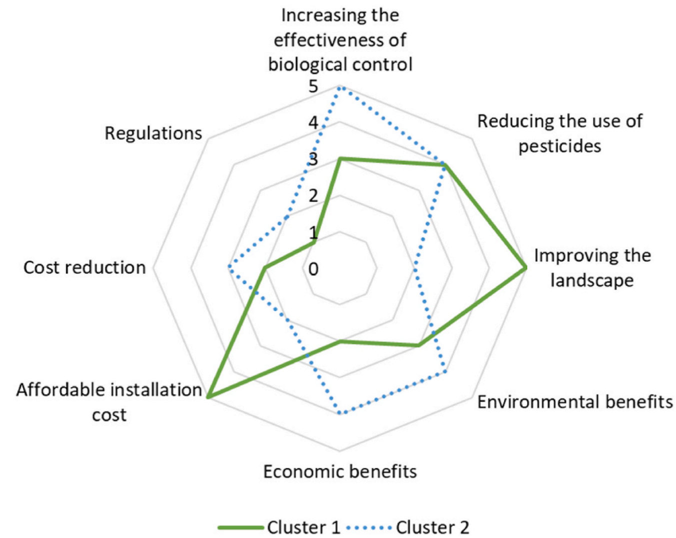

Fig. 2. Reasons to install hedgerows.

Regarding the reasons for choosing not to install this practice (Fig. 3), in the case of Cluster 3, space limitations and those derived from the characteristics of the farm stand out, in addition to the cost of installation. For its part, for Cluster 4, the possibility of developing pests is very relevant, as is the difficulty in choosing the appropriate composition of species that make up the hedgerow. Regulation has not been considered by farmers when making this decision.

The percentage of farmers in each cluster that selected each of the advantages of installing hedgerows in the vicinity of the greenhouses is shown in Fig. 4. In general, the four clusters agree that this practice allows improving the landscape. The farmers of Clusters 2 and 3 are those who value the set of advantages more, highlighting the increase in useful fauna and the improvement of biodiversity. Cluster 1 also values these two advantages, but to a lesser extent. The least valued advantages for the set of clusters are cost reduction and commercial advantages.

Fig. 5 shows the percentage of farmers in each cluster who selected each of the disadvantages of installing hedgerows. The clusters that have hedgerows in their farms are those that score the lowest these disadvantages, with the difficulty of selecting the appropriate composition being the most relevant for Cluster 1 and the limitation of space in the

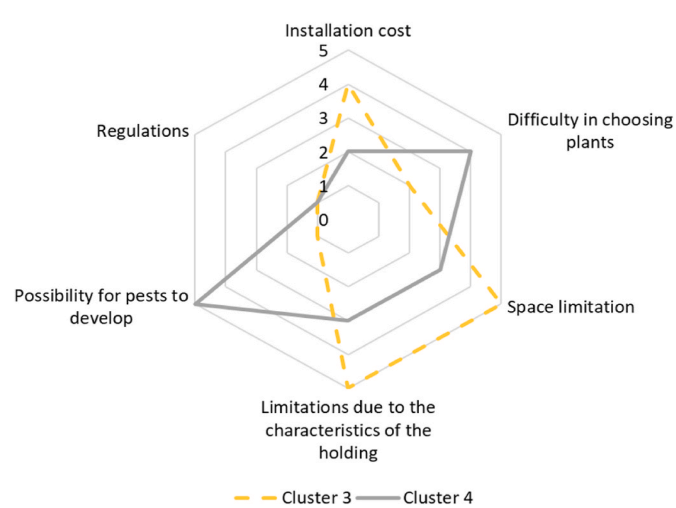

Fig. 3. Reasons for not to install hedgerows.

