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PROTOCOL FOR THE TRANSITION FROM CHEMICAL MANAGEMENT TO INTEGRATED MANAGEMENT OF *EUCALLIPTERUS TILIAE*

FINAL PROJECT

AGRONOMIC SCIENCES ENGINEERING

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Summary

Currently in Spain, chemical control practices are being carried out to combat pests and diseases in green spaces. These practices have traditionally been the main tool for the control of health problems in roadside trees, although chemicals are not exempt from causing risks to human, animal and environmental health.

However, at present there is also a citizen sensitivity parallel to the previous current, in front of public health and the environment. This awareness is causing an increase in the use of tools for integrated pest management.

The progressive replacement of phytosanitary products for integrated pest management techniques aims to reduce pests to a lower level than the damage thresholds established for each species of plant and tree. Instead, the main objective of chemical control is to eliminate the pest completely, eradicating all the harmful organisms present in the tree, without taking into account the possible problems that this can cause.

For these reasons, in this thesis, a protocol is proposed to combat the linden aphid (Eucallipterus tiliae) with biological control. Not only the method of execution is important, but also, raising awareness among citizens and knowing what they think about this change. For this reason, a survey of citizens has also been carried out, in order to assess their acceptance. To understand this behavior, is proposed a factorial and cluster analysis in order to relate the questions with which you agree or disagree with the groups of people who share certain characteristics. So, we will be able to know what type of person agrees or disagrees with the questions about chemical control and biological control.

Resum

Actualment a Espanya, s'estan duent a terme pràctiques de control químic per a combatre plagues i malalties en espais verds. Aquestes pràctiques han estat tradicionalment l'eina principal per al control de problemes sanitaris en arbrat viari, encara que, els productes químics no estiguin exempts d'ocasionar riscos en la salut humana, animal i del medi ambient.

Tot i així, a l'actualitat també existeix una sensibilitat ciutadana paral·lela al corrent anterior, en front la salut pública i la del medi ambient. Aquesta conscienciació està ocasionant un increment en l'ús d'eines per la gestió integrada de plagues.

La substitució progressiva dels productes fitosanitaris per a les tècniques de la gestió integrada de plagues, te l'objectiu de reduir les plagues a un nivell inferior dels llindars de danys establerts per a cada espècie de planta i d'arbre. En canvi, l'objectiu principal del control químic és eliminar la plaga al complert, erradicant tots els organismes nocius presents a l'arbre, sense tenir en compte els possibles problemes que això pugui ocasionar. Per aquests motiu, en aquest treball de fi de grau, es proposa un protocol per a combatre el pugó del til·ler (*Eucallipterus tiliae*) amb control biològic. No només el mètode d'execució és important, sinó també, conscienciar als ciutadans i saber què opinen sobre aquest canvi. Per aquest motiu, també s'ha realitzat una enquesta als ciutadans, per tal d'avaluar la seva acceptació. Per entendre aquest comportament, es proposa un anàlisi factorial i de clústers per tal de relacionar les preguntes amb què s'està d'acord o no, amb els grups de persones que comparteixen certes característiques. Així podrem saber quin tipus de persona està o no d'acord amb les preguntes sobre control químic i control biològic.

Resumen

Actualmente, en la mayoría de municipios de España, se están llevando a cabo prácticas de control químico para combatir plagas y enfermedades en espacios verdes. Estas prácticas han sido tradicionalmente la herramienta principal para el control de problemas sanitarios en arbolado viario, aunque los productos químicos no estén exentos de ocasionar riesgos en la salud humana, animal y del medio ambiente.

Sin embargo, en la actualidad también existe una sensibilidad ciudadana paralela a la corriente anterior, frente a la salud pública y la del medio ambiente. Esta concienciación está ocasionando un incremento en el uso de herramientas por la gestión integrada de plagas.

La sustitución progresiva de los productos fitosanitarios para las técnicas de gestión integrada de plagas, tiene el objetivo de reducir las plagas a un nivel inferior de los umbrales de daños establecidos para cada especie de planta y de árbol. En cambio, el principal objetivo del control químico es eliminar la plaga por completo, erradicando todos los organismos nocivos presentes en el árbol, sin tener en cuenta los posibles problemas que esto puede ocasionar.

Por este motivo, en este trabajo de fin de grado, se propone un protocolo para combatir el pulgón del tilo (*Eucallipterus tiliae*) con control biológico. No sólo el método de ejecución es importante, sino también concienciar a los ciudadanos y saber qué opinan sobre este cambio. Por este motivo, también se ha realizado una encuesta a los ciudadanos para evaluar su aceptación. Para entender este comportamiento, se propone un análisis factorial y de clústeres para relacionar las preguntas con las que se está de acuerdo o no, con los grupos de personas que comparten ciertas características. Así, podremos saber qué tipo de persona está o no de acuerdo con las preguntas sobre control químico y control biológico.

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1. INTRODUCTION

During all these years and with the arrival of the coronavirus, we have learned that distancing ourselves from nature generates economic costs, health and quality of life, which we can't and we do not want to assume.
The change that has occurred today is to understand that the planning of the urban green of the city goes beyond the design of the parks and gardens. Ecosystem green infrastructures and, in general, vegetation of cities, are an opportunity and a structural tool to improve the habitability of the city and reduce its environmental footprint.

In this age where technology predominates, we mustn't forget that an important factor for the good growth and balance of the population is direct contact with nature and the environment. Scientific studies prove that outdoor exercise in contact with the environment, stimulates metabolism, increases happiness in people and prevents cardiovascular diseases. In addition, it facilitates the recovery of exhaustion, and combats stress, anxiety and depression.
Therefore, interaction with nature increases the possibility of feeling successful in different aspects of life, and it is for these reasons, among many others, that changes and conservation criteria must be established for the maintenance of urban green spaces.

1.1. Urban green spaces

The concept of urban green space is applied to all those urban areas with vegetation for public use. These spaces bring ecological values necessary for the city such as biodiversity, naturalness and plant wealth. On the other hand, they provide many benefits to citizens, since they improve air quality by preventing the "heat island" effect from being generated by reducing temperatures; They promote and preserve biodiversity, in addition to reducing part of climate change; They improve social relations and increase life expectancy. In scientific terms, it has been shown that having green spaces in cities increases the practice of sport of the residents of the area, and physical and mental problems. Interacting with the green spaces of cities improves social cohesion and civic activity, as it makes us aware of its importance. The scientists Nutsford, D., Pearson, A., Kingham, S. (2013), published in the magazine *Public Health* a study investigating the association between green spaces and mental health. In this study, it was found that the increase in the proportion of green spaces in neighborhoods was associated with a decrease in the number of treatments for anxiety/mood disorders in an urban environment. This suggests that the benefits of green spaces in mental health can be related both to active participation in usable green spaces near the home and to observable green spaces in the neighborhood environment.

One of the main goals of implementing green spaces in cities is to bring about an improvement in the quality of life and well-being of citizens. Today's cities need to ensure well-being and health, and strategies and solutions need to be implemented to optimize their resources. At present, the implementation and good maintenance of urban green spaces and the renaturalization of new urban areas are the most economical and available strategies to meet the objectives.

As explained by Juvillà, E. (2019) "it is necessary to know how to achieve the balance between efficiency in the provision of services and the quality of the urban environment". For this reason, it is very important to protect and ensure good health in the vegetation of urban areas, paying special attention to their needs.

According to the Ministerio de Agricultura, Pesca y Alimentación (2020), parks and gardens are configured as green spaces where biodiversity shelters are created, due to the multitude of species that inhabit them. Ecosystems are formed that improve the quality of life of citizens through natural values. This richness has a positive impact on our quality of life and our own ecosystems, helping them to maintain pest control.

The vegetation of urban green spaces grows in environments of continuous stress, because in cities and even more with the establishment of climate change, warm and dry microclimate environments are created. In addition, trees grow in plantation holes with reduced dimensioning. The roots of this vegetation must coexist with urban service infrastructures (water, electricity, energy). The type of soil is still one of the other problems, since being limited by pavement, the floor where they are planted, is of the compact type. On the other hand, many of the species planted in urban green spaces are of exotic origin, which makes their adaptation more difficult, and on the contrary, it promotes their stress. All these situations generate stress conditions in trees and plants that cause their weakening, a problem that favors the appearance of pests and diseases.

For this reason, opting for studies in order to determine how different environmental conditions affect the vegetation of urban areas, is a good way to know which species are the most resistant and which are not. It can help to understand how vegetation responds in conditions of continuous stress and which are the best tree species depending on the geographical area.
If we analyze the inventories of urban trees, especially those trees implemented on sidewalks and forming alignments (Sánchez, M., López, A., Trigo, M., 2010), it is surprising that there is a little diversity of species. What the author reflects is that there is a very

small number of tree species that predominate and repeat in most Mediterranean cities. This tendency to plant the same species causes a reduction in biodiversity and, conversely, a susceptibility to an attack by organisms such as insects, mites and pathogenic organisms.

1.2. Pest

1.2.1. What is a pest?

Pests are considered unwanted organisms that interfere with human activity. They are described as unwanted because they damage and cause discomfort in vegetation that humans have planted. In order for a set of organisms to be classified as a pest, the sum of its set must exceed a certain density, in a certain place. Therefore, this set must exceed the tolerance threshold causing harm and discomfort in people.

1.2.2. How pests originate

The pest is conditioned by several components that favor that it can be established in an area. Some of the factors that determine pests are as follows:

- Climate factors:

  Temperature, humidity, rain, wind, solar radiation and photojournalism are climate factors characterized by their daily and seasonal variations. Therefore, we can say that the climatic conditions determine the geographical distribution of the pest and the possibilities of reaching high or low densities.

  The distribution and establishment of the pest in one place, is determined by the presence of food (Cisneros, F., 2010). This action is generally influenced by the fluctuations associated with the changes in seasonality, that is, changes in temperature.

  In general, (Polyakow, I., 1968), associates variations in seasonal abundance of pests with variations in infestation areas, distinguishing five phases in the annual cycle of a pest:

  1. Depression phase, where the pest remains in the low density and lives only in the reserve locations
  2. Colonization phase: Migration of the pest from the reserve areas to other areas of the plant, forming colonies to reproduce
  3. Reproduction phase, is the phase where the population density increases throughout the colonized area
  4. Density peak phase, characterized by being the phase where the pest reaches the maximum density
  5. Declination phase, phase where there is a gradual extinction of the population

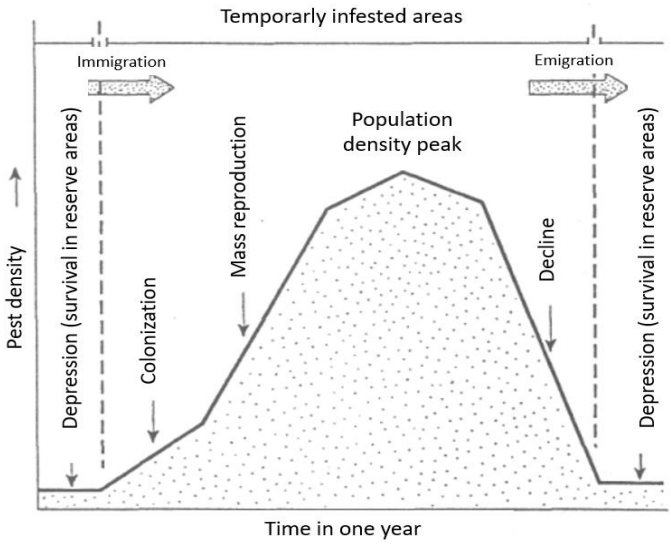

Figure 1: Diagram of the annual cycle of a pest (H. Cisneros, 2010)

- Availability of suitable and sufficient habitats to complete the life cycle:
  The number of generations that develops the pest is conditioned by the amount of effective heat that it requires to complete its cycle and develop in a certain place. In relation to climate factors, effective heat is determined by an optimal value of physical conditions. This heat can be altered by adverse effects such as: extreme temperatures, droughts, abnormal storms and excess pollution.

