



DELIVERABLE 2.2 BASELINE REPORT

RODENT PEST MANAGEMENT AT THE NEXUS OF AGRICULTURAL PRODUCTION AND SUSTAINABLE AGROECOSYSTEMS IN
THE MEDITERRANEAN REGION

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DATE: 31 January 2023

	This project is part of the PRIMA programme supported by the European Union	
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PROJECT	MEDiterranean alliance for ecological PEST management (MED4PEST)
PROJECT NUMBER	122N051
TYPE OF FUNDING	RIA
DELIVERABLE	D2.2 Baseline Report
WP NAME/WP NUMBER	WP2 - Research proxies' baseline on rodent parameters and damages
TASK	2.1-2.4
VERSION	1
DISSEMINATION LEVEL	PU (public)
DATE	31/01/2023
LEAD BENEFICIARY	MMR
RESPONSIBLE AUTHOR	Luwieke Bosma
AUTHOR(S)	WP2 Members
INTERNAL REVIEWER	Meheretu Yonas (MMR) & Thrassyvoulos Manios (HMU)

DOCUMENT HISTORY

VERSION	INITIALS/NAME	COMMENTS-DESCRIPTION OF ACTIONS
1	MED4PEST_DEL2-2_V16_12_2022	first draft
2	MED4PEST_DEL2-2_V27_01-2023	Second draft
3	MED4PEST_DEL2-2_V31_01_2023	Final version

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Contents

List of Tables	4
List of Figures	5
List of abbreviations	6
Executive summary	7
1. Introduction	8
2. Methodology	11
2.1 Study area description	11
2.2 Data collection	12
2.3 Data analysis	13
3. Rodent pests in the Mediterranean Region	15
3.1 Rodent species	15
3.2 Rodent Ecology and behavior	18
3.3 Rodent outbreaks and population dynamics	22
3.4 Rodent Borne diseases	24
4. Rodent inflicted damage in the agricultural sector	25
5. Rodent Management practices	26
5.1 Overview of rodent control approach and methods	27
5.2 Dependency on Synthetic Chemical Rodenticides	29
5.3 Non-chemical methods and ideas	32
6. Socio-cultural, market dynamics and regulations on rodent management	34
6.1 Socio-cultural aspects	34
6.2 Extension services	34
6.3 Market analysis	35
6.4 Policies and regulatory proxies related to rodent pest management	36
7. Conclusions	38
References	40
Annex 1	43
Annex 2	44



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LIST OF TABLES

TABLE 1 SOURCES OF PRIMARY DATA (GREECE (N=2), TURKEY(N=12), MOROCCO (N=1))	14
TABLE 2 THE MAJOR PEST SPECIES (FROM THE PRIMARY INTERVIEWS) AND THE MAJOR ABUNDANT SPECIES(FROM LITERATURE) AVAILABLE IN THE MEDITERRANZEAN REGIONS	16
TABLE 3 MAIN RODENT SPECIES	17
TABLE 4 LIFE HISTORY TRAITS OF PEST RODENTS	20
TABLE 5 RODENT BORNE DISEASES PER COUNTRY	25
TABLE 6 RODENT CONTROL MANAGEMENT	29
TABLE 7 AVAILABLE CHEMICAL RODENTICIDES IN THE MEDITERRANEAN REGION	30
TABLE 8 AVAILABLE CHEMICAL RODENTICIDES IN THE PROJECT COUNTRIES FROM LOCAL MARKET SURVEY	31



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LIST OF FIGURES

FIGURE 1 THE AVERAGE PRECIPITATION IN TURKEY DURING THE WINTER MONTHS	24
FIGURE 2 REDUCING CHEMICAL MANAGEMENT METHODS WITH CURRENT	36



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LIST OF ABBREVIATIONS

EBRM Ecologically-Based Rodent Management

FGD Focus Group Discussion

KAP Knowledge Attitude and Perceptions

KII Key Informant Interview

SCR Synthetic Chemical Rodenticide



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EXECUTIVE SUMMARY

Rodents are one of the most common agricultural and household pests in Mediterranean regions. Rodent-caused damage includes crop damage, stored food contamination, and other public good destruction. The presence of rodents not only causes economic damage, but also health implications. Many tools are being used to manage rodent populations, and the most common rodent management methods in Mediterranean regions are using synthetic chemicals. Though these chemicals are harmful to human health, there is a lack of sustainable alternatives in these countries. Most importantly, related to rodent species, damage, or disease and rodent management methods are scarce. The absence of baseline information is a big hindrance to creating a sustainable rodent management method.

To solve this problem, this study intended to create an inventory of the status of rodent management in Mediterranean regions. This research covers Turkey, Cyprus, Morocco, and Greece. We interviewed respondents from our study areas through a semi-structured questionnaire. The key finding of this study is that there are multiple gaps related to rodent damage, disease, and rodenticide regulations exist between public knowledge and scientific knowledge. Another important finding is that regulation related to chemical rodenticide use has been lacking in these countries.



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1. INTRODUCTION

Rodents are the most species-rich mammalian groups (42% of all species) with a wide range of impacts on human health, agriculture, urban areas, and ecosystems (Capizzi et al., 2014). Up until now, 2279 species of rodents have been discovered worldwide (Capizzi et al., 2014). These rodent species can be divided into two groups i) native field rodent species and ii) commensal rodent species (Wilson et al., 2005). Native field rodent species are part of wild fauna, for example *Microtus* and *Apodemus*, species living in the wild. In contrast, the commensal rodent species live close to humans and depend on them for food and shelter (Meerburg et al., 2004). Commensal species can reach high levels of abundance due to their high reproductive rates and omnivorous diets and have significant negative impacts on humans through their consumption or contamination of stored agricultural produce (e.g., wheat), disease transmission, or the demolition of infrastructure (Meerburg et al., 2004).

Commensal and field rodent species are very adaptable to temporal and spatial differences in environmental conditions, enabling them to survive both inside homes and in agricultural areas. As a result, the population density of these rodent species fluctuates in response to changes in environmental parameters (Meerburg et al., 2004). When a rodent density in agricultural fields or urban areas reaches more than a certain threshold limit, it can result in a wide range of losses in forestry and agriculture as well as in storage facilities and private houses (Jurisic et al., 2022). For example, in forestry rodents eat seeds of woody species and barks of young trees which can destroy a plantation (Kamler et al., 2010). Furthermore, an abundance of rodents increases the risk of spreading rodent-borne diseases.

According to World Health Organization (WHO) and Food and Agriculture (FAO), rodents cause 5-15% of the total food loss every year, which is equivalent to food for 133 million people annually (Jurisic et al., 2022). Rodents are also responsible for contaminating human food through urine and droppings (Sarwar, 2015). Rodent induced losses happen both in pre- and post-harvest stages. Studies show that rodents are the number one pest species in agriculture, horticulture, forestry, and public goods (Wondifraw et al., 2021; Kasso, 2013).

The Mediterranean area is referred to as the "fruit basket of the earth" (Excellup, 2014) and is also famous for the production of wheat. Especially citrus fruits, grapes, pears, plums, cherries, olives, peaches, almonds, figs and walnuts are produced in Mediterranean region (Gianluca, 2018). While the region is also known for Carob tree production, Carob pods are healthy alternatives to cocoa powder or sugar. Rodents are one of the major pests of this plant species (Gugliozzo et al., 2019). Rodents damage the carob pods, chew the outer bark, and eat the wood (Batlle, 1997). Rodents attack Carob trees not only for food, also to obtain water, since the Carob tree has an important feature of 'pumping up' the water from underground with its deep root system. Fulfilling an important role in the conservation of soil and water, hampered by rodents (Gugliozzo et al., 2019).

Moreover, the damage related to rodents ultimately results in economic loss. But it is challenging to estimate the economic impact of rodent induced losses due to the diversity of damage caused by rodents. Their rich diet makes that rats can eat almost anything in field and stores, they can gnaw through wires and storage structures, it can even cut bank-notes and also transmit more than 60



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different diseases, of which leptospirosis is well-known. However, despite being a significant agricultural pest, accurate information on the level of damage is frequently lacking. It is crucial to clearly map the financial burdens of rodents for developing a cost-efficient management plan.

Rodents cause substantial reductions to food production, water supplies, and the economy. They display a wide range of alimentary preferences, which often include grains, fruits and vegetables, thus making them major agricultural pests. Rodents may eat and spoil food in quantities that could feed 280 million person per year globally (Meerburg, Singleton, and Leirs 2009). In the Mediterranean region, rats are known to attack trees and other crops when they can't find water, e.g., Carob trees as they are deep-rooted and 'pump' water from very deep. Therefore, it is expected that climate change will augment pest problems, further rodents appear to be more adaptable to climate change, (Cameron and 2001) and they are spreaders of many diseases.

The economic cost of this is difficult to assess as it includes food and packaging losses, water losses, the cost of cleaning, and the cost of the diseases transmitted. Despite being a major agricultural pest, reliable data on the extent of damage is often missing, while control relies on synthetic rodenticides and trapping, both with insufficient effectiveness. Besides, rodent control expenses are often not considered as pest-induced economic burden yet are very important in devising a sustainable strategy. Synthetic rodenticides are losing ground for numerous reasons, rats are building up resistances to them, and they can cause adverse effects to non-targeted populations and environment. Furthermore, regulations are being set to limit their use. However, the rate in which new, safer rodenticides are being made available is very low, due to a fall in discovery of new active molecules and the increasing costs of registration.