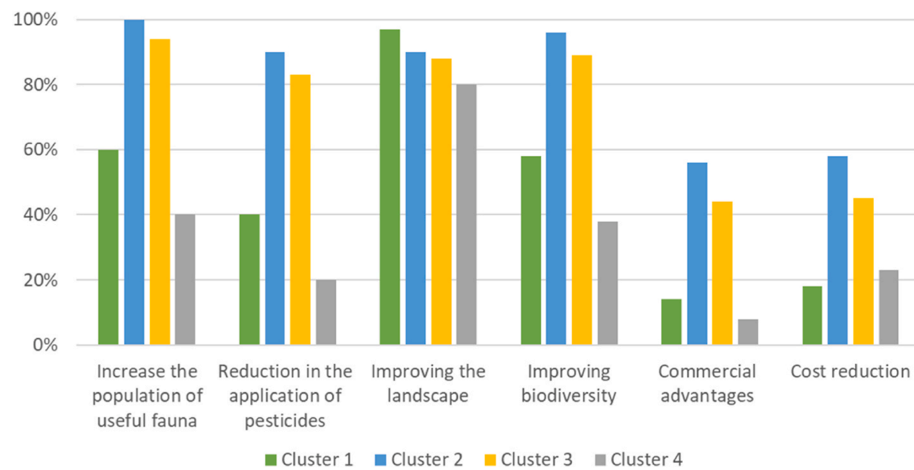

Fig. 4. Advantages of installing hedgerows.

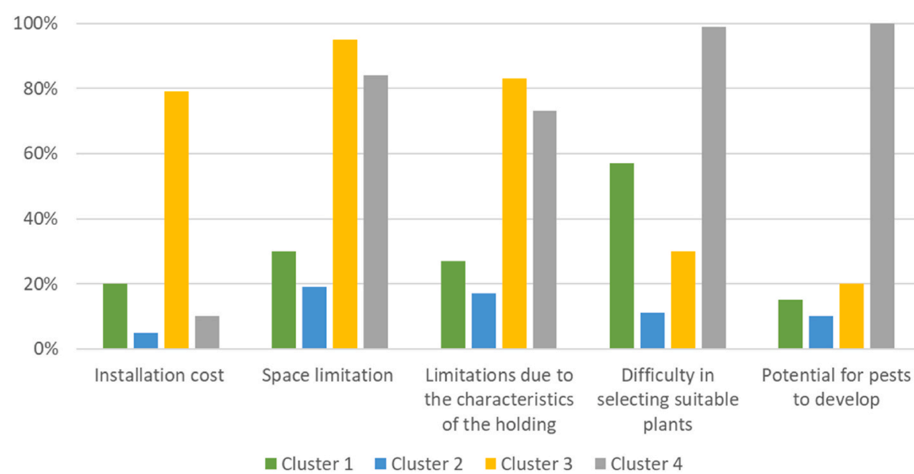

Fig. 5. Disadvantages of installing hedgerows.

case of Cluster 2. For Cluster 3, the limitation of space and those derived from the characteristics of the farm stand out, while for Cluster 4, all the disadvantages are quite relevant except the cost of installation.

3.4. Measures to increase the installation of hedgerows

Fig. 6 shows the level of agreement of the different clusters with the measures proposed to promote the installation of hedgerows. The most valued measures for all farmers are recurring payments for ecosystem services and the provision of training for an adequate development of this practice. Clusters 3 and 4 are opposed to the regulatory measures, while the other two clusters agree. Aid to cover the cost of installation is of greater importance for Cluster 3, while the rest of the clusters are only partially in agreement.

Fig. 6. Measures proposed to promote the installation of hedgerows.