- Presence and types of predators
  One of the most fundamental objectives for the pest is to find a presence of food in the area where it is located. This requirement will make it possible to reproduce and complete its cycle. Depending on the type of pest, it will feed on other organisms or plants, or organisms and pests.

1.2.3. Damage caused by pests in the urban environment

The loss of trees in the urban area makes it difficult to quantify them in economic terms. However, different criteria are taken into account, such as the economic losses linked to the implementation and maintenance costs, up to the decrease or absence of benefits for the residents. These damages can be classified by:

- Economic damage. To these damages in urban environment, they refer to the loss of value that the plague causes in the green spaces. These damages include the economic loss of the species, and what has been invested in its maintenance.

- Monumental damage. They produce the loss of monumental value to the species, which has accumulated dover time and has been considered valuable to society.

- Aesthetic damage. They cause a decrease in the aesthetic values of vegetation. A very common example is necrosis that can be observed on leaves.

- Functional damage. Damage that eliminates the functionality of the tree or the affected vegetation. The tree is impossible to perform normally.

- Comfort damage. They are those damages that cause discomfort to the residents of the area. They affect the quality of life of citizens. One example is the fall of molasses on the sidewalks of the streets, excreted by the plague.

In economic terms, the assessment of damages caused by pests is difficult to establish. The assessment should consider the functionality of the space, taking into account the aesthetic, cultural and social criteria, avoiding maximum subjectivity.
According to the *Ministerio de Agricultura, Pesca y Alimentación* (2020), the criterion of affecting a pest in a given place varies depending on the usefulness of that space, which will determine whether its degree of condition is higher or not.
Determining how much damage, caused by pest, can withstand a plant without having an impact on its functionality, is one of the main aspects to be treated in plant health. This criterion is based on the introduction of two concepts: "harm threshold" and "tolerance threshold".

1.2.4. Tolerance and damage thresholds

Urban green spaces have characteristics that differentiate them from agricultural crops. This causes that the concept of "tolerance threshold" is not exactly the same, due to the differences between them. In urban green spaces, it is difficult to establish an amount of damage and therefore an impact on the economic field. For this reason, the economic criterion, in landscape and urban areas, is in the background, unlike the agricultural sector.

We understand the concept of "damage threshold" as that variable that indicates the maximum density of a certain organism, or the maximum damage that this organism can cause to the plant so that (the plant) doesn't suffer an unacceptable loss of value.

The type of damage that the pest can cause in the vegetation can be measured in several ways:

- Observation and counting of the defoliated leaf foliage
- Observation and counting of the proportion of dead stems
- Observation and counting of the number of organisms plagued in the leaf
- Observation and counting of the proportion of trees affected

As Pons, X., Lumbierres B., Hiernaux I., (2017)) explain: "Before an amount of damage is reached, a control measure should be put in place to prevent and prevent losses, since none of them is effective instantly". The lowest value of pest density or damage (caused by the pest), is what is known as the tolerance threshold, intervention or treatment threshold.

In some of these cases, such as the loss of aesthetics and the inconvenience caused to citizens, the assessment made of the losses is influenced and conditioned by the human factor, since, according to a subjective criterion, some damage is accepted or not tolerated. These criteria and characteristics must be taken into account when establishing the harm and tolerance thresholds, The thresholds that we found in urban green spaces are (Pons, X., Lumbierres B., Hiernaux I., 2017):

1. Threshold of loss of vigor
   Trees can be affected by pest organisms that, if they are not eradicated or their concentration is not reduced, will decrease the life of the tree or even cause their death. Therefore, this threshold will be guided according to the amount of damage that the tree endures until it causes great harm

2. Functionality threshold
   This threshold is applied when a deficiency or anomaly that the plant suffers, cancels its functionality. For example, if a tree has been planted in order to provide shade, a health deficiency will reduce the number of leaves, and on the contrary, it will stop providing shade and giving functionality.

3. Aesthetic threshold
   As mentioned above, the aesthetic perspective is stipulated by people who define that criterion subjectively. In this criterion, the aesthetics that the tree supposes for the whole of the green space are valued. This one is closely related to the appearance that the tree provides in relation to its health. If the tree or plant consists of plague, symptoms of disease, desiccation or weakened areas, its aesthetic threshold will decrease.

4. Comfort threshold

   This threshold defines the effects and damages that vegetation causes to citizens and residents of the area where it is located when they suffer from diseases and/or are contaminated by pest organisms. Some of the damage that can be done to citizens is:

   - Allergic reactions to pollen and/or fruits of various species.
   - Discomfort due to the secretions that pests excrete when they parasite a tree or plant (dirty sidewalks, floor pollution, slips of the residents of the area...)
   - Defoliation of leaves on the pavement, as a cause of pest pollution.
   - Bites by pest organisms

   This threshold is only possible in areas that affect the public. “As we move away from the most frequent areas for users, this type of damage is losing relevance even if the attack by pest organisms is strong" (Pons, X., Lumbierres B., Hiernaux I., 2017)

Therefore, we can affirm that integrated pest management, aims to reduce the number of pest organisms to a tolerable level, and therefore do not exceed any of the thresholds.

1.3. Pest control

The main objective of pest control is the improvement of plant health so that they can carry out their cycle and increase the well-being of citizens. The objective of eradiate and control pests, makes us pay little attention and importance to the way in which we manage this control. Generally, this control is carried out by applying pesticides.

As doctors Badii, M., Abreu, J. (2006) explain, from the second world war, the use of pesticides was extended as they offered multiple benefits such as:

1) Quick healing action to prevent damage
2) Wide range of action on almost all pest situations.

Both advantages reflect fast economic income. However, problems soon emerged, such as:

1) Pest resistance to chemicals.
2) Waste problems.
3) Return of the main pests.
4) Increase in pests of secondary importance at the primary level.

5) the destruction of natural enemies.
6) Environmental pollution.
7) Increased costs
8) Promoting effects:
    a) Hormoligosis: alteration of the reproductive rate and survival rate of the pest
    b) Trophobiosis: increased susceptibility of the plant to the pest

For these reasons, it is necessary to design adequate control programs against those species that acquire the consideration of pest. The basic criteria for the design of control programs that reduce the negative consequences of the pests and also the risks derived from the application of measures for their control must be analyzed.

1.3.1. Integrated pest management methods

The most accepted definition according to the FAO (Food and Agricultural Organization), is that integrated pest management constitutes a pest management system that, in the context of the associated environment and the population dynamics of the species under study, uses all the appropriate methods and technology in a compatible way to maintain the population density of pest at sub-economic levels while preserving environmental quality.

Integrated control is a method that regulates pest's populations, and integrated pest management (GIP) is a component of resource management that contemplates ecological, socioeconomic, cultural, religious, political values and subsequent decisions and consequences.
The based on those defined as integral pest management (Badii, M., Abreu, J. 2006) are:

- Know the environment in which plants inhabit and their ecosystem, in order to understand them. That is, to be clear about their behavior, phenology and what their natural enemies are.
- Use methods that promote ecological and natural foundations:
    - Look for long-term optimal performance and not maximum performance in the short term.
    - Develop techniques to monitor and estimate the population of pest organisms
    - Develop thresholds to control and set the level of economic damage that pests can generate in plants

- Use of multiple handling methods to obtain better results, such as:
    - Biological control
    - Cultural control
    - Microbial control
    - Genetic control

- Inform citizens and raise awareness of what integrated pest management entails.

1.3.2. Regulations

To encourage the introduction of new practices that put aside the indiscriminate use of chemical products, national and European laws have been drafted where criteria are introduced to promote its regulation and the introduction of integrated pest management. At a European level, there is comprehensive legislation on chemical products, led by REACH and CLP, which aims to guarantee a high level of protection of human health and the environment. The main legislation at European level is as follows:

- Regulation (EC) No. 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

- Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances

At a European level we also find the European Chemicals Agency (ECHA) where its function is to achieve the safe use of chemical substances. It regulates the application of chemical substances at European level, to contribute to the protection of human health, the environment and innovation of Europa:

- Regulation (UE) Nº 528/2012 of the European parliament and of the council of the 22 of May of 2012 relative to the commercialization and the use of the biocides

- Directive 2009/128/EC establishes that Member States shall adopt national action plans to set quantitative objectives, goals, measures, calendars and indicators, to reduce the risks and effects of pesticide use on human health and the environment, in addition to promoting the development and introduction of integrated pest

management (GIP), as well as alternative approaches or techniques in order to reduce dependence on the use of chemical pesticides.

Nationwide,

- Royal Decree 1201/2002 regulates the integrated production of agricultural products. This voluntary system includes, among the general rules of integrated production, a group on integrated pest control, in which it is mandatory to put chemical methods, biological, biotechnological, cultural, physical and genetic methods first.

- Real Decree 1311/2012, by which establishes the frame of action to achieve a sustainable use of the phytosanitary products. In this sense and to comply with the provisions of this royal decree, in December 2012 the first "National Action Plan" was approved to achieve a sustainable use of phytosanitary products, defines in article 5 of Chapter II the following:

  "*The general objective of the National Action Plan to achieve a sustainable use of phytosanitary products is to reduce the risks and effects of the use of phytosanitary products in human health and the environment, and to promote the development and introduction of integrated pest management and alternative approaches or techniques in order to reduce dependence on the use of phytosanitary products."*

In other words, priority will be given to measures that contemplate integrated pest management before phytosanitary products, so that users opt for practices and products with a lower risk to human health and the environment. These activities will be carried out taking into account the general principles of integrated pest management described in Annex I "*General principles of integrated pest management*":

1. The prevention or elimination of harmful organisms must be achieved, among other possibilities, especially by:
   a) Crop rotation:
      i. Increase soil fertility
      ii. Increased yield of planted species
      iii. Reduce soil erosion
      iv. Reduces the use of pesticides
      v. It limits the concentration of pests and diseases, because it forces the pest species to abandon that soil
      vi. Reduces weed stress

b) Use of suitable cultivation techniques, for example, technique of the false sowing, dates and densities of seeding, adequate dose of seeding, minimal cultivation, pruning and direct sowing.

c) Use of resistant varieties as well as seeds and material of standardized or certified multiplication. Plant material with genetic characteristics of resistance in front of pathogenic organisms, it is a very useful resource to prevent and control diseases in plants.

d) Use of fertilization practices, soil amendment, irrigation and drainage balanced.

i) Subscriber: Using subscribers with a balance of nutrients, generates a good state of health in plants

ii) Irrigation: It is very important to adjust the irrigation needs to the demands of the plant, taking into account the characteristics of the soil together with the characteristics of retention, infiltration and displacement of water.
It is necessary to be very careful with the regulation of irrigation, in order not to exceed its demand.
Excess water could lead to the proliferation of fungi and, conversely, cause diseases. It is also necessary to be careful not to cause a lack of oxygen, since it would trigger in conditions of asphyxiation that the plant would not tolerate.

e) Prevention of the spread of harmful organisms through measures prophylactics (for example, periodically cleaning the machinery and teams)

f) Protection and improvement of important beneficial organisms, for example with appropriate phytosanitary measures or using ecological infrastructures inside and outside the production sites and reservoir plants.

2. Harmful organisms must be monitored using appropriate methods and instruments.

3. Based on the results of the surveillance, professional users must decide whether to apply phytosanitary measures and at what time. An essential element to make a decision is to have safe and scientifically sound threshold values.