We tackle exactly these challenges by introducing novel Ecologically Based Rodent Management (EBRM). It stands out from conventional rodent control techniques, including synthetic rodenticides, as it is biological and ecological, relies on robust scientific knowledge about pest rodent eco-ethology and accordingly tailored modifications of the habitats in order to decrease rodent density to endurable levels and to avoid re-infestations. It combines biological, ecological and physical methods, through a Community of Practice (CoP) approach, since organization is as important as the technology for effective rodent management. We ensure excellence through lab-innovations on a bio-rodenticide, testing and selecting best-suited EBRM approaches in diverse context and at significant scale, and through monitoring of impacts. Each of these innovations together will deliver a state-of-the-art project that demonstrates EBRM at scale, specifically tailored to the Mediterranean context, with a key focus on sustaining agroecology, where the end-products are made by and for farmers, tightly fine-tuned to their wishes.

Speaking of management, this is another area which requires much more attention. Currently, there is a big reliance on chemical rodenticides. (Witmer et al, 2007). However, there are major backlashes of using such CSRs, for one research shows that rats are developing resistance to synthetic rodenticides (EBPF, 2017). Secondly, these rodenticides can have negative impacts on the environment and non-targeted species (Witler et al, 2017). Both of these backlashes adversely impact the effectiveness and sustainability of CSRs, however, development of alternative biological and ecological rodent management methods are lagging behind.

There is an alternative, Ecologically-Based Rodent Management (EBRM) has been practiced and studied in several countries in South-East Asia and Africa, where it has proven to be a sustainable alternative solution to effectively manage rodents and reduce dependency on SCRs (Singleton, 2004). One of the aims of MED4PEST is to look for alternative solutions to manage rodents. In the baseline, we therefore investigated traditional methods practiced by farmers in the four countries that could be incorporated in an EBRM approach.

By managing rodent infestations with EBRM methods, synthetic rodenticide usage will decrease, thereby preventing pollution (e.g. residual toxicity and binding chemical compounds in the soil) from their application. We will therefore contribute to the EU zero pollution ambition in securing clean air, water and soil, through a.o. waste reduction and composting, and contribute to the Horizon Europe Mission on Soil Health and Food.

A comprehensive research in the Mediterranean region on impacts of rodents, their behavioral ecology and population numbers, damage and losses incurred and the feasibility of biological and ecological methods is required in order to develop effective and sustainable rodent management integrated in the agro-ecological farming context. This baseline provides the foundation for this research, as it builds up solid data and identifies and fills knowledge gaps on rodents and their impact. For purposes of management, it is crucial to have a solid understanding of rodent pests prior to devising management strategies.

This baseline report presents data on i) rodent pest species and characteristics, ii) rodent inflicted damage in the agricultural sector, iii) range of rodent management practices, and iv) an overview of relevant sociocultural, economic and regulatory aspects. Our research area consists of Greece, Morocco, Turkey, and Cyprus, representing a variety of farming systems in the region.

The main aim of the baseline report is to improve knowledge and understanding of rodent pests in the Mediterranean region. Through this solid understanding it will help us to: i) showcase economic losses and utilize this information in devising cost-efficient rodent management tools and practices, ii) identify the areas where additional monitoring is needed since there are still data gaps, and iii) guide us in determining what types of biological and ecological management practices should be tried and tested.



2. METHODOLOGY

The methodology for this baseline report has the purpose to gather data on rodent pests locally occurring in representative agroecosystems in the partner countries (TR, GR, MO), on changes in rodent populations over space and time, and identify the drivers of rodent population changes. In parallel, we review the roles of intrinsic (e.g., breeding, survival, recruitment, immigration, emigration) and extrinsic (e.g., changes in agronomic practices, local waste management practices, food sources, presence of natural predators, and environmental factors such as rainfall and land use changes) factors driving rodent population changes locally. Furthermore, we have identified data gaps in the rodent proxies' datasheet, which we can partially fill in this baseline report through surveys with farmers and local stakeholders.

2.1 STUDY AREA DESCRIPTION

The study sites are found in Turkey, Morocco, Greece and Cyprus. We here give you a brief introduction to the country as a whole, since we aim to provide information on rodent indices and damage numbers for the whole country. Whereas in the Country Baseline report, we will narrow it down to the specific study-sites and aim to provide a greater depth of information.

Morocco

The promise of Morocco begins with its geographic variety, making it a rarity in the Middle East and North Africa region. From the four mountain ranges that cross the country, to its plateaus and plains, the country is resource rich, especially in its highly diverse agriculture sector. With nearly 53,000 square miles of arable land, agriculture accounts for 80% of rural employment. (1. USAID Contract #608-M-00-05-00043-01, Statement of Work, pg 7) Morocco has been an agricultural country for millennia, with early appearances of some of the first known edible grains – such as wheat and bitter vetch - being traced to the country. And the country's riches are enhanced by its proximity to Europe and its range of climate zones. The World Bank (2001, Policy Research paper) broadly divides the country's cereal production— the mainstay of Moroccan agriculture to date—into six agro-climatic zones according to their cereal “production potential”. The zones are favorable, intermediaries, défavorable sud, défavorable orientale, montagneuse, and saharienne. These agro-climatic zones reflect topography and, most importantly, rainfall, which decreases from north to south and from west to east.

Greece

Greece is, in the main, a land of dry and barren mountains, poor in fertile, well-watered soil. Still, ancient authors refer repeatedly to the wooded hills and rich bottom lands of a remote past. Whether the disappearance of this lush landscape, if indeed it ever existed, was due to natural or to human causes has been debated with passion since Antiquity. Environmentalists of a pessimistic bent like to cite the eastern Mediterranean as a particularly horrifying example of what callous human disregard for the environment can bring about, while others have attributed the stripping of soil from the mountains to the severe climate of the Pleistocene. (Van Andel, 1986)



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Turkey

Turkey generally has a mountainous land structure. 55.9 % of the land in Turkey above 1000 meter and 62.5 % has a slope more than 15%. Turkey is under the impact of the winds coming from the Black Sea and North and under the sea impact of which the wind brings. But the impact of sea cannot pass over the range of mountains on the north and south. For this reason, there is a strict tie between climatic characteristics and landforms of Turkey. Land structure and climatic characteristics of Turkey provided different geographical region and microclimate to be formed. There is a positive relation between land use and land structure of geographical regions, climatic characteristics in Turkey. So, forestry in humid regions, livestock in high, mountainous and arid regions and vegetative production in every region can be done in Turkey. These characteristics make it possible to produce specific agricultural products in different ecologic regions (Armağan, 2008).

Turkey is a major producer of wheat, sugar beet, tomatoes, barley, potatoes, grapes, maize, watermelons, and apples. Apricots, cherries, hazelnuts with shell, figs, quinces, and poppy seed are the most produced agricultural commodities of Turkey in the world. (Aytop, 2014)

Cyprus

Cyprus is a small country with 9,251 km² (3,572 miles²) total area and a coastline of 648 km. Land available for agricultural purposes is very limited due to the small size of the country. The big influx of tourists (about 2.5 million) force local growers to avoid the practice of fallow land and soil rotation that results in intensive farming. As a result, serious problems with soil erosion and land degradation have been observed. Furthermore, for higher yields, the farmers find refuge in the continuous use of fertilizers, which are sometimes overused. Fertilizer use is important for a bona fide researcher of the island rural economy. Pesticides and fungicides are also important intermediate inputs. Before the 1980s, all the fertilizer needs of Cyprus were imported, as it had no local industry of its own. In the early 1980s, the Government decided to establish such an industry of its own (The Cyprus Chemical Industries Ltd). However, this industry has recently terminated its operation. Following EU accession and the implementation of the RDP 2004 – 2006 certain provisions, like EUREPGAP, Integrated Production Management, etc, have been introduced in order to reduce the usage of fertilizers and pesticides.

2.2 DATA COLLECTION

Data collection has been done in two phases. Firstly, English primary literature is collected from the Web of Science database and Google Scholar using specific search strings to collect information (title, publication year, and abstract) of research works in the four Mediterranean countries. In total, 419 papers (Turkey 234, Cyprus 6, Greece 144, and Morocco 35) were derived from the search. Then, articles were screened to fill our baseline inventory for "rodent control methods, damage, species, and rodent diseases" in our project areas. Of 419 papers, only 14 papers contained useful information related to the species, rodent management methods, and damages. The papers we couldn't use for this study are mostly related to rodents used in different types of laboratory research. To compensate for the lack of peer-reviewed scientific publications, multiple other sources of data and information



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were used, including news articles, blogs, and comment-section newspapers. Our information related to different types of rodent control management was collected from these sources.

In Addition, we also conducted in-depth interviews through a semi-structured questionnaire and focus group discussions (FGDs) with our key informants from the targeted countries through a specific set of questionnaires.