4. Discussion

The results of the cluster analysis show that there are four groups of farmers in relation to the installation of hedgerows around the greenhouses. The 'innovators without advice' (Cluster 1) are characterized by dedicating an average of 271 m^2 of the farm to the installation of hedgerows that are composed of an average of two species of plants. These are farmers who have carried out the installation of hedgerows without advice mainly motivated by the improvement of the landscape. The 'advised innovators' (Cluster 2) dedicate a greater surface of farm for the installation of hedgerows that are composed of more than nine species of plants. The main objective of this group is to promote biological control techniques and reduce the application of phytosanitary products, so they decided to seek advice to design the appropriate composition of plants. The 'followers' (Cluster 3) value the advantages of hedgerows but do not install them due to certain limitations derived from the lack of space in their farms or their characteristics. Finally, the 'reluctant' (Cluster 4) are older and more traditional farmers who distrust the benefits of hedgerows and consider that their installation can generate certain adverse effects.

Most farmers, especially those in Cluster 1, agree that the installation of hedgerows in the margins of the greenhouses implies an improvement of the landscape. The study region is characterized by a high concentration of greenhouses that makes the landscape dominated by plastic structures with few areas of native vegetation. Therefore, the incorporation of hedgerows would allow us to diversify this landscape, which would have a positive visual effect. Aesthetics was one of the advantages of hedgerows and forest strips pointed out by orchard managers in a survey conducted in different European countries (Penvern et al., 2019). The installation of hedgerows can also have a positive effect in commercial terms, since it can be used as a communication and marketing strategy, since consumers are currently willing to pay a higher price for food produced using more environmentally friendly techniques (Amoabeng et al., 2021). In addition, economic benefits can be obtained from possible increases in crop yield or from the sale of products at higher prices because they are of higher quality and more sustainable. Gurr et al. (2016) determined that the installation of nectar-producing plants in rice fields increased grain yield by 5% and resulted in an increase in income of 7.5%.

The farmers of the study region perceive the improvement of biodiversity as one of the advantages of the implementation of hedgerows, which is aligned with the results obtained in other studies (Penvern et al., 2019; Giagnocavo et al., 2022). The generation of biodiversity positively impacts the amount of useful fauna of the crop. For example, Li et al. (2020) concluded that the number of predators was more than 20 times higher in greenhouses adjacent to non-crop vegetation than in control greenhouses in a study conducted in Beijing. Several studies have confirmed the presence of natural enemies of the main pests in different non-crop plants for multiple crops, such as pepper (Bosco and Tavella, 2013), tomato (Perdikis et al., 2011) or eggplant (Li et al., 2020). In this way, by favouring the presence of natural enemies, the biological control of pests is enhanced (Messelink et al., 2021) Albrecht et al. (2020) estimated an average increase of 16% in the provision of pest control services in the fields of crops adjacent to non-crop vegetation compared to fields dominated only by crops.

In addition to biodiversity enhancement, the installation of vegetation around farms can have further positive environmental impacts such as water regulation, soil maintenance, nutrient retention and cycling (Rey Benayas et al., 2020). In relation to water, hedgerows can reduce runoff erosion by reducing the loss of soil nitrogen and phosphorus (Sun et al., 2020). Thus, Thomas and Abbott (2018) found that this type of vegetation can reduce nitrate pollution of water bodies, both groundwater and surface water, due to the excessive use of fertilisers. In the case of soil, the installation of vegetation around farms can improve the biogeochemical cycles of carbon, nitrogen and phosphorus, as well as soil microbial activity (Benítez et al., 2019; Sun et al., 2020). The presence of hedgerows on farms can positively impact nutrient cycling by capturing nutrients that are lost from the root zone of crop plants (Tully and Ryals, 2017). However, methods should be standardised to quantify all these benefits in aggregate across diverse environments, and to explore further how these benefits can incentive farmers to install hedgerows.

