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# The comparison of plant protection against plant diseases of greenhouse tomato in Poland and Greece.

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# Index

# Εισαγωγή

Στόχος της παρούσας διπλωματικής εργασίας αποτελεί η σύγκριση της φυτοπροστασίας της θερμοκηπιακής ντομάτας κατά των κυριότερων και βλαπτικότερων ασθενειών που έρχονται αντιμέτωποι οι παραγωγοί ντομάτας στην Ελλάδα και την Πολωνία.

Οι ασθένειες των φυτών αποτελούν ένα μεγάλο κα σοβαρό κεφάλαιο που οι επιπτώσεις τους έχουν αντίκτυπο σε ολόκληρη την κοινωνία, μπορεί να είναι οικονομικές, κοινωνικές και ενίοτε να επηρεάζουν σημαντικά, μερίδα της ανθρώπινης οντότητας με υποσιτισμό. Χαρακτηριστικό παράδειγμα ο μεγάλος λοιμός της Ιρλανδίας, το 1845, έπειτα από καταστροφή ολόκληρης της σοδειάς της πατάτας, σε όλη την χώρα, από περονόσπορο ( *phytophtora infestans*). Για αυτό κρίνεται απαραίτητη η συνεχής κατάρτιση και λεπτομερείς γνώση και έλεγχος των ασθενειών.

Στην παρούσα διπλωματική εργασία, θα γίνει πλήρης ιστορική αναδρομή για την καλλιέργεια του δεύτερου πιο σημαντικού λαχανικού στον κόσμο, την τομάτα. Θα εξετάσουμε το ταξίδι της στην Ευρώπη, θα γνωρίσουμε καλύτερα τις πραγματικές ανάγκες ανάπτυξης του φυτού, καθώς επίσης και όλα τα τρωτά σημεία, που κάνουν την εμφάνιση τους και επηρεάζουν την παραγωγή της.

Επιπλέον, γίνεται λεπτομερείς αναφορά στις πιο σημαντικές ασθένειες της ντομάτας, που αντιμετωπίζουν από κοινού οι χώρες του Βορρά και του Νότου, Πολωνία και Ελλάδα, αντίστοιχα. Δίνεται έμφαση στον έλεγχο και την φυτοπροστασία των φυτών, που αποτελούν ένα ξεχωριστό και σημαντικό κεφάλαιο, ρέουσας σημασίας.

Στο δεύτερο , πρακτικό μέρος της εργασίας, πραγματοποιείται σύγκριση μεταξύ δύο θερμοκηπίων, με υδροπονική καλλιέργεια ντομάτας, που τοποθετούνται στην Ελλάδα και την Πολωνία, αντίστοιχα. Γίνεται λεπτομερής αναφορά στο κόστος εγκατάστασης του υδροπονικού συστήματος, το κόστος θέρμανσης, το κόστος εφαρμογής φυτοπροστατευτικών προϊόντων, κόστος του θρεπτικού διαλύματος που χορηγείται στα φυτά, κόστος απόκτησης των μεταμοσχευμένων φυτών καθώς και το κόστος παραγωγής για τις δύο θερμοκηπιακές μονάδες.

Ακόμη, τονίζονται και επεξηγούνται οι διαφορές του υδροπονικού συστήματος που εφαρμόζεται. Στην Πολωνία είναι εγκατεστημένο ανοιχτό σύστημα υδροπονίας, ενώ στην Ελλάδα κλειστό σύστημα. Δίνεται έμφαση και γίνεται σύγκριση στον τρόπο αντιμετώπισης της ασθένειας που προκαλείται από τον αδηλομύκητα *botrytis cinerea,* καθώς και στην διαφορετική αντιμετώπιση και χρήση των φυτοπροστατευτικών προϊόντων.

Στην Πολωνία, το μεγαλύτερο κόστος, προέρχεται από την θέρμανση του θερμοκηπίου, και συγκεκριμένα, θέρμανση που γίνεται με καύση κάρβουνου, που αποτελεί την ίδια στιγμή και μεγάλο ρυποφόρο παράγοντα. Σε αντίθεση με το εξελιγμένο θερμοκήπιο της Ελλάδας, που εκμεταλλεύεται την προσοδοφόρα γεωθερμία, και γεύεται τα πλεονεκτήματα της.

Στην Ελλάδα, το μεγαλύτερο κόστος προέρχεται από τον εξοπλισμό της υδροπονικής εγκατάστασης και την απόκτηση των φυταρίων από καλούς οίκους, με εξασφαλισμένη την απαλλαγή τους από ασθένειες.

Η σύγκριση της ασθένειας του Βοτρύτη (Gray mold) και η ανάλογη αντιμετώπιση της, από τις δύο χώρες, μας οδηγεί στο εξής συμπέρασμα: Στην Ελλάδα λόγω του ζεστού κλίματος, και του ιδιαίτερα εξοπλισμένου και μοντέρνου θερμοκηπίου, η ασθένεια του Βοτρύτη, δεν επιτρέπει εξάρσεις στα φυτά της ντομάτας. Για αυτό και δεν χρησιμοποιούνται φυτοφάρμακα, οπότε η διαχείριση των προσβεβλημένων φυτών είναι η απομάκρυνση τους από τη φυτεία. Προληπτικά γίνεται εφαρμογή με ήπια προϊόντα για να μην διαταραχθεί η ισορροπία των εντόμων που εξαπολύουν στο θερμοκήπιο. Στην Πολωνία λόγω της υψηλής σχετικής υγρασίας, και των νεφοσκεπών μηνών, ο Βοτρύτης, παρίσταται, και για την αντιμετώπιση του, γίνεται χρήση συνδυασμού φυτοπροστατευτικών προϊόντων, για την καταστολή του μύκητα.