4. Sustainable, biological, physical and other non-chemical methods must be the first option before the choice of chemical methods, provided that they allow a satisfactory control of pests.

   - Cultural control

     Cultural control is based on the use of agricultural practices with the aim of contributing to prevent insect attacks or reduce their damage. In general. It includes measures such as:

     - Preparation of the land of the tree planting hole:
       1. Subscriber
       2. Nutrients
       3. Irrigation
     - Selection of resistant species

     The proper application of agricultural practices requires several appropriate knowledge about the physiology and phenology of the vegetation we plant and also of:

     - Its agronomic characteristics
     - The modalities of the practices
     - Knowledge of the biology of local pests and planted species
     - Plant behavior
     - Seasonality features

   - Ethological control

     Ethology is the study of the behavior of animals in relation to the environment. There are methods of repression that take advantage of insect behavioral reactions. Behavior is determined by the response of insects to the presence or absence of chemical stimuli or physical and mechanical stimuli. Pheromones are the most well-known and used substances in this field, in particular they are used in population monitoring and monitoring (Cisneros, F.,2015)

   - Physical control

     Physical control consists of the use of a physical agent to alter the physical environment of the pest, generating conditions that are lethal for it.

   - Biological control

     Biological control uses natural enemies for pest control. It is an ecosystem resource for sustainable production. Organisms are used to regulate and maintain pests, reducing them to tolerable population levels for plants.

Unlike chemical control, natural enemies are not constant, but depend on various circumstances in the environment. Their range of population density on which they act, will be variable according to the species of pest to which they prey or parasitize, besides depending on other factors as they are it: the established volume of plague, the temperature, the relative humidity, the meteorological conditions of the geographical area...

This mechanism can be difficult, as not all natural enemies of all species are known today. In addition, the implementation of biological control requires specific knowledge that comes from research and appropriate training for technicians.

On the other hand, biodiversity can favor pollinators and biological control because biodiversity means an increase in food and an increase in shelter habitats for natural enemies. Biodiversity influences the trophic dynamics between the pest and the natural enemy, favoring biological control and preserving it.

- Chemical control

  The chemical control of pests consists of the decrease, repression or prevention of harmful population levels through the use of chemical substances. In order for the application of a chemical to pest control to be successful, the following criteria must be considered:

  - Product type
  - How the product is applied
  - Application stage.

  In chemical control, actions are taken in relation to the pest, seeking maximum mortality or temporary eradication. It is a healing measure that produces a quickly decrease in the pest, which will increase again when the waste of the product disappears in the plants. Conversely, with this powerful resource, many abuses have been committed. Their abuse and misuse of pesticides, overrides the benefits that may arise from their good use. All pesticides, when applied, select the least susceptible insects, and end up forming a resistant population.

Currently, the use of pesticides is regulated by EC Regulation 1107/2009 on the commercialization of phytosanitary products and Directive 2009/128/EC, which creates a European framework to achieve the sustainable use of pesticides. In Spain, phytosanitary treatments in agriculture and in the non-agricultural field are regulated by RD 1311/2012, establishing the framework of action to achieve sustainable use of phytosanitary products.

Phytosanitary products should not have a harmful effect on human or animal health, nor for the environment, especially in relation to surface and underground waters, air, soil, or have a harmful effect on biodiversity.

5. Applied phytosanitary products must be as specific to the objective as possible, and must have the least side effects for human health.

6. Professional users must limit the use of phytosanitary products and other forms of intervention to the levels that are necessary, for example, by reducing doses, frequency of application or through fractional applications, taking into account that the level of risk they represent for vegetation must be acceptable and that they do not increase the risk of development of resistance to populations of harmful organisms.

7. When the risk of resistance to a phytosanitary measure is known and when the level of harmful organisms requires repeating the application of phytosanitary products to crops, the strategies available against resistance must be applied, in order to maintain the effectiveness of the products. This may include the use of multiple phytosanitary products with different modes of action.

8. Professional users must check the effectiveness of phytosanitary measures applied based on the data recorded on the use of phytosanitary products and the monitoring of harmful organisms.

1.4. Eucallipterus tiliae

Eucallipterus tiliae, is a monophagous species, this means that it is an aphid that only feeds on sap and soft tissues of the tree genus *Tilia sp.* It is a group of sucking insects, belonging to the order *Heipteria*, suborder *Homoptera* and form the superfamily *Aphidinae*. They originated in the Cretaceous era, approximately 100 million years ago, and appear as a result of radiation given to the Tertiary era. They are currently distributed in the temperate clima.

In our climatic conditions, the reproductive period of *Eucallipterus tiliae* occurs at the beginning of spring (late March) and population densities grow exponentially until reaching the highest concentrations at the end of May or beginning of June. During the period of greatest abundance, aphids produce a large amount of molasses. The concentration of these organisms decreases until they reach zero concentrations. In autumn, males and females lay the winter in the form of an egg.

One of the main objectives (regardless of the cycle in which the aphid is found) is to feed on sap from tender tissues of plants, especially the tips of shoots and cocoons of flowers. This activity causes serious problems in the host plant, causing diseases or death itself. Once established in the tree, they are placed on the front of the broadly large leaves of the lime trees causing large excretion of molasses.

The damages and symptoms that this aphid can cause are:

Direct damage

These damages occur when the pest, partially or totally, destroys the organs of plants (stems, leaves...), causing symptoms such as the rolling of leaves, necrosis and the proliferation of fungi.

Indirect damage

These occur when the pest that is attacking the plant propagates viruses, bacteria and fungus. This causes the weakening of the plant, since, apart from infecting the plant; it also feeds on its sap. As a result of this intake, aphids excrete excess sugar in the form of molasses that is deposited on the back of the leaves.

Excessive molasses promotes the development of molds, which leads to a reduction in photosynthetic activity of the plant. Therefore, toxic substances can be transmitted to the plant.

Figure 2: *Eucallipterus tiliae* (Russo, 1976).

1.5. Tilia sp

The linden tree (figure 3) is an outdated tree belonging to the family *Malvaceae* and belongs to the genus *Tilia sp*. It can reach up to 40 meters in height. They can live up to 900 years.

It consists of a large leafy crown, with small and large leaves, with a serrated edge and a dark green obverse and a light green reverse. Its flowers are aromatic and form inflorescences in the shape of yellow grapes. Its trunk is thick and dark, with a rough bark, depending on the species.

It is a tree widely used in the regions of Barcelonès and Baix Llobregat. The most commonly used species are *Tilia x european, Tilia tomentosa* and *Tilia euchlora.*

Figure 3: *Tilia sp.* (Elarbol.org, 2020)

1.6. Symptomatology of *Eucallipterus tiliae* in *Tilia sp.*

The main external symptoms that can be seen when *E. Tiliae* attacks *Tilia sp*, are:

- Roll up leaves and shoots, as they feed on the sap of the phloem. Adults extract nutrients from the plant, altering the balance of the growth hormones of the plants themselves. These damages can lead to the death of the plant.
- Weakening of the plant caused by the bites of the aphids when they suck the sap.
- Molasses excretion in leaves and trunk, causing damage as a result of the extractions of sap (substance from which they feed) and the inoculation of toxic sap, producing as a consequence raisins, chlorosis and low yields. This causes the proliferation of black saprophyte fungi. In addition, the excretion of molasses causes the arrival of ants looking for the sugars present in the molasses to feed

2. TARGETS

This work consists of two targets:

1. Design a protocol to carry out a transition from chemical control to biological control in the treatment of aphid *Eucallipterus tiliae* in the species *Tilia sp*.
2. Analyze the predisposition and behavior of people to make this change.

3. PROTOCOL PROPOSAL

To combat the *pest Eucallipterus tiliae* in linden trees and carry out a transition from chemical control to integrated pest control, the first thing to do is to observe and evaluate the concentration of aphids. Then we have to identify the time of application, and the biological control mechanism that we want to use.

3.1. Material and methods

3.1.1. Observation

In order to know if our geographical area consists of aphid species *Eucallipterus tiliae,* we must observe the urban green areas that have linden trees, and that in previous years have been treated with chemical control. The most abundant species-plant associations will be analyzed visually and fortnightly. The observation begins two weeks before the start of the reproductive phase of the aphids, that is, the first week of March

It is of special interest that the transition is carried out in various types of urban green spaces, located in different neighborhoods of the same municipality. In this way, the study will take detail of several areas located in different places, with a common pattern but with various uses.

It should be noted that in the year to be carried out this process, the tree should not have been treated with any pest control, since the objective is to make a transition to prevent the plague of the consecutive campaign.

3.1.2. Sampling

The objective of sampling is to identify the pest, study its phenology and count the number of individuals found in each tree. In this way, we will know which biological control mechanism will be the most suitable and effective, and how many predators or parasitoids should be introduced.

The various trees must be sampled, between 5 and 7 trees of each chosen green zone. From each tree, 8 samples will be taken. The samples will be terminal shoots about 30 centimeters long, (Pons, X., Lumbierres B., 2004). Visually, the sphere of the tree crown will be divided into 4 parts and two samples of each part (Figure 4) will be extracted:

Sampling distribution

1. **Part 1:**
    a. North Zone
    b. South Zone
2. **Part 2:**
    a. North Zone
    b. South Zone
3. **Part 3**
    a. North Zone
    b. South Zone
4. **Part 4**
    a. North Zone
    b. South Zone

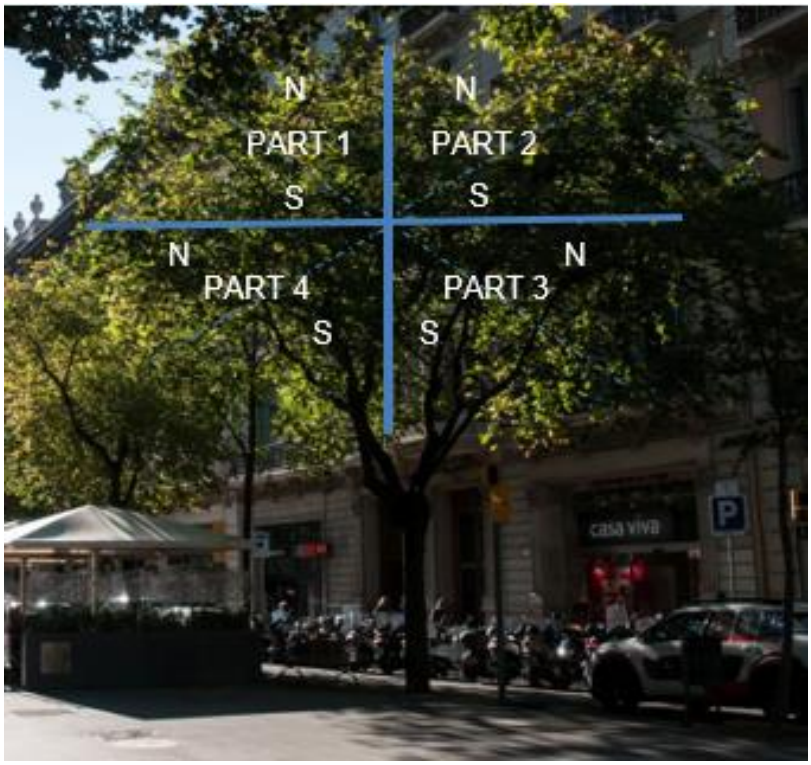

Figure 4: Sampling distribution

The samples will be cut with scissors with pole and bag (figure 5) so that the pest is isolated and dead out.