Several studies have shown that the homogenization of crops leads to a greater use of insecticides to combat pests (Meehan et al., 2011; Gagic et al., 2021). Specifically, increases in the application of insecticides of between 10% and 20% are expected by 2036 as a result of this fact (Malaj and Morrissey, 2022). The incorporation of hedgerows can lead to a reduction in the application of phytosanitary products by favouring the biological control of pests. Thus, non-crop vegetation reduced the application of insecticides by an average of 34% in the eggplant greenhouses of Beijing (Li et al., 2020), while the installation of nectar-producing plants in the rice fields of Southeast Asia minimized its use by 70% (Gurr et al., 2016). The results of a survey of 91 farmers in the Spanish Mediterranean region indicated that 80% of the participants considered that the installation of hedgerows in the vicinity of the farms meant an increase in the useful fauna present in the crops, while 70% reported having reduced the number of phytosanitary products applied (Giagnocavo et al., 2022). In our study, these advantages are also valued by farmers, especially those in Cluster 2 who have experience with this practice.

The implementation of hedgerows can lead to a reduction in costs derived mainly from two aspects. On the one hand, the reduction in the application of phytosanitary products represents 5.4% of the annual expenses of agricultural operations in Almería and has shown a growing trend in recent years (Cajamar, 2021). On the other hand, the implementation of this practice favours CBC and decreases the purchase of natural enemies raised in the laboratory (Naranjo et al., 2015). Likewise, it must be taken into account that the presence of natural enemies in greenhouses is especially relevant when they are not commercially available (Messelink et al., 2021).

The results of this research show that most farmers do not consider the installation cost as a problem when installing this practice. This may be because they only represent 1% of the total cost structure of the farm (Parra et al., 2020). However, these costs may increase due to certain limitations of the farms, which are especially relevant for the farmers of Cluster 3. Many of the farms have asphalted surroundings, since traditionally, it has been considered that this was the best way to maintain the greenhouse environment clean and free of weeds. In these cases, it would be necessary to eliminate part of the asphalting or use flowerpots, which can affect the cost necessary to install this practice. Some farmers also indicated that the strong winds in some areas make it difficult to install the plants or make it necessary to replace them from time to time. The lack of space also acts as a limitation due to the high concentration of greenhouses in the study region, which makes it difficult to expand the area of cultivation so that farmers try to make the most of the surface they have. In this context, ceasing to produce a part of the farm to install hedgerows implies an opportunity cost for farmers that can materialize in a loss of yield (Moon and Cocklin, 2011; Byerly et al., 2021). However, this perception of farmers seems to contradict what is actually happening. Thus, for example, Pywell et al. (2015) concluded that the withdrawal of the production of up to 8% of the land in the herbaceous crops to create a habitat for fauna did not produce significant losses of yield per hectare. In short, although farmers who have these limitations are not opposed to the use of this practice, they need greater evidence of the benefits that it can bring to carry out its installation. In this sense, Byerly et al. (2021) concluded that farmers should know the benefits derived from useful fauna and the services it can generate, since the installation of non-crop vegetation involves an initial cost of time and money.

It must be taken into account that not all plant species are suitable to keep predators (Messelink et al., 2014). Therefore, the choice of the set of species, the techniques of establishment of the plants and the method of managing the crop and the hedges can be a limitation for the installation of hedgerows (Brodt et al., 2009). In addition, there is the possibility that pests can feed on the hedges if the installation is not done properly (Pretty et al., 2018; Amoabeng et al., 2021). These aspects are the main reasons why farmers in Cluster 4 are reluctant to implement this practice. Messelink et al. (2021) establish that farmers usually prefer that there is no vegetation or only a few species near their greenhouses because they consider that this reduces the risk of pest inflow. However, the choice of suitable species can reduce the presence of pests in greenhouses. For example, the number of pests was reduced by 43% on average in the eggplant greenhouses adjacent to non-crop vegetation in Beijing (Li et al., 2020). In the case of Almería, there is extensive research in relation to the plants that can be included in the hedgerows, including autochthonous species with interspersed flowering periods and diverse habits (Rodríguez et al., 2012, 2014, 2018; Cotes et al., 2018).