The aim of the interviews and FGDs was to get detailed information from the respondents about rodent behavior, management methods, damage, and which rodent species are present in their area/region. In total, our respondents were 15 (GR-2, TR-12, MO-1). We divided them into "key informant" and "focus group discussion". Key informants were experts in rodent issues in our project countries, these were difficult to find, therefore their number is low. They provided information regarding problems related to rodents, damage, and rodent management methods. Based on this information, we conducted our FGDs with farmers and local respondents. Table 1 includes information related to our primary data sources.

Table 1 Sources of Primary data (Greece (n=2), Turkey(n=12), Morocco (n=1))

Data type	Data collection method	No. of participants	Data Source
Primary Data	Key Informant Interview	M=3, F=2, Total =5	Researcher in Rodent Ecology. Pest control professionals, Agricultural engineer
	Focus group discussion (FGD)	M=7, F=3, Total =10	Farmers, members of the local community (both urban and villages), plant protection officers

The guiding questions used in the interviews and FGDs are attached in Appendix 1. In cases where English was not the primary language of the respondent, translators were engaged to allow communication between the researcher and the respondent.

2.3 DATA ANALYSIS

Data from source materials (articles and blogs) were collected in Excel as a form of information and categorized for further analysis. The information from interviews and FGDs were collected via handwritten notes by both the primary researcher and the translator. To interpret data from interview transcripts, we followed the guideline for qualitative data analysis by the (Casterle et al, 2012.) We distributed all the concepts in a separate excel worksheet to keep track of possible data gaps. To respect the privacy of respondents, there were no recordings from the meetings. The informants were from Greece, Morocco, and Turkey.

For our surveys, we used thematic analysis as a method of analyzing qualitative data to identify the common theme from interviews or transcripts (Caulfield, 2022). We aim to identify the theme of our survey responses and cross-check the current scenarios with the secondary information collected from the literature and news articles.

3. RODENT PESTS IN THE MEDITERRANEAN REGION

In this chapter we describe the characteristics of rodents in the four countries in the Mediterranean region, focusing on species diversity, population dynamics and their ecology and behavior. There are gaps in the data that could be retrieved and generated, however during the span of the project we expect to continuously update this data in parallel with developing enhanced monitoring systems and effective and sustainable management solutions.

3.1 RODENT SPECIES

From literature, we found 32 species from Morocco, 44 species from Turkey, 5 species from Greece, and 6 species from Cyprus, although there is overlap between countries. During interviews, the respondents specified which species are considered pests in agricultural and urban areas. In total 7 pest species were identified: *Meriones shawi*, *Rattus rattus*, *Rattus norvegicus*, *Mus musculus*, *Apodemus sylvaticus*, and *Gerbillus campestris*, and *Spalax microthalmus*.

Table 2 is the compilation of pest species we identified during our interviews with the farmers and experts from the representative countries and the species we found during our literature search for the background information collection.

Table 2 The major pest species (from the primary interviews) and the major abundant species (from literature) available in the Mediterranean regions



Country name	Pest rodent species (Identified by the respondents)	Available rodent species (In literature)
Morocco	<i>Rattus rattus</i> , <i>Meriones shawi</i> , <i>Gerbillus campestris</i>	<i>Rattus rattus</i> , <i>Mus musculus</i> , <i>Apodemus sylvaticus</i> , <i>Mus spretus</i> , <i>Meriones shawi</i> , <i>Rattus norvegicus</i> , <i>Meriones libycus</i> , <i>Mastomys erythroleucus</i> , <i>Gerbillus campestris</i> , <i>Lemniscomys icrophth</i> , <i>M. libycus</i> , <i>Acomys cahirinus</i> , <i>Pachyuromys duprasi</i> , <i>Merione grandis</i> , <i>Gerbillus nanus</i> , <i>Gerbillus henleyi</i> , <i>Gerbillus hesperinus</i> , <i>Gerbillus hoogstraali</i> , <i>Gerbillus occiduus</i> , <i>Gerbillus gerbillus</i> , <i>Gerbillus riggenbachi</i> , <i>Gerbillus simoni</i> , <i>Gerbillus maghrebi</i> , <i>Gerbillus tarabuli</i> , <i>Atlantoxerus getulus</i> , <i>Xerus erythropus</i> , <i>Jaculus orientalis</i> , <i>Jaculus jaculus</i> , <i>Ctenodactylus gundi</i> , <i>Ctenodactylus vali</i> , <i>Hystrix cristata</i> , <i>Eliomys quercinus</i>
Turkey	<i>Rattus norvegicus</i> <i>Rattus rattus</i> <i>Mus musculus</i> <i>Apodemus sylvaticus</i> , <i>Spalax microphthalmus</i>	<i>Cricetulus migratorius</i> , <i>Rattus rattus</i> , <i>Mus musculus</i> , <i>Rattus norvegicus</i> , <i>Apodemus sylvaticus</i> , <i>Apodemus hermonensis</i> , <i>Dryomys nitedula</i> , <i>Spermophilus citellus</i> , <i>Microrus arvalis</i> , <i>Microtus gud</i> , <i>Arvicola terrestris</i> , <i>Micromys minirus</i> , <i>Myomymus roachi</i> , <i>Eliomys quercinus</i> , <i>Dryomys pictus</i> , <i>Meriones persicus</i> , <i>Meriones libycus</i> , <i>Tatera indica</i> , <i>Nesokia indica</i> , <i>Acomys cilicicus</i> , <i>Calomyscus bailwardi</i> , <i>Myocastor coypus</i> , <i>Spalax nehringi</i> , <i>Spalax citellus</i> , <i>Apodemus terrestris</i> , <i>Microtus persicus</i> , <i>Apodemus cilicicus</i> , <i>Castar fiber</i> , <i>Microtus subterraneus</i> ,

		<i>Apodemus agrarius, Microtus roberli, Sciurus anomalus, Glis glis, D. nitedula, Apodemus jlavicollis, Dryomys laniger, Microtus nivalis, Meriones tristrami, Allactaga williamsi, Cricetulus migratorius, Clethrionomys glareolus, Microtus subterraneus, Micro majori, Mus cardinusavelanarius</i>
Greece	<i>Rattus norvegicus</i> <i>Rattus rattus</i>	<i>Dryomys nitedula, Rattus rattus, Mus musculus, Apodemus flavicollis, Rattus norvegicus</i>
Cyprus	<i>Rattus norvegicus</i> <i>Rattus rattus</i>	<i>Mus macedonicus, Mus spicilegus, Mus cypriacus, Mus spretus, Rattus norvegicus, Rattus rattus frugivorus</i>



However, from this extensive list of species, none of the literature has specified which species are dominant in which location. Witmer et al, 2007 mentioned that there are only 5% of total rodents considered as pests. From our results, we observed similar trends. According to the respondents of our survey, there are some species, for example, *Spalax microphthalmos* causing a great problem in the agricultural sites in Turkey, but there is no mention of it in the published literature. Also, we did not find life history-related information for this species during our search. One reason could be that researchers are focusing on the two major pest species groups *Rattus rattus* and *Rattus norvegicus* and the rest of the species have been ignored.

We also found that most of the farmers still identify the rodent species by size or the damage they are causing in the agricultural field. This situation may complicate identifying the prevalent pest species, which can lead to ineffective control strategies. Specially, *Mus musculus* (20.5g) and *Apodemus sylvaticus* (23.5g) can create confusion in identification. See the table below for an overview of the main rodent species identified.

Table 3 Main rodent species

Species	Common Name	Picture
<i>Meriones shawi</i>	Shaw's jird	 <p>Courtesy: Wikipedia¹</p>
<i>Rattus rattus</i>	Black Rat	 <p>Courtesy: Wikipedia²</p>

<i>Rattus norvegicus</i>	Brown Rat	 <p>Courtesy: Wikipedia³</p>
<i>Mus musculus</i>	House Mouse	 <p>Courtesy: Wikipedia⁴</p>
<i>Apodemus sylvaticus</i>	Wood Mouse	 <p>Courtesy: Wikipedia⁵</p>
<i>Gerbillus campestris</i>	North African Gerbil	 <p>Courtesy: Wikipedia⁶</p>
<i>Spalax microphtalmus</i>	Greater Blind Mole Rat	 <p>Courtesy: Wikipedia⁷</p>
<i>Spalax leucodon</i> <i>Nortmann;</i>	Lesser Blind Mole Rat	 <p>Courtesy: Wikipedia⁸</p>
<i>Microtus arvalis</i>	Common Vole	 <p>Courtesy: Wikipedia⁹</p>
<i>Meriones spp</i>	Meriones	

<i>Apodemus agrarius</i>	Striped Field Mouse	 Courtesy: Wikipedia ¹⁰
<i>Muscardinus avellanarius</i> L.	Hazel Dormouse	 Courtesy: Wikipedia ¹¹

Of rodent species *Rattus rattus*, *Rattus norvegicus*, *Microtus arvalis*, *Apodemus sylvaticus*, *Apodemus agrarius*, *Mus musculus*, *Spalax spp* are mentioned as the primary harmful pest species of rodents in the four countries together. Though not every species may occur in every country, see the list of species per country in this baseline report. Especially *Microtus spp*, *Citellus*, *Spalax* can be most harmful as pest for agricultural areas. *Mus musculus* is a pre-harvest pest. *Rattus spp* as known post-harvest pest. There are also other rat species not mentioned by respondents who are found to be harmful to agricultural production, we give a description of damage incurred by all major pest species below.