Figure 5: Sampling pole (Pons, X., Lumbierres B.,2004)

The requirements to carry out quality monitoring will not only depend on fieldwork, but also a conditioned enclosure where the work areas do not interfere with the development of the activities and that do not involve the risk of possible contamination. Some of the recommendations to carry out a correct analysis will be:

- Have a storage area for the material used in the monitoring field.
- Disinfection of the material used in the field and having it again.
- It consists of a storage area and pest management.
- Have a reception and storage area for samples taken in the field
- It consists of an area of analysis of the samples for the correct recognition of the species, phenology, and counting.

3.1.3. Sampling analysis

Once the samples have been collected, they will be taken to the laboratory, in order to identify the pest species, determine its phenology and proceed to its counting. This laboratory recognition may not last more than 48 hours, because the reproductive cycle of aphids is extremely fast and if we take a long time to identify and count, the concentrations of aphids in the trees will increase. At the time of the identification of the pest species, other species present will also be counted, such as natural enemies, in order to have more information about the environment of the pest.

The laboratory where the pest analysis and research will be carried out, must have the infrastructure, equipment and material established in the Specific Regulation for the authorization of analysis/testing laboratories, D-GF-CGP-PT-012 code, and those required

for the development of DS monitoring and analysis, in accordance with the activity to which it postulates.

The evaluation of the number of populations present in a terminal outbreak will follow a scale of abundance proposed by Pons, X., Lumbierres B., 2004, (Table 1). This resource will facilitate the count of *E. Tiliae* and will allow us to identify the moments of maximum abundance of the pest and therefore, we will be able to determine what will be the best time to do the treatment and reduce the concentration.

Table 1: Scale of abundance of pests. (Lumbierres, 2004)

Abundance class	Characteristics
0	No aphid
1	Presence of aphid
2	Small colonies
3	Medium colonies
4	Very large colonies

Where:

- Class of abundance 0 "without aphid" is equivalent to not finding any aphids or remains of molasses excretion
- Class of abundance 1 "presence of aphid" is equivalent to finding between 1 and 2 aphids on one of the leaves.
- Abundance class 2 "small colonies" is equivalent to finding between 10-25% of the leaves of the sample with aphid. We take as a model that 100% refers to the set of all the leaves of those 30 centimeters of sprout cut in the sampling
- Abundance class 3 "medium colonies" is equivalent to finding between 25-50% of the leaves with aphid and several areas of the branches also with some aphid.
- Abundance class 4 "very large colonies", is equivalent to finding more than 50% of the leaves with aphid and more than 10% of the stems with quite aphid.

In order to counteract, the aphid count obtained from sampling, the amount of molasses excreted by aphids will be evaluated in the laboratory. Because molasses is a viscous fluid, the water-sensitive paper cards should be placed randomly and distributed across each selected tree in each area. These cards will be in the trees for two hours, where they will retain the molasses and then collect them. These impacts of drops will be related to the number of aphids previously counted in the sampling.

In the case of finding aphid predators, natural enemies, an abundance scale (Table 2), will also be used to recognize how abundance this is in an environment naturally:

Table 2: Scale of abundance of predators. (Lumbierres, 2004)

Abundance class	Characteristics
0	Absence
1	Presence
2	Abundance
3	Great abundance

It is assumed that the E. *Tiliae* relationship with linden trees is of seasonal abundance and short periods (Pons, X., Lumbierres B., Hiernaux I., 2006). Therefore, the integrated control strategy will be proposed only for this relationship, because not all aphid associations with trees are the same. Figure 6 shows how the relationship between *Eucallipterus tiliae* and lime trees is short-lived.

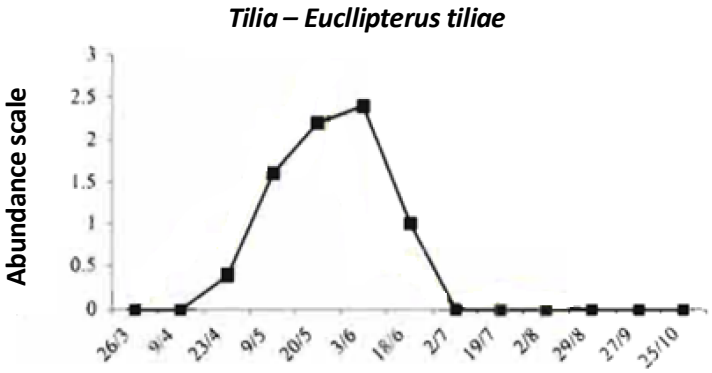

Figure 6: Seasonal abundance of *E. tiliae* (Pons, X., Lumbierres B., Hiernaux I., 2006).

Figure 6 also shows how *E. Tiliae* individuals have an annual peak of abundance catalogued in the spring-summer season. This peak is related to the hatching of eggs in March and April. These eggs were laid in the winter season, where a low and zero concentration of pest is observed. Once this peak has passed, the pest concentration decreases, coinciding with the months of late summer, August and September.

However, this example not should be taken as the only reference, since each region and geographical area consists of different climatic and urban characteristics to others. It should be noted that thanks to several studies that have been carried out on *E. Tiliae*, this is an aphid that consists of many fluctuations depending on the climate zone. Therefore, depending on where this protocol is applied, the climatic conditions of the studied area must be studied and observe the phenology and cycles that develop the pest.

This will force to initiate the control of presence in the month of February in very climatic zones, and in the month of April in very cold areas.

In several studies, related to the counting of pest organisms through abundance classes, regression curves have been performed for pest-plant associations. The results extracted reflect the reliability of the regression curves. Therefore, we can conclude and demonstrate that abundance classes reliably represent the number of individuals present in trees.

3.1.4. Biologic control and cultural measures

In this protocol, biological control is chosen as a control measure for the association described *E. Tiliae-Tilia sp*, but it also wants to highlight and promote the need for the application of cultural measures, since they promote the stability of natural enemies in the place where the application is to be made.
First of all, we must be clear that there are already urban green spaces where predators and parasitoids of certain pests already coexist naturally. On the contrary, and consequently, as a result of a lot application of insecticides and chemicals that we have been applying over the years, much of this useful fauna has been disappearing.
Therefore, taking advantage of the action of these already established natural enemies and increasing their conservation, will encourage their response to combat pest individuals. Some of the techniques that promote these biodiversity reservoirs can be:

- Creation of biodiversity islands
  An example of this action is the planting of flowering meadows and the use of reservoir plants. These practices contribute to the ecological restoration of green areas, favoring the presence of beneficial fauna (useful fauna and natural enemies) that are part of the trophic chain and that can intervene in the biological control of other species. It brings benefits such as the increased presence of pollinators in green areas, in addition to attracting the population to the landscape.
- Creation of insect shelters
  An example of this action is insect hotels. These are artificial structures, usually made of wood, with the aim of giving shelter to multiple beneficial insects, especially pollinators and pest controllers.

- Living trees
  The objective of sowing flowering plants in the trees of an urban area, is to create micro-habitats that generate shelters of habitats where the useful fauna can inhabit to favor the biological control of pests. With this decision, actions and measures are taken to promote biodiversity and the naturalization of urban areas.

Not only biodiversity is provided with this practice, but the soil conditions of the trees will also be improved. In addition, it will decrease the level of compaction and increase the infiltration of water.

3.1.4.1. Release of predators

Once the urban ecosystem has been studied and identified, natural enemies will be released for the pest and the tree in particular. In our case, we will choose to release adult ladybugs of the type *Adalia bipunctata* or ladybug of two points.

Figure 7: *Adalia bipunctata* (Plant tailoring, 2019)

DOSE

The dose that will be released from natural enemies will depend on the number of aphids concentrated in the lime and the size of it. In relation to Table 1 where the concentration of aphid is characterized according to an abundance class, the dose of *Adalia bipunctata* that must be applied to the lime trees will be as follows:

- Abundance class 0 (characteristic "without aphid"):
  If no aphid is observed in the tree, no concentration of ladybugs will be applied because they will not persist in the corresponding place due to the lack of food, that is, the lack of aphids. In this case, the lime trees must be constantly monitored, in order to be able to act when the first aphids are observed.
  The times when you have to be more tentative at the arrival of the aphid, are the times of reduction of these, that is, in mid-March and beginning of April, with the arrival of spring and rising temperatures.

- Abundance class 1 (characteristics "presence of aphid"):
  If the presence of aphids begins to be observed in the tree, a tree box with 20 specimens of *Adalia bipunctata* must be released, because the aphid has a great reproductive capacity and must be intervened in a row.

- Abundance class 2 (characteristics "small colonies"):
  As soon as the first aphid colonies appear, a tree box with 30 specimens of *Adalia bipunctata* will be released.

- Abundance class 3 (characteristics "medium colonies") and classes of abundance 4 (characteristics "very large colonies"):
  In these two situations where the colony of aphids is very high, we will apply a greater number of ladybugs to be able to control quickly the plague of the tree. The boxes installed in the trees will consist of 60 specimens in total.

APPLICATION

Will be tried to install the boxes in the trees, outside the hours of maximum temperature. In general, the organisms of *Adalia bipunctata*, are presented in boxes, so they must be transported and released delicately, without shaking the box, to avoid stressing them.

The steps for your release will be as follows:

1. Hang the box on a branch of the tree with shade location, near the area or areas where the presence of aphid has been observed.
2. Remove the tape to allow ladybugs to leave the box in search of aphids. Check that the output hole is completely open.

Recommendations

- The ladybugs will come out of the opening hole progressively, you should not be in a hurry.

- On the other hand, the presence of ants should be avoided, since you frighten the ladybugs. In the case of finding them, they must be eliminated with useful fauna against the corresponding species of ants.

APLICATION SCHEDULE

The months of the year in which insects can be released are as follows:

G	F	Ma	A	Mg	Jn	Jl	Ag	S	O	N	D

ACTION MODE

Adalia bipunctata ladybirds feed on aphids at all stages of development, both young and adult. Each ladybug can feed on 60 aphids a day over the 3-4 months of life.
Once installed in the plants, the ladybugs will remove the aphids as they appear. Several generations of the first ladybirds released could develop throughout the season if aphids are still present. A female can lay up to 20 eggs a day.

CONSERVATION

In the event that on the day of the release of ladybugs there are adverse weather conditions such as rain or granite, the ladybugs can be put back in the initial box. This box can be kept for between 1 and 2 days in the dark, at a temperature of 10-15ºC.

RESULTS

During the first weeks after release, the effects of ladybugs can be observed in the areas most polluted by pest. The way in which we measure the effect that the predator (ladybird) does on the plague (aphid), is visually. In urban areas, the most effective way to account for the reduction of pest in trees is by observing two parameters in each of the trees contaminated by pest:

1. Observing the decrease in symptoms caused by the pest in:
    - Leaves:
        - Observation of the decrease in the number of aphids in the leaves of trees (any area of the glass)
        - Observation of the decrease in screwed and necrotized leaves
        - Observation of the decrease in molasses in leaves and fruits
    - Trunk:
        - Observation of the decrease in the amount of molasses in the tree trunk
        - Observation of the decreased presence of ants in trees that are attracted by the smell of molasses detached by aphids when sucking the sap.
2. Observing an increase in ladybugs in a state of pupae and larva, since this will ensure a good consolidation of the ladybug in the tree.

As mentioned above, biological control depends on living organisms that need a period of establishment and comfort in the area where it is interesting that they last. For this reason,

the chosen predator, *Adalia bipunctata*, should be deployed at the time where aphid already exists but not in its maximum presence

3.1.4.2. Monitoring of pest-predatory populations

It should be noted that these types of controls are of great importance in their monitoring and monitoring, since this fact will allow to assess the effectiveness of the actions carried out and to be able to assess, if necessary, the adoption of other measures. This monitoring will be carried out with weekly inspections systematized, in which the date of the review will be related to the location and the species on which the control is being carried out. The municipality must manage and regulate its monitoring in order to evaluate the control mechanisms, in order to adopt the most suitable measures and/or the adoption of new strategies.