Several studies have established that environmental awareness has a positive effect on the implementation of sustainable practices by farmers

(Liu et al., 2018; Prokopy et al., 2019). The results of our research reaffirm this consideration since the most aware cluster of farmers is the one that opts to install this practice, while those with lower awareness values are reluctant to do so. Finally, although in the study region there is a regulation that requires the establishment of hedgerows, it is a recent regulation that only affects newly created greenhouses, so it is not considered a relevant factor when deciding to install this practice (BOP, 2017).

Regarding the strategies for the widespread adoption of this practice, there is a great disparity in the valuation of the different measures between the different groups of farmers. Those that do not have hedgerows are opposed to the existence of regulation in this regard, while the farmers of Cluster 2 consider that the existing regulations should be expanded to include all farms and not only those of new creation. For its part, Cluster 3 fully agrees with the existence of aid that covers the cost of installation of this practice, while for the rest it is a less relevant issue. Currently, there are regional grants for this purpose that can finance up to 80% of the total cost of installation (BOJA, 2017). However, these aids may not be sufficient for the farmers of this cluster because they have the greatest limitations in their farms to install the hedgerows, and their cost would be higher than for the rest of the clusters. A more valued measure is the establishment of a recurring payment with which farmers are rewarded for the ecosystem services that the installation of these green infrastructures provide to the environment in which they are located. Other studies show that this action can be an adequate alternative to promote the adoption of more environmentally responsible practices in the agricultural field (Bianchi et al., 2013; Gatto et al., 2019). In addition, this type of payment can reduce the financial risk posed by these practices, especially in those cases in which their application conflicts with the production objectives of the farmer (Moon and Cocklin, 2011). However, financial aid may not be a sufficient measure in many cases since support and training programmes for farmers are needed. Most farmers agree with the importance of training sessions to encourage the installation of this practice. This is because it is a novel practice in the study region on which a greater transmission of information is needed. In this context, it must be taken into account that farmers are more receptive to implementing a new practice when they learn about it through the previous experience of other farmers (Liu et al., 2018). These results are especially relevant for policy-makers since knowing the existing heterogeneity between groups of farmers can help them design programmes aimed at encouraging the installation of hedgerows based on their needs and attitudes.

5. Conclusion

This study aims to analyse the factors that influence the decision to install hedgerows in order to establish the appropriate lines of impulse for their establishment. To this end, the case of intensive agriculture in Southeastern Spain has been studied. The cluster analysis has classified farmers into four groups with different opinions, motivations and limitations in relation to the hedgerow installation in their greenhouses. Considering these aspects, it is very important to develop specific programs fostering this practice; measures demanded by farmers with farm physical limitations cannot be the same as those addressed to farmers who distrust effectiveness. In this sense, the establishment of financial aid may be an appropriate incentive for those who have to make a great investment due to farm limitations; and, on the other hand, the implementation of training plans and the improvement of advice may contribute to change farmers' reluctance. In any case, it should be considered that some measures might be cross-cutting since they provide incentives to different types of farmers, like the financial aid related to the ecosystem services generated by the hedgerow's installation.

As future lines of research, research should be broadened in relation to the installation of hedgerows in the study region, in such a way that the opportunity cost of allocating a part of the surface dedicated to the incorporation of this practice is analysed, their ability to reduce the application of phytosanitary products and their impact at the commercial level. Finally, it must be taken into account that this study was carried out in Southeastern Spain, so the attitude and perception of farmers about hedgerows may be conditioned by the specific characteristics of the study region. However, the results obtained in this research may be useful in regions in which the installation of non-crop vegetation is to be promoted, especially in those areas in which the loss of biodiversity is compromising the biological control of pests and jeopardizes the sustainability of agricultural activity.

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Credit author statement

All authors contributed to the study conception and design. Material preparation and data collection were performed by B López-Felices, JF Velasco-Muñoz and JA Aznar-Sánchez. Data analysis and interpreting the results were performed by B López-Felices, E Mesa-Vazquez and JA Aznar-Sánchez. The first draft of the manuscript was written by B López-Felices and JA Aznar-Sánchez. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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