For ***Microtus arvalis*** it is found that they eat the green parts of plants and seeds, as well as damage them by gnawing at the trunk and root collar of trees. Depending on the density of their population, the damage can be as high as 100%. It is harmful to field crops, meadow and pasture crops, vegetables, and fruits. They also cause damage to young forest trees. ***Rattus rattus***: There is no material that he does not eat and gnaw, they literally eat everything. ***Apodemus sylvaticus***; It is harmful to grain, legumes, fodder crops, meadows, pastures, many other cultivated plants and nurseries. ***Apodemus agrarius***; it is harmful to grain, legumes, fodder crops, meadows, pastures, many other cultivated plants and nurseries. ***Mus musculus* L.**; they eat various foodstuffs at home, in the warehouse and everywhere, as well as gnaw packaged materials, sacks and boards. They pollute foodstuffs with the dirt they remove, making them unusable. They can even gnaw electrical and telephone cables. Furthermore, they carry many diseases such as rabies, typhoid, paratyphoid, plague between humans and animals. ***Meriones spp***: Most often they are found in cultivated fields. They cut the spikes and carry them to their nests. They feed on all kinds of seeds, roots and cereals. ***Muscardinus avellanarius* L.**; They become harmful by piercing and eating peeled fruits. ***Spalax leucodon* Nortmann**; They become harmful by piercing and eating peeled fruits.

3.2 RODENT ECOLOGY AND BEHAVIOUR

From the Survey it has been found that 7 species are considered a pest in different countries. In table 4 you find a documentation of the life history traits of 6 of these rodent pest species *Meriones shawi*, *Rattus rattus*, *Rattus norvegicus*, *Mus musculus*, *Apodemus sylvaticus*, and *Gerbillus campestris*. We did not find information on the life history traits of *Spalax microthalmus* during this study.

Anthropophilic rodents



Rattus Rattus

- Black rat
- The length of the tail always exceeds that of the body
- Nocturnal, omnivorous
- Feeding mainly on cereals stored by humans



Rattus Norvegicus

- Brown rat
- The length of the tail is always shorter than the body
- Nocturnal, omnivorous
- Feeds in food stocks for humans, it also consumes grasses, cultivated plants



Mus Musculus

- The general coloring is grey, mixed with beige
- Mainly granivorous

Table 4 Life history traits of pest rodents

Life history traits	<i>Meriones shawi</i>	<i>Rattus rattus</i>	<i>Rattus norvegicus</i>	<i>Mus musculus</i>	<i>Apodemus sylvaticus</i>	<i>Gerbillus campestris</i>
Female sexual maturity	102 days	90 days	90 days	42 days	71 days	
Male sexual maturity	120 days	112 days	70 days	42 days	65 days	
Gestation	26 days	22 days	21 days	19 days	23 days	
Weaning	23 days	26 days	21-28 days	21 days	21 days	
Litter size	5.4 (viviparous)	8 (viviparous)	9.9 (viviparous)	7 (Viviparous)	5.2 (viviparous)	4.3 (viviparous)
Inter-litter interval	31 days	-	-	30days	41 days	
Weight at birth	4.46 g	4.55g	3.7g	1.25g	1.5g	
Weight at weaning	25 g	39.7g	5.81g	-		
Adult weight	185g	200g	300g	20.5g	23.5g	28.4g
Breeding season	-	All year round, peak in summer and in Autumn	All year round, less in colder months	Throughout the year		
Lifespan	-	Wild condition :1 year Captivity: 4 year	Wild: 2 years Captivity: 2-3 years	Wild: 12-18 months Captivity:2 years	Wild: 1 year Captivity:4.4 years	
Breeding interval	-		7 times per year			
Behaviour	-	Arboreal, nocturnal, territorial, polygynous	Nocturnal, excellent swimmers, dominance hierarchy, store foods	Nocturnal but also in day times, quick runner (8 miles per hour), climber, colonial and territorial.	Climbers, jumpers, swimmers, Nocturnal or crepuscular	
Territory size	-	100m ²	2000m ²	-		
Food habit	-	Primary diet: Herbivore	Omnivore Animal diet: Bird,	Omnivore Apart from human foods	Root, grains, berries, nuts, grasses, grain, and insects	

		<p>Animal food: Insects</p> <p>Plant Food: Leaves, wood, barks, stem, seeds, fruits</p>	<p>Amphibians, mollusks, insects, fish, eggs, mammals, arthropods, and other invertebrates</p> <p>Plant diet: Leaves, roots, tubers, wood, bark stem, fruits, nectar, flower, and all plant parts.</p> <p>Also, fungus, detritus</p>	<p>they also consume soap, glue, and other household materials.</p> <p>Plant diet: seeds, grains, nuts, leaves, stems</p> <p>Animal: carrion, insects, and arthropods</p>		
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It can also be seen that there is limited information on some pest species ex – *Meriones shawi* and *Gerbillus campestris*. Also, the adult weight of *Meriones shawi* (185g), *Rattus rattus* (200g) and *Mus musculus* (20.5g), and *Apodemus sylvaticus* (23.5g) are closer in numbers which can create complications in the identification of these species.

3.3 RODENT OUTBREAKS AND POPULATION DYNAMICS

There has only been one recording of a rodent outbreak, in 1983 in Greece. This is surprising, however through the surveys and further study in this project we seek to dive deeper into this to bring out more information about possible outbreaks, linked causes in the light of population dynamics at large.

In general, rodent outbreaks are a consequence of enhanced reproduction where natural mortality is of minor importance, particularly in rapidly increasing populations. Changes in cropping intensity that provide high quality food. (e.g. cereals at the reproductive and ripening stages) for longer periods of time per year will lead to an increase in the frequency of rodent – population outbreaks because females will breed for longer each year (Sudarmaji at al, Singleton et al). This is a major concern given the push for increasing the intensity of cropping in many countries. We need to focus on the factors that limit reproductive output for rodents in agricultural systems and the development of methods of disrupting reproduction in pest species (see Singleton at al and Brown et al for discussion of progress with research on fertility control of rodents).

Population dynamics of rodents are influenced by the quality of food available, the degree of predation by climatic/ seasonal variations, and the level of competition from other rodents, birds, ants and other animals. An explosive population growth can result in a catastrophic agricultural situation, e.g. *Arvicanthis* species in Senegal, *Holochilus* spp in Brazil and *Microtus* spp and *Arvicola* spp in Europe. A first year with higher-than-normal rainfall upsets the annual demographic cycle: The reproduction season lasts longer, there is a higher peak density, and the annual cycle ends at a higher level than in a normal year. If this is followed by a second season of abnormally high rainfall, the reproduction season will continue for as long as in the previous year, but with an already higher than usual initial population. With sexual maturity at 10 weeks of age, one litter every 3 to 4 weeks, and 10 or more young per litter (in the case of *Mastomys*), the population increase may be virtually exponential.

Generally, the annual minimum is reached in the rainy season when reproduction has not yet begun, and the population is affected only by mortality. After that, there is an increase in numbers with the first births and drop in mortality because food is plentiful. In a year of normal rainfall, the peak population will be reached in the middle of the dry season, followed by a decline in numbers on account of halt in reproduction. If irrigation is more or less permanent, it is possible to grow crops for a longer period. The reproduction season will then be extended or even uninterrupted, and the annual peak populations will be higher.

The destruction of predators such as snakes, preying birds and carnivores will lead large numbers of rodents to survive and cause an upset in the population balance. In the general course of nature, most



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populations of young rodents do not directly play a role in population dynamics of the species since they are all devoured by predators and their role seems rather to help predators to survive. Their elders know how to survive in avoiding predators and giving birth to the following year's generation.

A rat population explosion may destroy all available vegetation, especially crops. It is extremely important, therefore, to keep watch on the status of the local rodent population and take steps to prevent the threat of a population explosion. Such an explosion can cause epidemics and enzootics, particularly if there is change of the population pattern from one predominant species to another. All available measures should be taken to reduce drastically the number of rodents and to remove those factors favoring population explosion, Such measures include the elimination of neglected food, discarded rubbish, open sewers and some others. These measures will contribute to preventing any zoonoses transmission through soil and food contaminated with rat excreta, fleas, lice, parasites, biting insects (mosquitoes, sand flies, ticks) or through direct rat bites. The reproduction cycle of female rats, annual population dynamics of rodents with a view to crop cultivation, rainfall in cropping seasons and in off-crop cultivation seasons, are all mechanisms of rodent population explosion.

In the case of the Mediterranean region, the most active period of rodents in urban areas is in the winter months, though activity is year-round. In agricultural areas, there is a higher activity observed of rodents during the winter months, according to our key informants. In Turkey for instance, the most active period of rodents is said to be September to February, in the figure below you can see the average precipitation over the period from 1999 to 2021.