Therefore, biological control will be a tool of great importance to use within the integrated control of pests of the municipality studied. It requires specialization and dynamic and constant monitoring over time to adopt the most effective and environmentally friendly measures.

3.1.4.3. Other actions

The need of certain municipalities to carry out a transition from chemical control to an integrated pest control, more specifically to biological control, entails a series of benefits but also a decrease in the effectiveness and immediacy of treatment compared to chemical control. Not only are the results of the treatment necessary and the effectiveness of the selected mechanism, but it also requires prior awareness and knowledge to be understood.

A few months ago, doing internships in the environment department of the public administration, I was aware of the great need to remedy citizen complaints. A city council, whose objective is to satisfy the needs of the residents of its municipality and facilitate its demands, but this reflection is not always accompanied by good management.
Over time, I observed the great limitation of satisfying the opinion of the residents and combining it with natural practices in relation to urban green spaces.
For this reason, among others, I was aware of the great importance of having to raise awareness among the citizen and keep it informed of the new practices of urban green. When we do not know about something, we tend to comment without knowing, on the other hand, when we know what they are talking about, our opinion tends to objectivity and not so much to subjectivity. A council must be able to inform and keep up to date with its practices in the neighborhood, but we will tend to complaints and limit an opinion that it does not know.

According to Royal Decree 1311/2012, of 14 September, which establishes the framework for action to achieve a sustainable use of phytosanitary products, chapter V: *"Sale of phytosanitary products and information and awareness"*, specifically in article 26: "*Information and awareness to the public*", it is explained that the competent bodies will adopt, each in its territorial scope, in coordination with each other and with the Ministry of Agriculture, Food and the Environment, measures to inform the general public, promote and facilitate information and awareness programmers, and the provision of accurate and balanced information in relation to phytosanitary products.

This relationship between a public body and the residents of its municipality, will be determined by practices and activities proposed by the city council. It is for this reason that any city council or public body that is willing to carry out a transition from chemical control to integrated pest control, must know that a large part of the process will have to be used to raise awareness among citizens. Raise awareness in a clear, simple way and exposing the benefits and whys of that decision**.**
The explanation of biological control is a challenge for many councils, so a variety of measures will be set out below to deal with the improvement of the ways in which this process is carried out.

- Explaining posters
  Posters or informative posters are a good option to report this change. They are useful for disseminating information and publicizing it in a visually attractive way. These, show little data, since they are of immediate reading and serve to capture the attention of the citizen. It is very useful to hang them in the areas of the municipality where you want to make the transition

- Information leaflets
  Once the posters have been hung, the improvement in way of informing of the benefits and explaining what this change consists of, is to distribute information leaflets in the mailboxes of citizens. In this way, it will be possible to reach the houses in a clear and safe way.

- Ads on social networks
  Posting an explanatory poster on the public body's website, even on the various platforms most in demand today (Instagram, Twitter, Facebook...), will be very useful to send and introduce this new information to young people and to be active on these platforms.

- Talks and debates
  Being able to organize talks in the public spaces of the municipality on the occasion of exposing the new measures that the city council wants to take in front of the urban green, will always be very useful to be able to deepen and explain on firsthand the reason for the transition. The citizen can be directly sensitized and the doubts and questions that are demanded by citizens can be answered.

- Articles in journals
  Writing an article in the municipal journal, explaining how the established decision has been agreed and what its benefits will be, is a good way to re-mark the advantages it will bring

3.1.5. Protocol Summary

Figure 8 shows the steps that must be followed to carry out a biological control of *Eucallipterus tiliae* in *Tilia sp.*

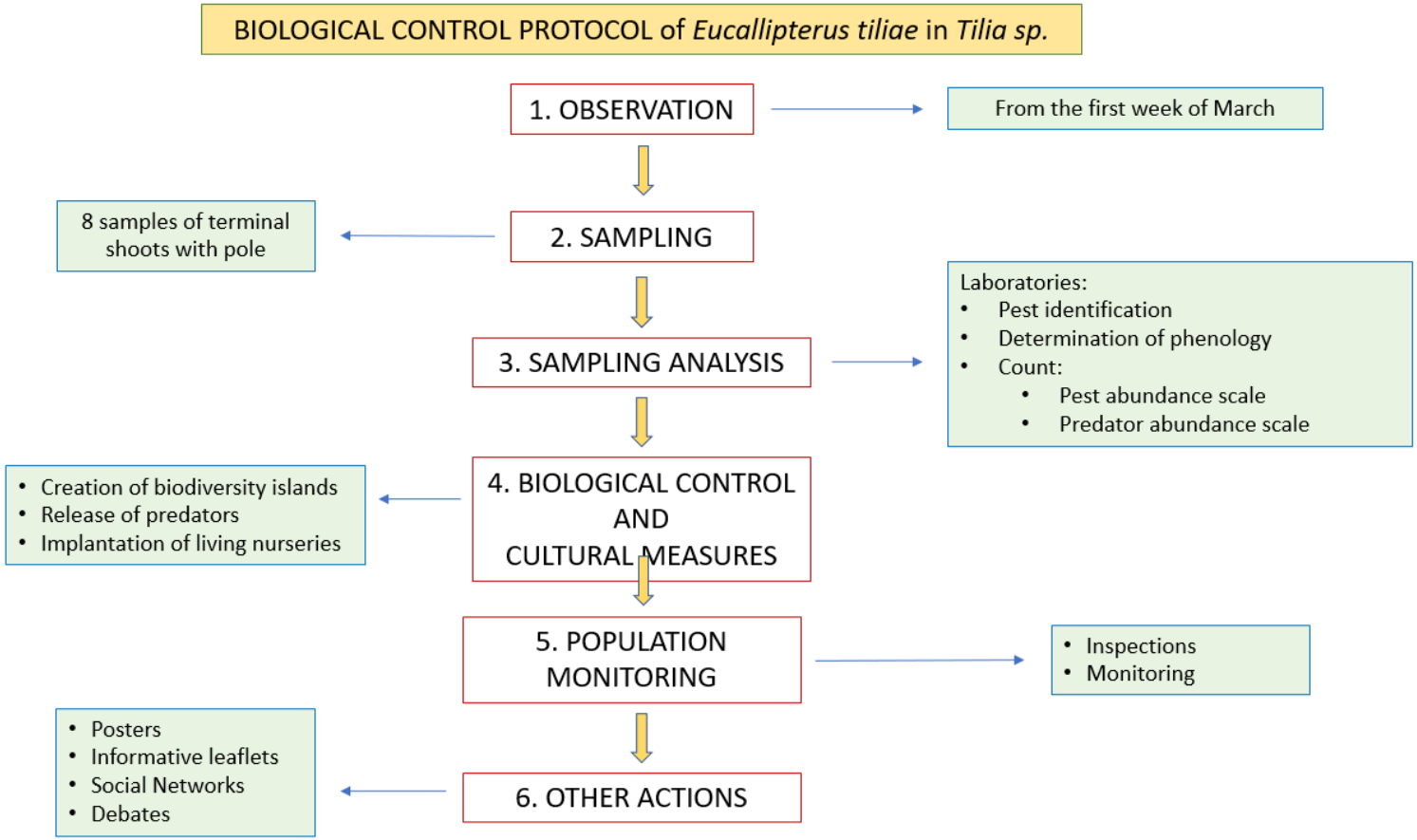

Figure 8: Outline of the protocol for the transition from chemical management to integrated management of *Eucallipterus tiliae*

4. SURVEY

4.1. Objective

In March 2022, a survey was carried out with the aim of knowing what the population's opinion on chemical control and biological control was.

4.2. Materials and methods

The survey was sent to 100 people who were characterized by being of different ages, being from different cities and practicing different professions. We wanted to achieve a population surveyed that was not homogeneous, which is why a wide range of people with different views and lifestyles were selected. Of these 100, 94 people answered the survey. The respondents received a *Google Drive* form with a brief objective introduction on pest management and the control methods used for their control.

The collected demographic variables were:

- Residence area:
    1. "Urban"
    2. "Rural"

- Level of studies
    1. "Superior"
    2. "Secondary"
    3. "Primary"

- Employment status
    1. Employer
    2. Salaried
    3. Student
    4. Unemployed
    5. Retired
    6. Others

- Age of the respondent:
    1. (The respondent wrote his/her age)

As in the survey there were few individuals with the employment situation "Unemployed", "Others" and "Retired", these have been recorded to the group "Others".

25 affirmative questions of *Likert* type, related to environmental health and opinion on biological treatments, were redacted to compared biological treatment with chemical one. The questions were written taking as a model other surveys related to the environment and green spaces in cities.
The values of the Likert scale used were:

1. "Completely disagree"
2. "Disagree"
3. "Neutral / does not know, does not respond"
4. "Agree"
5. "Completely agree"

The questions were asked in Spanish and are collected in table 3:

Table 3: Survey Items	
1	Well-maintained urban green spaces make our cities and neighborhoods more attractive places to live and work.
2	I would be willing to see more insects than usual on the trees, in order to reduce their pests and avoid using chemicals.
3	The human being is the main responsible for climate change
4	It is important that an urban region has green areas
5	It is necessary to invest time and money in the good preservation of the green areas
6	Although spraying a tree with chemical products ensures that I eliminate the pest that it contains, I would prefer to use another mechanism that is not chemical (for example, biological control)
7	Taking action to care for the environment is a moral duty
8	It brings me benefit and/or satisfaction to save from home and to meet vegetation (shrubs, shrubs and plants)
9	The urban gardens contribute to reducing the levels of carbon emissions in the cities, which has made the air cleaner and healthier for its residents.
10	I would eliminate traffic or parking lanes to widen the sidewalks in order to plant more trees, shrubs and plants
11	I prefer not to see organisms, such as ladybugs, flying around the trees of a city, even knowing that they can fight pests
12	It is important to pay attention to the needs and care of the trees, shrubs and plants of a city

13	Some individual freedoms should be limited to care for the environment
14	It is in my command to carry out specific actions to take care of the environment.
15	Pollution is one of the main environmental concerns
16	The actions undertaken by municipalities and governments in relation to the fight against climate change can be effective
17	Chemicals (insecticides) can cause contamination and toxicity in the areas where they are used
18	The cities that take the time to take care of and maintain their green space contribute to a half of the health of the city.
19	It is necessary to eliminate the urban plagues found in the arboreal, shrubs and plants (aphid, mites, processionary of the pine...)
20	The urban green space provides multiple benefits to the urban populations (reduction of stress, mood enhancement…)
21	It is important to pass or practice sport in green areas (parks and gardens)
22	Pollution and toxicity would be reduced if the plagues of urban vegetation with non-chemical products will be traversed
23	Protecting the biodiversity (flora and fauna) of urban green areas is vital to guarantee the health of our environment and strength our physical and psychological form.
24	I would be willing to eradicate a pest from an entire tree, even if that entails contamination and possible toxicity problems for citizens
25	It is necessary to enhance the vegetation in the cities or towns, knowing its benefits.

For the realization of this survey, we believed necessary to focus on three important issues: 1. Urban green spaces; 2. Pest control; 3. Pollution and the environment. We considered that these three questions were of great importance to analyze the responses of the population surveyed.

4.2.1. Statistical analysis

A descriptive analysis of demographic variables by area of residence (Rural or Urban) was carried out using summary statistics such as counts, mean, standard deviation, minimum and maximum for continuous variables, and frequency and percentage for categorical variables. The reason for this classification by area of residence occurs because the number of respondents varied between zones (70 urban area and 14 rural area) and we believed interesting to see if the distribution of the rest of demographic variables was the same in both areas.