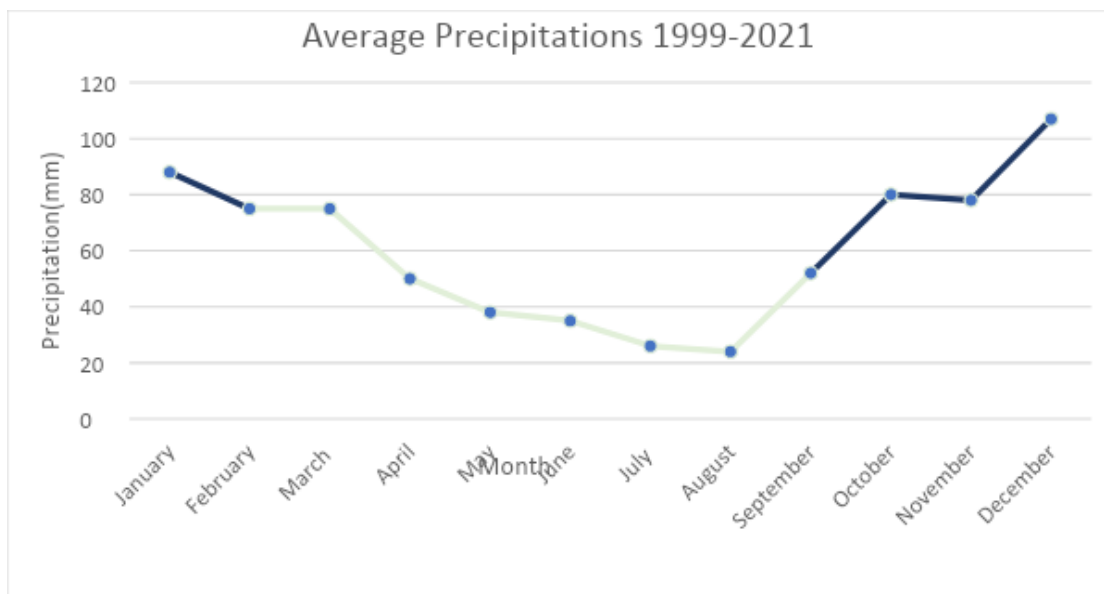


Figure 1 The Average precipitation in Turkey during the winter months

Our hypothesis was that rodents would be most active in the dry months or summer season. Eccard et al., (2013) stated that rodents have a low density in winter and peak density in summer, and seasonal variations affect population fluctuations and activity. However, the results from Turkey indicate a high rodent activity during the winter months. It is important to note that also other factors determine the activity of rodents, e.g. food production and habitat options. Moreover, for each

country and each specific agro-ecological zone this is expected to be different. Though largely, one can say that rodents' reproduction seasons go hand in hand with rain seasons and food production. After a cropping season, there are still leftover foods on the field, even though most of the time fields are left bare in winter. Even when rodent populations could be low, it can be argued that they are still more visible to humans, hence the observation of high rodent activity. Also in winter, they go to urban areas or indoors in search of food and shelter (Boren et al, 2002). Another reason can be in the winter, the rodents come closer to human homes due to lower temperatures and wetter conditions. This behavior would bring them more into contact with humans, but that might not mean they are more active, they are just more visible to human eyes.

3.4 RODENT BORNE DISEASES

There are several infectious numbers of pathogens and diseases that are carried by multiple rodent species, such as *R. norvegicus* (16 diseases), *M. musculus* (14 diseases), *R. rattus* (13 diseases), *M. persicus* (7 diseases), *Apodemus spp.* (5 diseases), *T. indica* (4 diseases), *M. libycus* (3 diseases), *R. opimus* (3 diseases), *C. migratorius* (3 diseases), and *N. indica* (2 diseases) (Rabiee et al 2018). From these highly infectious 10 species, 5 species have been found and are dominant in our project countries(*R. norvegicus*, *M. musculus*, *Apodemus spp.*, *R. rattus* , *C. migratorius*). During our survey, our respondents mentioned that they were unaware of any diseases caused by rodents in recent times. But from our inventory, we found 19 types of rodent-borne diseases exist in our project countries. These diseases are mostly virus borne (hantavirus, leptospirosis, lymphocytic choriomeningitis, tularaemia, arenavirus, salmonella etc.) and tick-borne (rat-bite fever, tick borne relapsing fever) diseases. The following table 5 consists of all the diseases we found during our research.

Table 5 Rodent borne diseases per country

Rodent borne disease	Turkey	Morocco	Greece	Cyprus
<i>Babesia microti</i>	x			
<i>Hepatozon spp.</i>	X			
<i>Sarcocystis spp.</i>	X			
Arenavirus	x			
Hantavirus	x			
Cowpox virus	x			
<i>Francicella tularensis</i>	x	x		
Tickborne encephalitis virus	x	x		
Cutaneous Leishmaniasis	x	x		
Tick-borne relapsing fever (TBRF)		x		
Dobrava Belgrade			X	
Rickettsia Typhi			X	
Murine typhus			X	
Bartonella vinsonii			X	



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Ratbite fever (RBF)			X	
Leptospirosis			X	
Trichinosis			X	
Salmonellosis			X	
West Nile virus				x

During our research, we identified that there are 21 diseases present in these countries but when we are talking to our respondents, they said they are not aware of rodent diseases around them. One reason can be that they are unaware of the disease itself and can confuse it with another viral fever. Also, the transmission and prevalence of these diseases can vary per geographic location and virus-host systems, environmental controls, and anthropogenic, genetic, behavioral, and physiological factors (Rabiee et al, 2018). For example, lymphocytic choriomeningitis has been reported as endemic in humans in the European region.

All diseases we found during our research are mainly tickborne and viral-borne diseases. Diseases transmitted by ticks are a major global health concern. In Mediterranean project countries, a few tickborne diseases have been found in lab studies by sampling the rodent blood sample. For example, In Turkey molecular studies on rodents identified the presence of *Babesia microti*, *Hepatozoon spp.*, and *Sarcocystis spp* in the PCR test (UsLuca et al, 2019).

Viral fevers are one of the major potentially fatal disease groups among humans and rodents are one of the major reservoirs for these viruses. From our study, it has been found that the Mediterranean area hosts a few of these virus pathogens and diseases for example: Arenavirus, Hantavirus, Cowpox virus, Tickborne relapsing fever which is also known as Rat bite fever, and tickborne encephalitis virus among others. But during our research, we did not find out what major groups of humans are affected by these viruses. A study on the Hantavirus identified that people who work in the forestry or agricultural sector who have direct contact with rodents are more prone to these viruses (Kalio-Kokko et al, 2006). Also, agricultural intensification, land-use change, and irrigation have influenced these virus transmissions (Herrero-Cófreces et al, 2022).

Leishmaniasis is one of the significant parasitic diseases in Mediterranean countries, with wide-ranging clinical forms. For example, according to the Ministry of Health of Turkey, 46.003 new Cutaneous leishmaniasis cases have been reported in Turkey between 1990 and 2000 (Culha et al, 2014). But for other countries, we couldn't find any databases related to rodent disease. In Morocco, leishmaniasis is a growing public health problem. According to the Moroccan Ministry of Health, 2 877 cases of cutaneous leishmaniasis were reported in 2012, while rodents of species *M. shawi* is the main reservoir host of *L. major*.

4. RODENT INFLICTED DAMAGE IN THE AGRICULTURAL SECTOR

According to our key informants, the main issue of rodents in urban areas is disturbance, while for agricultural areas it is damage to crops. In urban areas the main signs of contamination include rodent faeces and urine. Damage includes scratches on the wall, damage to cables, and disturbance in

gardens; also, noises are heard. Whereas in an agricultural field the main signs are burrows, signs of rodent tracks and holes, and the presence of natural predators to rodents. The damage in rural areas is seen on the field itself, for instance when tillers are damaged or fruits of a crop are eaten. Additionally, storage materials or infrastructure can also be damaged.

For each of the four countries we searched for any literature, anecdotal evidence or news-items that gives indication of pre- and post-harvest damage in the agricultural sector. In the literature we only found just 2 figures, which lacked the detail to understand the duration of the research and the exact area. For Cyprus the figures mentioned 5-10% damage on average. For Morocco, research indicated 40-70% losses in cereals & vegetables of damage is caused by *Meriones shawi* spp. but literature didn't quantify the time period of it. It does specify that damage is specifically very high during outbreaks.

For Greece there is very little known on damage numbers, we however retrieved information from the northern part of the country that gives an impression of the scale of the problem. In an article from July 2022, Kostas Agorastos shares that “the problem with rodents is cyclical, when there is an infestation, damages can reach up to 200 million euro. It is a lot”¹.

In Turkey, especially in some pepper greenhouses, it has been determined that rodents cause more than 50% damage to the pepper before harvesting period. Also, according to some respondents there was a huge invasion at some university and urban areas that caused huge economic losses by eating expensive cables. Some of them also cause severe damage to the structures. The survey from Turkey, some of the experts in agricultural zones conveyed that especially *Spalax* species are given huge damages in pre-harvest period by eating the root of cereals. And they said they still don't have a solution for controlling this species. Also, according to the survey rodents cause huge damage post-harvest, in storage they damage seeds of cotton, cotton, corn, barley, and wheat. Regarding pre-harvest losses one of the agricultural experts shared that generally rodents cause most damage to wheat in the tillering period. One of the researchers from Turkey mentioned that in general there are 10-30% of crop loss that happens in wheat production because of rodent issues in different stages of crop production. This year the wheat production amount is 17 million tons in total and a loss of 10% is approximately 1.7 million tons (IndexMundi, 2022). Saving this huge amount of wheat can be a good step towards enhancing food production.