The possible differences for demographic variables between the place of residence have been analyzed using the *Student t test* statistic for age and the exact test of *Fisher* or *Chi-square* for the studies and the employment situation.

Items were described alone and also classified by demographic variables using the median value and dotted diagram.

The objective of the survey was to have an idea of the degree of agreement or acceptance by the population of the municipality, on the chemical or biological control of pests. That is, given the answers to a series of questions, the target is to obtain information about:

1. Which questions the respondent agrees with
2. Who agrees or not (people characteristics)

In the following figure (Figure 9), the process is summarized: An exploratory factorial analysis is carried out in order to obtain groups of items (=factors = dimensions), which the respondents agree or disagree with. Subsequently, with these new variables (factors) a cluster analysis is carried out, to obtain different groups of respondents who tell us who agrees or not and with which groups of questions (factors). Respondents in one group are more similar than respondents from different groups.

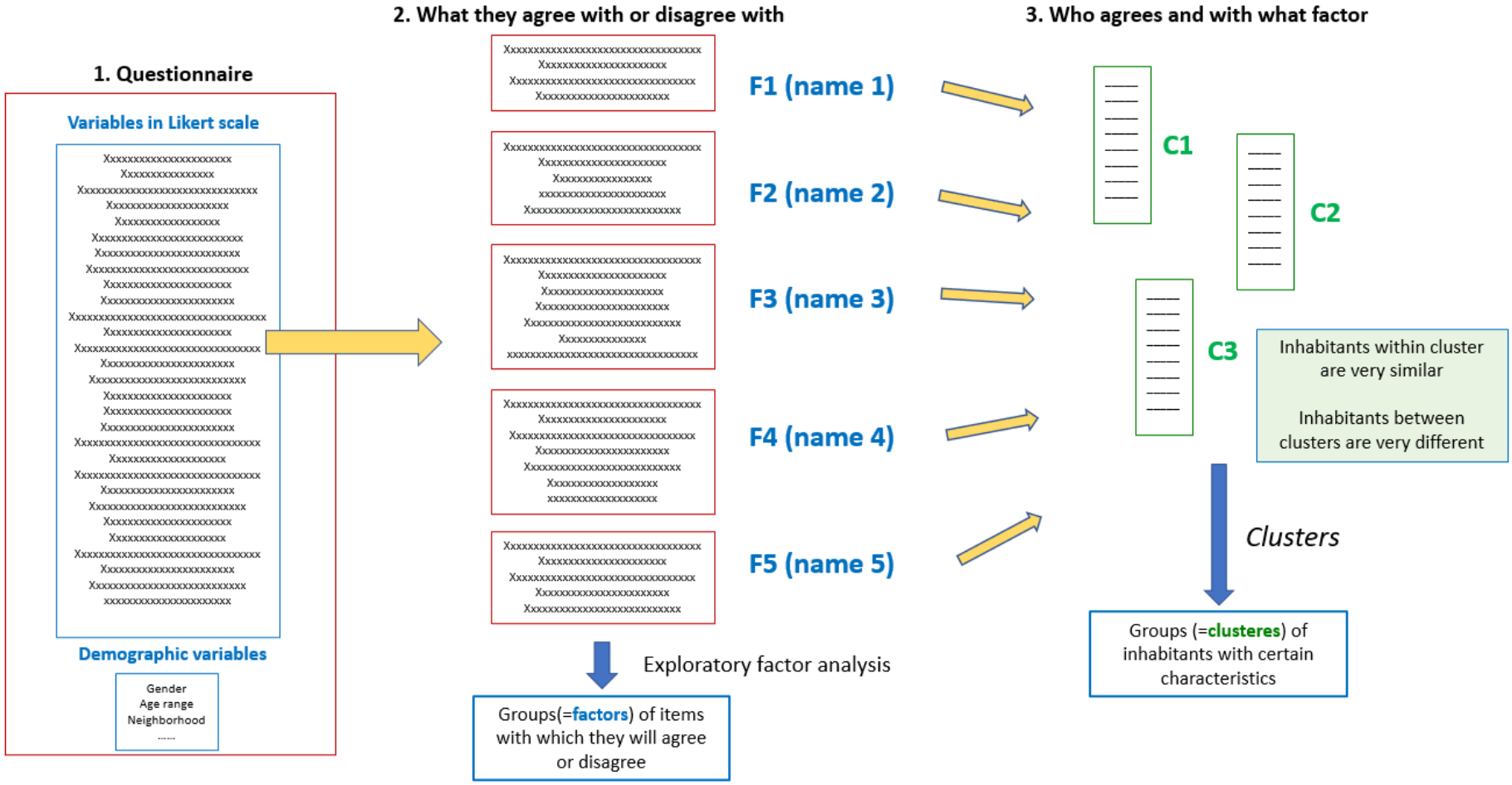

Figure 9: Outline on how the results obtained from the survey would look

4.3. Results

The 94 respondents answered all the questions.

4.3.1. Demographic variables by area

The distributions of demographic variables by urban and rural area are as follows:

4.3.1.1. Age

With respect to age, table 4 shows the values of means and standard deviations (SD)

Table 4: Distribution of the age by resident areas

Zone	N	Mean	SD	Min	Max
Urban	79	45.12	45.31	21	72
Rural	15	45.4	45.16	21	59
Total	94	45.17	14.21	21	72

In urban and rural populations, the age is similar: Mean (SD):

- Urban: 45.1 (14.3)
- Rural: 45.4 (14.1)

The *t-test*, to compare means, suggests that there are no statistically significant differences (Table 5):

Table 5: Results of the *t- test*

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf.	interval]
Urban	79	45.12	1.61	14.31	41.92	48.33
Rural	15	45.4	3.65	14.16	37.55	53.24
Combined	94	45.17	1.46	14.21	42.25	48.08
diff		-.27	4.02		-8.26	7.72

diff = mean(Urbana) - mean(Rural) t = -0.06

H0: diff = 0 Degrees of freedom = 92

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0

Pr(T < t) = 0.4730 Pr(|T| > |t|) = 0.9460 Pr(T > t) = 0.5270

The mean difference between zones is -0.27, (95% confidence interval: -8.3, 7.72, P = 0.9460)

Regarding the categorical age (less than 50 years or bigger than or equal 50 years), we observe (Table 6) that there were no differences (P = 0.644).

Table 6: Categorical age vs Residence zone

Age	Zone Urban / Rural		Total
< 50	42	7	49
	85.71	14.29	100.00
	53.16	46.67	52.13
>=50	37	8	45
	82.22	17.78	100.00
	46.84	53.33	47.87
Total	79	15	94
	84.04	15.96	100.00
	100.00	100.00	100.00

Pearson chi2(1) = 0.2133 Pr = 0.644

4.3.1.2. Studies

In the following table (Table 7) we can see the frequencies and percentages of the variable's studies and residential zone. The first value of a cell represents the number of respondents, the second the percentage with respect to row (studies) and the third the percentage with respect to column (residence area).

Table 7: Studies vs Residence zone

Studies	Zone Urban / Rural		Total
Higher	63	13	76
	82.89	17.11	100.00
	79.75	86.67	80.85
Secondary	16	2	18
	88.89	11.11	100.00
	20.25	13.33	19.15
Total	79	15	94
	84.04	15.96	100.00
	100.00	100.00	100.00

Fisher's exact = 0.728
1-sided Fisher's exact = 0.415

We can see, for example, that there are 63 respondents out of a total of 76, with higher education and living in the urban area. This represents 83% of all higher education or 80% of all those living in the urban area.
We can't see a relationship between the type of study and the urban area (P=0.728), that is, they are independent.

4.3.1.3. Employment status

In table 8, we can see the frequencies and percentages of the variable's employment situation by residential area:

Table 8: Employment situation vs Residential area

E. Situation	Zone Urban / Rural		Total
Entrepreneur	11 100.00 13.92	0 0.00 0.00	11 100.00 11.70
Salaried	49 80.33 62.03	12 19.67 80.00	61 100.00 64.89
Student	10 76.92 12.66	3 23.08 20.00	13 100.00 13.83
Others	9 100.00 11.39	0 0.00 0.00	9 100.00 9.57
Total	79 84.04 100.00	15 15.96 100.00	94 100.00 100.00

Fisher's exact = 0.200

There is no relationship between the employment situation and the residence area (P=0.200).

4.3.2. Descriptive of items

1. "Completely disagree"
2. "Disagree"
3. "Neutral or "You do not know; you do not answer"
4. "Agree"
5. "Completely agree"

Table 9: Distribution of items

	Valor					
Item	1	2	3	4	5	Total
1	2	1	0	13	78	94
2	1	4	3	44	42	94
3	1	1	2	29	61	94
4	1	0	0	7	86	94
5	0	0	1	20	73	94
6	0	1	5	41	47	94
7	0	1	2	26	65	94
8	0	0	0	8	86	94
9	0	0	3	24	67	94
10	4	12	16	34	28	94
11	61	27	1	4	1	94
12	0	0	0	25	69	94
13	4	5	17	43	25	94
14	0	2	4	41	47	94
15	0	0	1	31	62	94
16	1	14	16	33	30	94
17	0	2	9	35	48	94
18	0	1	2	27	64	94
19	2	5	15	38	34	94
20	0	0	0	22	72	94
21	0	1	1	27	65	94
22	0	5	15	26	48	94
23	0	2	2	27	63	94
24	30	40	17	6	1	94
25	0	0	0	26	68	94

In Table 9, we observe a trend to answer 4. “Agree" or 5. “Completely agree” for the except for the majority of the items. Except for the question "11. I prefer not to see organisms, such as ladybugs, flying around the trees of a city, still knowing that they can fight pests" and "24. I would be willing or willing to eradicate a plague of a tree to the full, even if this entails contamination and possible toxicity problems in citizens".

Regarding items,

- 10. It would eliminate traffic or parking lanes to make the sidewalks wider, in order to plant more trees, shrubs and plants
- 13. Some individual freedoms must be limited to take care of the environment
- 16. The actions carried out by local councils and governments in relation to the fight against climate change can be effective
- 19. It is necessary to eliminate the urban pests found in trees, shrubs and plants (aphid, mites, pine processionary...)

we find high frequencies of 3. “Do not know, does not answer", concluding that some respondents have not understood the question or do not have criteria to answer.

The median of the items calculated with respect to all individuals, is shown below in figure 10 in the following dot diagram:

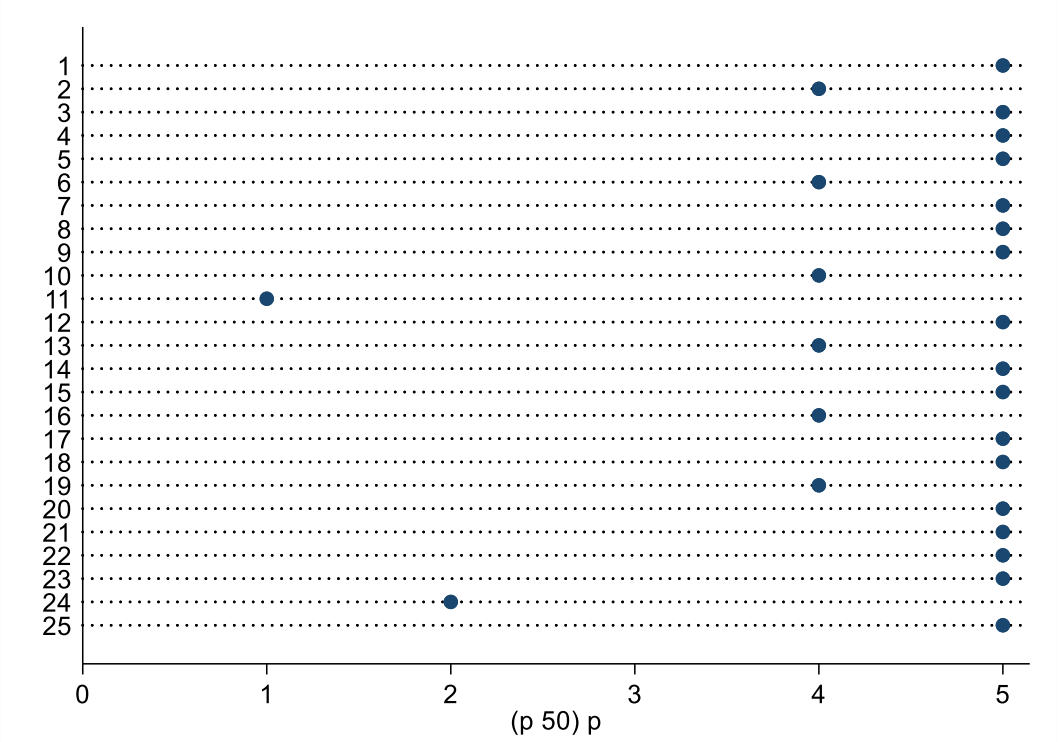

Figure 10: Dot diagram of the items

As before, we observe the general predisposition in 4. “In agreement" and 5. “Completely in agreement" except for items 11 and 24 with which they disagree.