All of our respondents in the interviews mentioned that there is damage caused by rodents in public goods and crops but they do not know about any study on the amount of loss in monetary units.

5. RODENT MANAGEMENT PRACTICES

This chapter provides an overview of the current rodent management practices used by stakeholder in the target countries, and especially the dependency on chemical products. However, there are also alternatives known and partly used, often in combination with chemical products. It provides opportunities to leverage such methods and enhance these fine-tuned to the demands of farmers.

¹ <https://www.investigate-europe.eu/en/2022/how-owls-are-flying-to-save-greek-farmers-from-rodents-and-pesticides/>



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Lastly this chapter concludes with ideas shared by interview respondents indicating alternative rodent management methods which are not chemical-based.

5.1 OVERVIEW OF RODENT CONTROL APPROACH AND METHODS

Rodent control in the Mediterranean region is mainly done through usage of synthetic chemical rodenticides (SCR). These have adverse impacts to the environment since they do not degrade and can cause indirect harm to non-target species, e.g. a raptor eating a rat that has eaten SCR. In addition, an imbalance in the killing rate can disrupt the food chain and it can also kill species with positive effects which are not necessarily considered pest species.

All respondents indicate that in case rodent nuisance is experienced in their surroundings, they contact responsible authorities. And 87% of them contact private pest control companies, while 13% contacts government pest control offices. Furthermore, most respondents think there are no regulations related to chemical rodenticide use, and they can directly buy it from the market. Whereas, only 13% of the respondents indicate that they know about the regulations regarding buying rodenticides. Cats are widely recognized as biological rodent predators. Whereas also dried mint and lavender were suggested as botanicals that can repel rodents. However, there is high uncertainty as to what extent such botanicals are used in practice by farmers.

In all four countries, chemical methods are widely used in mouse control. In Turkey, people apply chemical pests to rats according to economic threshold damage. Aluminium phosphide and zinc phosphide are most common chemical pesticides used for controlling rodents. Simpos (57% Aluminium phosphide) are used more to control rats in the warehouse. In Morocco they are using Murin Facoum, Pellet, Raticide %95, PATRON, RATICIDE 70, Ramet, RATICOL special, Gardenocol as a chemical and physical rodenticide control. In general, as in other countries, ministry-licensed rodenticides are used for chemical control in Mediterranean countries. Based on the research on those countries, the most effective period for applying rodenticide is spring and late autumn. Because the rats are physically weaker during this period. Farmers shared that it's necessary to start controlling rodents when you find 5 holes in 25 m² in the field, or when a high amount of damage is identified in the field one should also start controlling rodents. (Note that this is reactive rodent management, which is scientifically proven to be largely ineffective, for effective management the timing of control measures must be pro-active and take place in the lean season of the rats, when they are few and weak, since there is no food to be found in the fields.)

Table 6 Rodent Control management

Type of rodent management	Specific method	Cyprus	Turkey	Greece	Morocco
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Chemical	Synthetic Chemical Rodenticide (SCR)	X	X	X	X
	Second Generation Anticoagulant Rodenticides (SGARs)			X	
	Tracking powder?		X		
	Pellets / concentrate?		X		x
	Chemical repellent			X	
	Naphthalene			X	
	Fumigants			X	
	EPA approved Ro-pel			X	
	Toxicants			X	x
Mechanical / Physical	Multi-capture trap	X			
	Walk in rat traps, live single capture (e.g., Hamane, cages, other)	X			
	ASPECTEK Large Size Rat Trap	X			
	Air rifles	X			
	Plastic pipe method	X			
	Old-fashioned spring-loaded spine crusher style with a piece of apple/apple core as the bait	X			
	RatMat – Rat Repellent Electrified Flooring	X			
	Glue boards	X		X	x
	Lanate	X			
	Snap trap			X	
	Steel wool	X			
Cultural					
Biological	Cat (domestic or feral cat)	X	X		x
	Barn owls	X		X	

Note that there is overlap of the management methods used, sometimes for instance a chemical bait is provided in combination with a trap. Furthermore, different methods can be applied simultaneously. The types of mechanical and physical management methods greatly relies on caged traps, snap traps and blue boards.

5.2 DEPENDENCY ON SYNTHETIC CHEMICAL RODENTICIDES

In the project countries, residents are heavily dependent on Synthetic Chemical Rodenticides (SCR) both in agriculture and urban areas. 14 respondents out of 15 responded that they use chemical management methods in controlling rodents. As a part of this research, we documented all available rodent management methods in our project countries. Our survey results showed that not only chemical, but also physical and biological management methods are used in those areas as a Rodent Control Strategy.

From survey data in Crete, respondents indicated that in 49.9% of the properties, owners use strictly chemical measures, in 40.6% use a combination of chemical and non-chemical measures. In 9.6% of the properties, strictly non-chemical measures are used. At least 40.9% of the surveyed properties had a rodent infestation problem in the past 3 years. From these cases, only 28% used strictly chemical control to eradicate the problem, only 1.4% used strictly non-chemical means, and 71.1% used a combination of measures. It is noted that non-chemical measures included (a) mechanical or adhesive traps etc., and (b) predators (e.g., cats).

The interviewees indicated that for rodent management the people heavily depend on chemical-based methods, they buy these products at local shops. In this study, we have found different types of CSRs used in Mediterranean regions. According to scientific literature and online materials, most rodent baits are anticoagulants like Bromadiolone or Brodifacoum (Capizzi, 2020). But during our survey, our respondents referred to the most common chemical rodenticide as Zinc Phosphate. Table 7 consists of all the available chemical rodenticides in our project countries that are still in use (both indoor and outdoor usage).



Table 7 Available Chemical rodenticides in the Mediterranean region



Types of use	Anticoagulant type
Outdoor use	Second-generation Anticoagulant RodenticideGAR
	First Generation anticoagulant rodenticide
	Bromadiolone
	Difenacoum
Indoor use	Flocoumafen
	Brodifacoum
	Zinc Phosphate Bait
Most Common	Zinc Phosphate Bait

Table 8 is the summary of all the available products in local markets we were able to find through our respondents. We tried to identify the major chemicals in these products. Though there are many

active ingredients in it, mostly it is a very high concentration of Zinc Phosphide >80%. Zinc phosphide is highly toxic to humans and other organisms. These easily accessible rodenticides can affect non-targeted animal groups and can have long-term harmful effects.

Table 8 Available chemical rodenticides in the project countries from local market survey

Local Available image	Name	Active ingredient	Local name
	Synphos	Zinc Phosphorus-85% filler-15%	Synphos
	AloTrap	Polybutene %80-90 Polyisobutylene %5-10 Hexane %5-10	Mouse sticky
	Asyem	Safwarfarin (cas no 129-06-6 %0.05), Dye, Additive	Toxic seed
	Paste Farex	Difenacoum	Mouse cake
	Napoleon 25 WP	Napoleon 25,Wp 200gr(%25 Chlorpyrifos-Ethyl)	Powder poison
	Tmate	80% Zinc Phosphorus	Powder poison
	Ratol Technical	Zinc phosphide	Black powder

	Murin Facoum Pellet Brodifacoum 0,005%	Brodifacoum 0,005%	Pellet
	Raticide 95%	Alphachloralose 95%	Graines
	PATRON	Brodifacoum 0,004%	Pellet
	RATICIDE 70	Alphachloralose 70%	Graines
	Ramet	Chlorophacinone 0,005%	Pate
	Ramet	Chlorophacinone 0,005%	Bloc
	Ramet	Chlorophacinone 0,005%	Pellet
	RATICOL special	None	Glue
	GARDENOCOL	None	Glue

We asked our respondents as well about the rodent resistance increase. 40% of people said they think that rodents are getting rodenticide resistance with time. Though, 60% of people responded did not think that rodents would build up resistance against Synthetic Chemical Rodenticides. In addition, people mentioned that from their observation, *Rattus Norvegicus* is hard to kill with current drug doses.

Resistance to chemical rodenticides has already been found in some EU countries. House mice (*Mus musculus*) are getting resistant to both first and second-generation coagulants. Already, the resistance gene is present in their genotypes. Also, Norway rats (*Rattus norvegicus*) are refusing to enter the conventional trap boxes (EBPF, 2017). Our farmers narrated that these small rodents are intelligent and get used to the situation very quickly. As a response farmers try to switch between different SCR products to still lure the rats to eat the bait. But nowadays they observed that Norway rats are harder to kill by using SCR, if they only smell something or sense a suspicion, they do not eat the bait. Rats cannot vomit, so rather they are very cautious and stay away from the bait. Furthermore it can happen that rats just eat a very little amount that does not cause a lethal impact, this causes resistance to grow to this chemical usage. In the target countries there is no specific information on usage of SCR, however we did find through popular news sources that despite regulations against SCR, and some insights that rats avoid these, farmers still use SCRs. They will get them illegally and still apply it despite the negative impact.

5.3 NON-CHEMICAL METHODS AND IDEAS

Mechanical/physical control

All respondents indicate that they are using Live trap, and trap using for mechanical controls. Also, plastic traps, barn tubes in storage and houses. Another mechanical controlling method is fill in with the water active holes on the field.

Cultural practices

From the survey that the damage can be reduced to some extent with measures such as deep tillage, alternation, and field cleaning. Also mowing grass, shorten plant heights and preventing nest construction.

Biological control

The main natural enemies of mice are cats, dogs, foxes, weasels, owls, kestrels, eagles and snakes. In environments where the natural balance is intact these natural enemies put the field rodents under controlling. In order to protect these creatures, they should not be hunted and pesticides should not be used unnecessarily against diseases and pests in the fields.

As a result of surveys we conducted, they stated that some farmers in Turkey used plants with high repellent effects such as Mint (*Mentha*) and Cumin (*Cuminum cyminum*) against the rats in their storage. In another interview, it was reported by the farmers who are living in Lavanta village in Isparta located southwest in Turkey. They told that rats are usually don't seem around the lavender gardens also around the village and in their house and their storage because of the repellency effects of the lavender. According to literature research that we have done such as those plants ; Jimson weed¹ (*Datura stramonium*), Harmel² (*Peganum Harmala*), Nerium³ (*Nerium oleander*), Red squill³(*Urginea maritima*), Ricinus⁵ (*Ricinus communis*), Coclebur⁶ (*Xanthium strumarium L.*), Hemlock (*Conium maculatum*)⁷ plants were studied and lethal doses were found in all plants. In addition, some of them, such as Lavender⁸ (*Lavandula angustifolia*) and Eucalyptus⁹ (*Eucalyptus globulus*) have a high repellent effect. With our research, it has been seen that the biologically based product called BIORAT is effective in controlling rodents and has been tried and succeeded in many different countries. An



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indiscriminate spread of this pest has occurred in all latitudes due to its skillful adaptation to very different living conditions.

Other biological control methods such as predators and fertility control

In some regions of Turkey, columns have been erected so that birds of prey (falcon, falcon, etc.), which are the natural enemies of the vole, can observe the agricultural lands and thus gain an advantage against voles.

Recommendations from the respondents

Based on the interviews with key informants we discussed possible rodent management methods that inhibit effective sustainable measures, in the figure below we share the outcome of these discussions which gives ideas on the type of EBRM measures fitting for the Mediterranean countries.

Our framework is divided into four phases. This framework is for agricultural areas.

Initial phase: Before cropping season, farmers need to plow the soil deeply so that all rodent holes are broken down. And then fill the land with water. This phase will destroy all rodent nests, and they will not have any place to hide and stay.

Preparation Phase: Before planting the crops, we need to create a hedge with rodent-repellent plants. Also, avoid planting the same grain species from the previous season.

Pre-harvest Phase: Most of the damage happens during the planting and harvesting phase. This time is very important to monitor and quantify the damage caused by rodents. Releasing predatory animals is necessary for this phase. Also, monitoring the active rodent hole and applying biocides or bio-based lethal materials (ex – oleander seeds) is important to control the rodent population.

Post-harvest phase: After harvesting, field cleaning is the most important step. This will ensure that rodents will not find any food in the field and their population will reduce.



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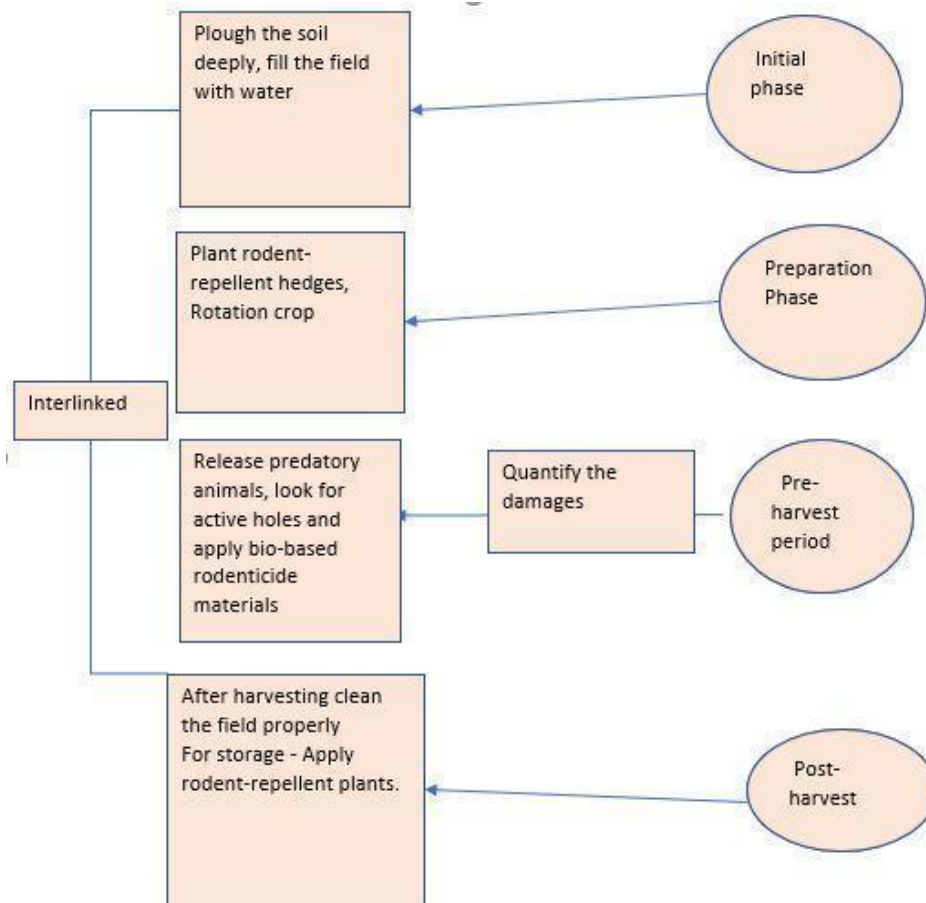


FIGURE 2 REDUCING CHEMICAL MANAGEMENT METHODS WITH CURRENT

6. SOCIO-CULTURAL, MARKET DYNAMICS AND REGULATIONS ON RODENT MANAGEMENT

6.1 SOCIO-CULTURAL ASPECTS

Farmers and local residents have typical buying habits is current practice to deal with rodent problem in their region.

6.2 EXTENSION SERVICES

Moroccan agricultural education-training-research-extension system such as the regional directorates of agriculture (e.g. Directorate of Rabat-Salé-Zemmour-Zaer), the provincial directorates of Agriculture (e.g. Directorate of Essaouira), the National School of Agriculture (ENAM) and the National



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Institute of Agronomic Research (INRA). Extension providers in Turkey, agricultural bureau is main responsible for extension services. Their services are providing free chemical pesticides during infestation periods. In urban areas, municipality is responsible organization by applying chemical rodenticides regularly in city. Extension Providers in Greece, in the public Sector Ministry for Rural Development and Food . The National Agricultural Research Foundation may merge with the Organization of Agricultural Vocational Education, Training and Employment and thus there may be the kind of Public Research Institution with Extension Unit organization. Farmer Based Organizations: In principle, the Unions of Cooperatives employ agronomists who are able of performing extension functions; however, these agronomists are largely confined in the role of suppliers of inputs to farmers (by the coops). The following list shows an excerpt from the GFRAS Directory of Extension Providers for Greece. Some of these entries may be specially marked for having more detailed information in the database of the Worldwide Extension Study WWES.

Extension providers in Cyprus in the Public Sector, Ministry of Agriculture, Natural Resources and Environment. "The Ministry of Agriculture, Natural Resources and Environment is responsible for developing and implementing government policy in the agricultural, animal husbandry, natural resources and the environment sectors. Its main objectives are to improve the standard of living for farmers and the general welfare of the rural world." (retrieved 5/16/2011)

The following sections and within those departments are within the Ministry:

- Agriculture
- Department of Agriculture
- Agricultural Research Institute (does not provide extension services)
- Department of Fisheries and Marine Resources
- Veterinary Services Department
- Natural Resources
- Environment
- Remote Sensing Unit

"The Department of Agriculture bears the primary responsibility for extending the agricultural scientific knowledge, implementing the agricultural policy and helping improve the financial situation and the standards of living of the people in the rural areas. In recent years, the scope of the development function of the Department of Agriculture has expanded beyond the advisory role and that of scheme management. The following list shows an excerpt from the GFRAS Directory of Extension Providers for Cyprus. Some of these entries may be specially marked for having more detailed information in the database of the Worldwide Extension Study WWES.

6.3 MARKET ANALYSIS

Today, over 400 different active pesticide substances are approved in the EU. Global pesticide sales have doubled in the last 20 years, to about €52 billion in 2019. The European market for agricultural pesticides is one of the largest in the world, with sales of around €12 billion in 2019. The EU is also the



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global leader in pesticide exports. Since 2018, only China has exported more pesticides than Germany. Then comes France, the US, Belgium, Spain and the UK as the largest country distributors.