The median of the items calculated with respect to the categorical age of all individuals, is shown in figure 11 in the following dot diagram:

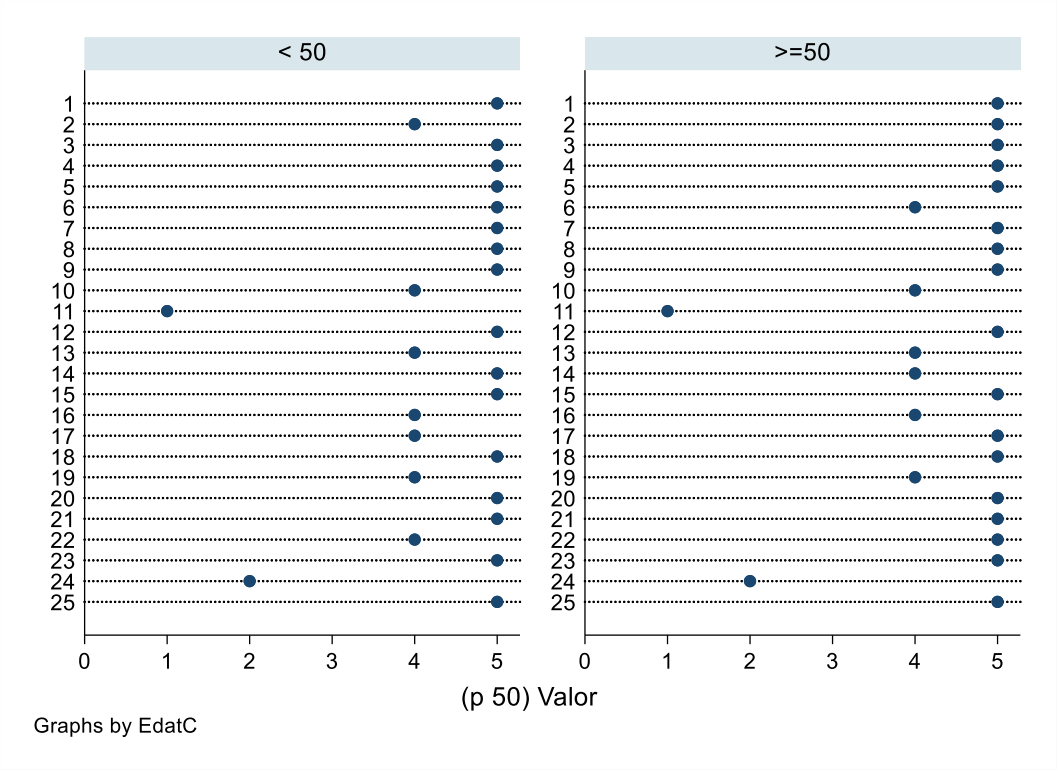

Figure 11: Dot diagram of the items by categorical age

We observe that due to the categorical age, no differences can be seen, the medians located in the values 4. “In agreement" and 5. “Completely in agreement."

The median of the items calculated for each of the level of studies, is shown in figure 12:

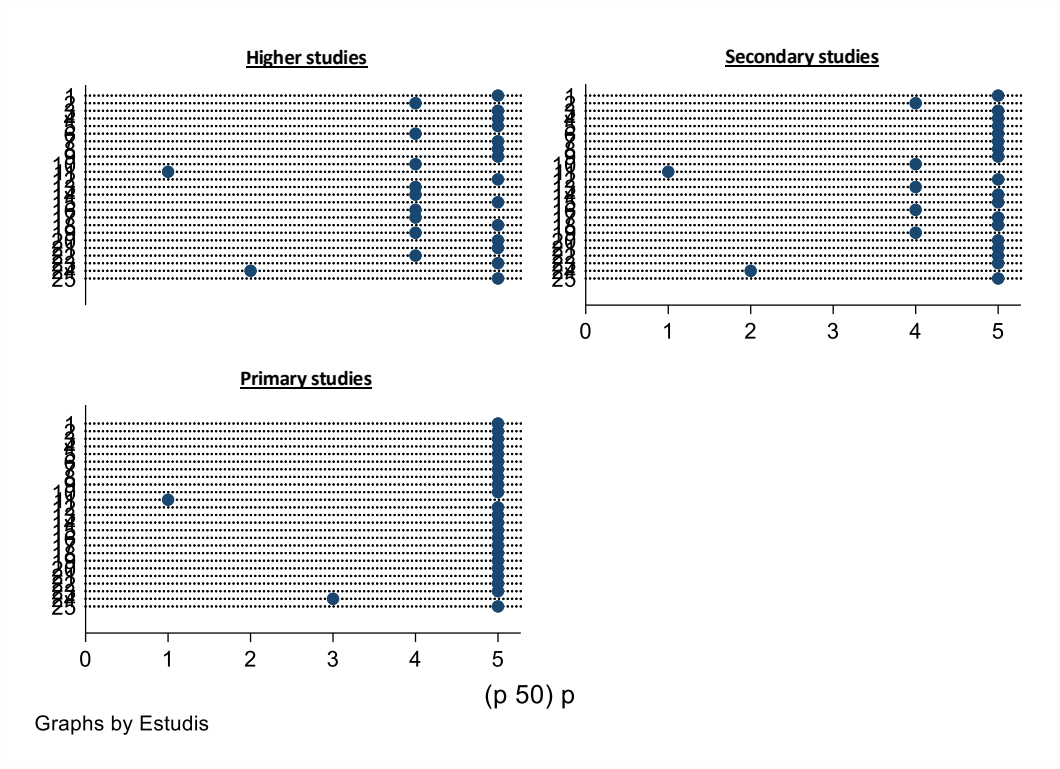

Figure 12: Dot diagram of the items by type of studies

As with age, no differences can be observed, the medians located in the values 4. “Agree" and 5. “Completely agree."

The median of the items calculated for the employment situation, is shown below in figure 13:

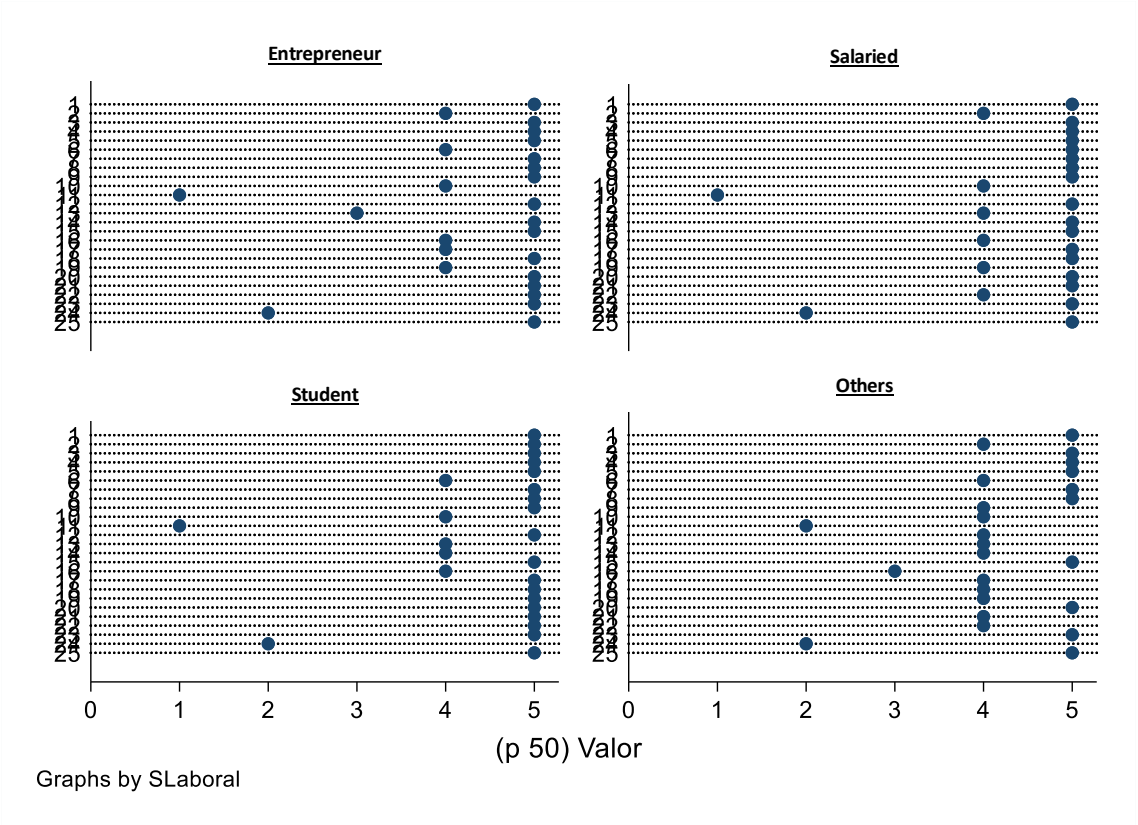

Figure 13: Dot diagram for the items by employment situation

For the working situation, there are also no differences in general for the values of the median.