6.4 POLICIES AND REGULATORY PROXIES RELATED TO RODENT PEST MANAGEMENT

The most important advanced rodenticides – Second Generation Anticoagulant Rodenticides (SGARs) – have been banned for use in EU fields since May 2021 when authorisation of bromadiolone expired. Numerous scientific studies have shown that SGARs are exceptionally harmful to the environment. They do not break down easily, are highly toxic and accumulate in the bodies of larger predators. Across Europe, SGARs are still applied legally in and around buildings and in open spaces, such as parks, golf courses and dikes. “Anticoagulants fail many regulatory environmental risk assessments, nonetheless they continue to be heavily used because of the societal need for rodent control and the limited availability of safer alternatives,” wrote Nico van den Brink, toxicologist from the University of Wageningen in the Netherlands and author of a book on the subject.²

The European Commission accepted the recommendations of the European Chemicals Agency (ECHA) for the reclassification of currently used anticoagulant rodenticides (European Commission Regulation 2016/1179). Based on this regulation, all available anticoagulant rodenticides must be used in reduced doses of (<30 ppm). Before this restriction, all anticoagulant rodenticides contained 0.005% or more of the anticoagulant dose (50 ppm).

In 2020 the Farm to Fork policy, the flagship EU strategy to make European agriculture green and sustainable, set a target to reduce pesticide use by 50 per cent by 2030. The Sustainable use of pesticides regulation (SUR), currently being developed in Brussels, is central to this goal and will be the first binding EU law to tackle the problem. However, this strategy is up against a counter-alliance of chemical companies and agribusiness lobby-groups, who are pushing to defend the status quo not to reduce pesticide use and risk lower agricultural yields.³

Literature and respondents of our survey indicated that these project countries are still heavily dependent on chemical-based management methods. The respondents mentioned that they don't experience any regulation related to rodenticide use, and they can easily buy it from their local market. Though local experts in the interviews did indicate that there are some regulations around this issue in the target countries. For example, In Turkey, only legalised Agricultural Engineers are allowed to give chemical rodent baits to the farmers (Dr Mehmet Mamay (Harran University, Crop Protection Department), Personal communication, 2022). The main reasons for this knowledge gap can be the lack of awareness of rodenticide use among the public and also the easily available rodenticide in the market. Also, there is a lack of enforcement of existing regulations by governments. Moreover, the public is not aware of the harmful effect of rodenticides. In 2010, There was a proposition to ban the Difenacoum in the European parliament because of its harmful effects (Murphy, 2010) but This

² <https://www.investigate-europe.eu/en/2022/how-owls-are-flying-to-save-greek-farmers-from-rodents-and-pesticides/>

³ <https://www.investigate-europe.eu/en/2022/pesticides-europe-biodiversity-crisis/>



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rodenticide is still available in our project countries. That shows one of the multiple existing knowledge gaps.



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7. CONCLUSIONS

This study is a baseline research to get a clear overview about the characteristics of rodents and their impact in the Mediterranean region, specifically on the chapters of 3) rodent pest species, including: history of outbreaks and population dynamics, rodent ecology and behaviour, rodent borne diseases, 4) rodent inflicted damage in the agricultural sector, 5) rodent management practices, and 6) socio-cultural aspects, market dynamics and regulations around rodent management.

The main finding from this study is that although rodent damages are prevalent and persistent, it is still an under-researched area that needs explicit research. Through literature review and interviews with respondents, we found that most of the available knowledge is on the topic of rodent pest species and their characteristics (chapter 3), although little is known about outbreaks in relation to population dynamics specific to the target countries. Furthermore, among respondents we found that species identification and understanding of the behaviour of species was very basic and deemed insufficient for successful rodent control.

Here we found apparent gaps that the MED4PEST project will address. For successful implementation of EBRM it is critical to fully understand which rodent pest species are prevalent, how they behave and what damage they cause in what time of the year. This understanding of the rodents themselves is something we must build up during this project and will largely happen through the Community of Practice and living labs. As most of it relies on qualitative research and fieldwork, where field trials with management methods for instance will display great insight into many behavioural aspects of rodents.

What is strikingly lacking in almost all the countries are quantified studies of the damage that rodents cause (chapter 4), and the range of management options (chapter 5) related to its effectiveness. We could not find specific studies that have researched the pre- and post-harvest crop losses, while such studies can be found for other countries for instance in South-East Asia. Though we can only guess why this information is not there, it is essential to understand the economic cost of rodent pests' impact, and in extension thereof the development of cost-effective management methods. In addition to the interviews and desktop review, in Greece, Morocco and Turkey a survey with farmers is underway to capture more information on damage and management methods, this will be shared in the country inventory and is an essential part of baseline data as well.

Concerning socio-cultural aspects, not much is known specific to the 4 countries and from the interviews the approach people take seems rather pragmatic and it lacks any taboos/superstitions around rats. The market dynamics reveal a huge industry around rodent control products which is very strong, this may be a hindrance to our work since farmers rely so much on SCRs and since there are hardly any other products available with similar cost, labour and time required. However, the EU regulations are drastically changing, phasing out a number of critical SCRs and fully support biological and ecological alternatives. We have picked up that since farmers have limited alternatives, they still find SCR products illegally, despite regulations prohibiting its usage. The MED4PEST project therefore comes at a critical time to develop ecologically sustainable methods with the farmers together to ensure rodent pest species can be managed effectively and sustainably.

This baseline report has only made it more clear how little is known about rodent pest species across the board, from literature sources to local experts to farmers. Though some harmful effects of rodents are recognized and identified, it is evident that there is a lack of knowledge on multiple aspects ranging from species identification, to damage numbers to management. These knowledge gaps are currently a major hindrance for successful and environment-friendly rodent control. The MED4PEST project is



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set-up in such a way to develop this knowledge and understanding throughout all the stages of the program, from this baseline report to the development of EBRM products and measures. We will first and foremost focus on improving the understanding, through a co-creation process with multiple stakeholders. Eventually the aim is to help local governments, crop protection agencies, farmers and other relevant stakeholders to better be equipped for management of rodents. We therefore need to develop knowledgeable and skilled perspectives together to develop rodent management strategies tailored to the local situations. A first step in this process will be the country inventory deliverable, which will present more specific information to each of the countries for testing and implementation.



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XTRAIT DU BULBE D%27URGINEA MARITIMA RODENTICIDE ACTIVITY OF URGINEA MARITIMA BULB EXTRACT

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Source of Rodent species table:

Wikipedia 1 https://en.wikipedia.org/wiki/Shaw%27s_jird 16.01.2023

Wikipedia 2 https://en.wikipedia.org/wiki/Black_rat 16.01.2023

Wikipedia 3 https://en.wikipedia.org/wiki/Brown_rat 16.01.2023

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Wikipedia 8 https://en.wikipedia.org/wiki/Lesser_blind_mole-rat

Wikipedia 9 https://en.wikipedia.org/wiki/Common_vole

Wikipedia 10 https://en.wikipedia.org/wiki/Striped_field_mouse

Wikipedia 11 https://en.wikipedia.org/wiki/Hazel_dormouse

ANNEX 1



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Rodenticidal compounds authorised for use in plant protection in the European Union in the Member States per compound (Jacob et al , 2018)

	Al-Ph	Ca-Ph	Mg-Ph	Zn-Ph	Broma	Difena	CO ₂	Sum
Austria	x	x	x	x				4
Belgium	x		x					2
Bulgaria	x		x					2
Croatia	x		x		x			3
Cyprus	x		x					2
Czech Republic	x	x		x	x			4
Denmark	x							1
Estonia	x		x					2
Finland	x							1
France	x		x	x	x			4
Germany	x	x	x	x			x	5
Greece	x		x					2
Hungary	x	x	x	x				4
Ireland	x							1
Italy	x		x		x	x		4
Latvia	x	x	x					3
Lithuania	x		x					2
Luxembourg	x	x	x	x				4
Malta	x							1
Netherlands	x		x		x			3
Poland	x	x	x	x				4
Portugal	x		x		x	x		4
Romania	x		x		x			3
Slovak Republic	x							1
Slovenia	x	x	x	x				4
Spain	x		x		x			3
Sweden								0
United Kingdom	x	8	x	8	8	2	x	3
	27		21				2	

ANNEX 2



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A specific set of questions to respondents for KII

1- How do you control rats?
2- How do you know there are faeces in your house?
3- How do you notice the damage done by the rodent in the field and the storage?
4- At what time of day do you see more rats?
5- Do you have any idea about the type of mouse?
6- What kind of ecological method you can suggest or possible?
7- How often do you apply rodenticide?
8- Is there any state oversight for this?
9- How much rodenticide is thrown into how much space?
10- Do you think rats are becoming more resistant to pesticides that are being applied day by day?
11- Do you have rodents in your working place?
12- How do you identify the rodents?
13- What period of time they increase in number? / more active period for rodents in year?
14- What period of the day they are active?
15- What do they do when they have rodent issues at home,field or storage?
16- How do you identify the number of rodents?
17- How do you manage rodents in your house?
18- Do you have any rodent regulation in your country?
19- Is there any regulation on how much rodenticide is needed?



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