The median of the items calculated for the areas of residence, is shown in figure 14:

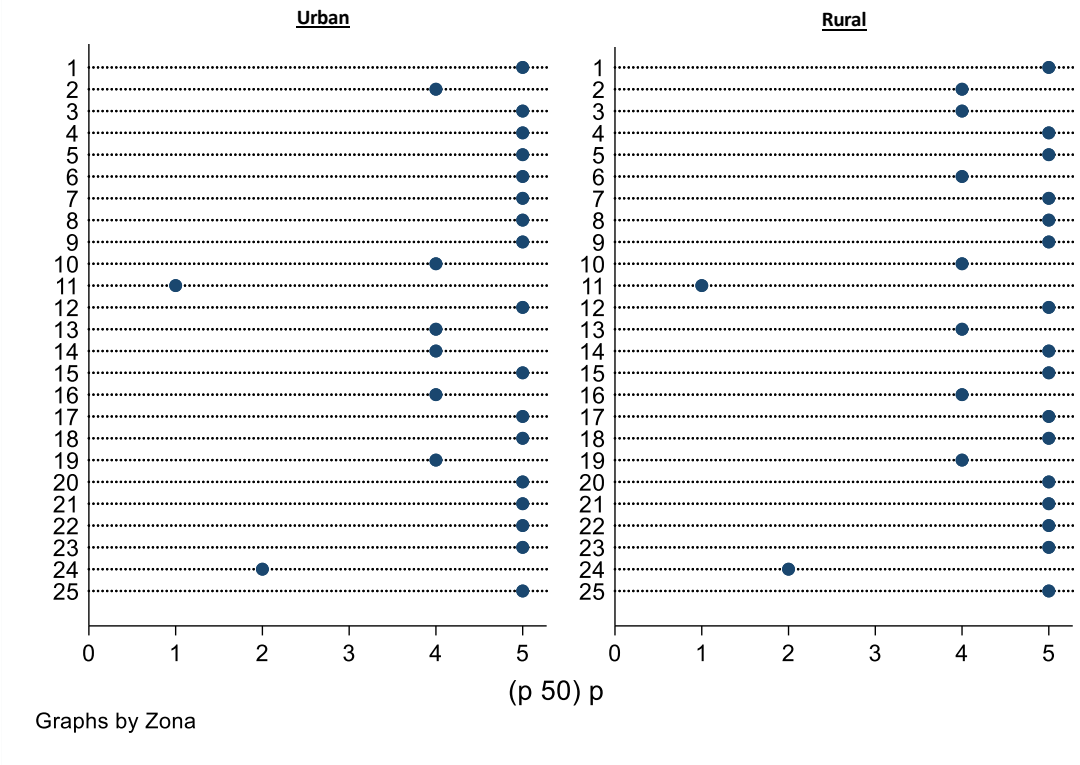

Figure 14: Dot diagram for the items by area of residence

There are no differences with the position of the medians.

4.3.3. Factorial exploratory analysis

The results of the factorial exploratory analysis showed three factors:

- Factor 1: Very related to items p5, p7, p9, p12, p18, p20, p21, p23, p25 that are related to opinion on green areas, environment and actions to achieve health.
- Factor 2: Closely related to p2, p6, p14, p22, which are related to the concept of pest and chemical control.
- Factor 3: Not being conclusive

4.4. Conclusions

The interpretation of the results obtained is very favorable in relation to the transition to biological control. The vast majority of respondents agree that they want to reduce the use of chemical products in order to introduce cleaner and more ecological controls for the environment and the health of the citizen. However, there are key questions such as:

1. "I would be willing to observe more insects than usual in trees in order to reduce pests and use chemicals"

11. "I prefer not to see organisms, such as ladybugs, flying around the trees of a city, although knowing that they can fight pests,

that have generated more response variability. We believe that these are two questions that were not well understood, since if we compare the answers of previous questions related to the same topic, the opinions do not match.

Therefore, except for these two questions where it is considered that there has been a misinterpretation of the question, the general perception of the 94 respondents is very positive. A clear example is the following questions:

- "I would be willing to eradicate a full-on tree plague, even if this entails contamination and possible toxicity problems to citizens." In this question, more than 71% of respondents replied that they disagreed, and 23% responded that they agreed. This type of response makes us see that the respondent already has a brief opinion on that they prefer not to use chemicals even if they eliminate the pest to the complete.
- On the other hand, we find the question: "I prefer not to see organisms, such as ladybugs, flying around the trees of a city, despite knowing that they can fight pests". Almost 70% of respondents responded that they completely disagreed,

that is, they did not cause them any discomfort observed predators in trees, as long as pest levels decreased.

In general, it is understood that people are prepared to make a transition and start introducing more environmentally and friendly practices. The perception of respondents is very positive and this can be very beneficial. However, it should not be forgotten that the public administration has a great role in the communication that is provided to citizens. We must explain and make objectively understand why this change is being made, and what benefits it brings compared to chemical control.

4.5. Proposal of new survey

As a result of the inconclusive factor analysis, we realized that many of the survey questions referred to other topics that did not provide information about what we really wanted to know (the opinion of chemical control and biological control). An example of this failure is the questions related to green spaces and the possible benefits they bring. This fact has nothing to do with the opinion on the transition from chemical control to biological control. Therefore, once the survey was carried out, we realized the poor design of the questions, because they did not focus solely and exclusively on the topic to be discussed (chemical control and biological control), possibly due to a lack of experience in the development of the survey.

Below we can find the same survey, in which we marked in green the questions focused on the topic to be discussed, and in red those related to external topics.

Table 10: Marked survey items	
1	Well-maintained urban green spaces make our cities and neighborhoods more attractive places to live and work.
2	I would be willing to see more insects than usual on the trees, in order to reduce their pests and avoid using chemicals.
3	The human being is the main responsible for climate change
4	It is important that an urban region has green areas
5	It is necessary to invest time and money in the good preservation of the green areas
6	Although spraying a tree with chemical products ensures that I eliminate the pest that it contains, I would prefer to use another mechanism that is not chemical (for example, biological control)
7	Taking action to care for the environment is a moral duty
8	It brings me benefit and/or satisfaction to leave the house and find vegetation in my street (shrubs, shrubs and plants)

9	The urban gardens contribute to reducing the levels of carbon emissions in the cities, which has made the air cleaner and healthier for its residents.
10	I would eliminate traffic or parking lanes to widen the sidewalks in order to plant 52oret rees, shrubs and plants
11	I prefer not to see organisms, such as ladybugs, flying around the trees of a city, even knowing that they can fight pests
12	It is important to pay attention to the needs and care of the trees, shrubs and plants of a city
13	Some individual freedoms should be limited to care for the environment
14	It is in my command to carry out specific actions to take care of the environment.
15	Pollution is one of the main environmental concerns
16	The actions undertaken by municipalities and governments in relation to the fight against climate change can be effective
17	Chemicals (insecticides) can cause contamination and toxicity in the areas where they are used
18	The cities that take the time to take care of and maintain their green space contribute to a half of the health of the city.
19	It is necessary to eliminate the urban plagues found in the arboreal, shrubs and plants (aphid, mites, processionary of the pine...)
20	The urban green space provides multiple benefits to the urban populations (reduction of stress, mood enhancement...)
21	It is important to pass or practice sport in green areas (parks and gardens)
22	Pollution and toxicity would be reduced if the plagues of urban vegetation with non-chemical products will be traversed
23	Protecting the biodiversity (flora and fauna) of urban green areas is vital to guarantee the health of our environment and strength our physical and psychological form.
24	I would be willing to eradicate a pest from an entire tree, even if that entails contamination and possible toxicity problems for citizens
25	It is necessary to enhance the vegetation in the cities or towns, knowing its benefits.

Being aware of the mistake when designing the survey, a new survey has been designed to be used in the execution of this protocol.

This new survey consists of questions that are primarily based on the only topics to be covered: chemical control and biological control. So, with this new survey we will be able to acquire the opinion of the respondents only on the topics to be discussed, without the need for information on other topics.

Making this change will allow us correctly perform a factorial and cluster analysis. We will be able to get different groups of respondents to tell us which groups of questions they agree or disagree with, and who agrees or disagrees with them.

In table 11, we can see the new citizen survey on the opinion of chemical control and biological control:

Table 11: Items from the proposed survey	
1	I believe that the use of chemical control to eliminate pesticides is appropriate
2	I am willing to observe more insects than usual in the trees, in order to reduce their pests and avoid using chemical products.
3	Chemical control is not a health problem
4	I think a change from chemical control to biological control is appropriate
5	The chemical control is adapted to eradicate the pest 100%
6	Although biological control is not as effective as chemical control, I think it should be used
7	The safety provided by chemical control is not provided by biologic control
8	I think biological control is more appropriate, although it takes longer to reduce the concentration of the pest
9	I want to take care of the vegetation in my neighborhood without chemical products
10	Pest reduction with biological control is more convenient, although less effective than chemical control
11	I prefer not to see organisms, such as ladybugs, flying around the trees of a city, even knowing that they can fight pests
12	Biologic control is adapted to reduce the pests of vegetation
13	I consider that there is no need for any transition from chemical control to biologic control
14	I think the advantages of biological control are obvious
15	I think the effectiveness of chemical control is an advantage

16	Although the time to reduce the pest is longer with biological control, I think it is better
17	Although chemical control produces contamination, I prefer it to biological control
18	The result of biologic control is satisfactory
19	It is necessary to eliminate pests with chemical control
20	The result of biological control is safe and clean
21	Chemical control assures me a cleanliness of pests
22	Pollution and toxicity are reduced if pests are treated with non-chemical products
23	See insects that decrease the plague, it bothers me
24	I am willing to eradicate a pest from an entire tree, even if that entails contamination and possible toxicity problems for citizens
25	I am indifferent to a chemical product, as long as it ends with the plague

The objective of the survey is to know the opinion of the citizen once they have been informed with the corresponding communication and dissemination measures. Therefore, to ensure reliable survey results, it will be very important to implement talks objectively, explaining the benefits and disadvantages of each of the two control methods. This will ensure that the citizens generate their own opinion, without any influence or repercussion.

An example of **invented results** that we would obtain (having made a correct formulation of the questions) would be expressed as follows:

FACTORS	CLUSTERES	C1 N = 110 (46%)	C2 N = 128 (53%)
F1: Disturbance	Qüestion 11 Qüestion 23	0.38	-0.52
F2: Effectivity	Qüestion 7 Qüestion 25	0.45	-0.25

Higher positivity ➔ Higher agreement

Respondent characteristics of cluster 1:

Mostly composed by:
- Women
- With age behind 60-70 years
- Living in the neighborhood "A"

Respondent characteristics of cluster 2:

Mostly composed by:
- Men
- With age behind 25-45 years
- Living in the neighborhood "B"

Figure 15: How the results would look like

Suppose the survey is answered by a total of 238 people. Once the survey has been carried out, factors are obtained, that is, new variables closely related to certain questions. For example, factor 1 is closely related to questions: 11." I prefer not to see organisms, such as ladybugs, flying around the trees of a city, even knowing that they can fight pests" and with question 23. "See insects that decrease the plague, it bothers me", since both They refer to the nuisances that pests can cause to citizens, and are described in factor 1. The same happens with factor 2, since it is closely related to the questions: 7 "The safety provided by chemical control is not provided by biological control" and "I am indifferent to a chemical product, as long as it ends with the plague", since both refer to the effectiveness of the method.

On the other hand, we have clusters, which are defined as groups of individuals with certain characteristics. For example, cluster number 1 is made up of 110 respondents (46% of the total number of respondents), and of these 110 respondents, mostly made up of women, aged between 60 and 70 years, who preferably live in neighborhood "A". For example, cluster number 2 is made up of 128 respondents (53% of the total number of respondents), and of these 128 respondents, mostly made up of men, aged between 25 and 45 years, who preferably live in neighborhood "B".

Interpretation of the table: Individuals from cluster 1 are bothered by the presence of useful biological control fauna, that is, they do not want disturbances caused by biological control (0.38) and they agree that chemical control is more effective (0.45). On the other hand, the individuals of cluster 2 do not mind observing the presence of useful fauna, therefore, they agree with biological control (-0.52) and do not agree with the use of the chemical method (-0.25).)

5. REFLECTION

The conclusions of this thesis are various:

We can affirm that this protocol is feasible to be established in any municipal council that wants to make a transition from chemical control to biological control.

It is important to know that this protocol will have to be carried out by a technician specialized in the pest control sector in urban areas, because it is necessary to have some knowledge about the scope of application and the work context.

On the other hand, the people surveyed demonstrate an interest and a predisposition to make a transition in the way of managing pests from chemical control to biological control. We can see how the respondents are aware of the favorable change that this transition entails at the environmental and public health level.

Even so, it must not be forgotten that the public administration has a very important position in these actions, because it must communicate and provide the necessary information to citizens.

Finally, this project can help us reflect and make us question the environmental practices that are being carried out in the green spaces of our municipalities. Time, money and knowledge must be invested in the vegetation that surrounds us, because if we understand its needs, we can obtain many benefits.

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