Τέλος, δίνεται έναυσμα, για περαιτέρω έρευνα πάνω στην φυτοπροστασία, ένας τομέας που αφορά ολόκληρη την κοινωνία. Η φυτοπροστασία αποτελεί την όαση μπροστά στον κυκεώνα από νέους επιβλαβείς οργανισμούς και ασθένειες, που εμφανίζονται συνεχώς.

# 1. Introduction

The word "tomato" refers to the plant *Solanum lycopersicum* or the eatable, typically red, fruit that it represents. It emanates from America, grace to the Spanish colonization, the tomato spread all over the world and its many varieties are now widely grown, either in open farming, or in greenhouses for cooler climates. (http://en.wikipedia.org). The *S. lycopersicum*, from botanical view is a fruit, but the decision of United States Supreme Court, classifies it in the family of vegetables, mainly for culinary purposes. The cultivated tomato is coming second in the world consumption, after the potato (Foolad 2007). Different varieties of tomato are cultivated in a large range of different climates around the world, even in the Arctic Circle. Nevertheless, the most productive areas with the best fruits quality are the warmer Mediterranean countries in the percentage of 30% of world production. (http://en.wikipedia.org).

The leading producers of tomato fruits among the European Union countries are: Italy (6.0 m tones), Spain (3.7 m tones) and Greece (1.5 m tones). Poland ranks eighth in the EU, with a tomato production of 0.25 m tones according to Kalbarczyk et al. (2011). In Poland the vegetable cultivation plays an important role to the vegetal production and therefore to the economy. In the internal structure of cultivated vegetables, tomato occupies the percentage of 6%. This low ranking of tomato happens due to its high thermal requirements. The tomato is known as a thermophylous plant that needs temperatures of 22-27$^{o}$C during the day and during the night 16-18$^{o}$C and is defined by tomato growth stage and light intensity. It observed yield reduction when the temperature exceeds 25$^{o}$C. Tomato cannot cultivated in cold climates, is very sensitive to the cold (0-5$^{o}$C) and the frost. In Poland these temperatures in the winter is a common condition, and the plants freeze and die, when the temperature falls below the 0$^{o}$C. It is necessary a minimum of four mouths without freezing. So in Poland are limited the climate thermal requirements. The western region of Poland, like Wrocław and the south-eastern Sandomierz-Lublin region are the most suitable areas for ground cultivation. The best yield is harvested in the years which are considered by Polish terms, as warm and dry. In Poland, tomato yield slightly overdraws 20 $t \cdot ha^{-1}$. In the southern regions of Poland, like Wroclaw and Krakow the harvesting of tomatoes has the biggest duration throughout Poland that it starts on 21st of May after the danger of frost (Kalbarczyk *et al.* 2011).

The total cultivated agricultural land in Greece it is 3.92 million ha and it is counted that only the 3.4% is occupied by vegetable crops, while the confluence of vegetable crops to the composite value of horticultural produce is 18.3%. The main purposes for vegetable production in Greece are to satisfy local requirements, and also to export those vegetables, which are in demand at profitable prices. The Greek Ministry of Agriculture is promoting selected new hybrids for the production of vegetables in greenhouses and low tunnels. Out-of-season production of vegetables in greenhouses and low tunnels is of great economic importance to Greece as the geographical position of the country offers basic climatic advantages in comparison to northern European countries according to Olympios (2004). The greenhouses and the low tunnels are situated in places with no frost and with mild winters. Crete includes the greater proportion of greenhouses because of the higher air temperature comparing to the northern regions of Greece. In cultivated land with greenhouse tomato second is the Peloponnese and third the Macedonia. The recent years in Greece the soilless culture of vegetables (hydroponics) is developing, is estimated about 150 ha the majority of which hold the tomato with 100 ha. Germany, France, Italy, Britain, Rumania, Bulgaria, the Netherlands and Poland are the main countries of European Union that Greece exports its vegetable crops. In 2002 the tomato exports from greenhouse cultivation in the E.U it was 6.259 tons, but the total domestic tomato production is about 1.3 million tons per year (Olympios 2004).

A large number of plant pathogens, that cause fungal, bacterial and viral diseases, have destruction effects on crop plants. Their effects range from bland symptoms to total destruction of the whole cultivation. Plant pathogens are difficult to control because their populations are variable in time, space, and genotype. Most insidiously, they evolve, often overcoming the resistance that may have been the hard-won achievement of the plant breeder. In order to combat the losses they cause, it is necessary to define the problem and seek remedies according to Strange & Scott (2005). From a biological standpoint, the pathogen should be recognized as soon as possible and treated appropriately. Additional is very important the choice of a resistant cultivar. At the political level, there is a need to acknowledge that plant diseases threaten the food supplies and to dedicate sufficient resources to their control.

The purpose of this work is to present the most common greenhouse tomato diseases and methods to control them. Furthermore, we will compare the protection methods against of *Botrytis cinerea* and the production of tomato between Poland and Greece.

# 2. Literature review

## 2.1. Botanical description

Tomato belongs to the nightshade family of *Solanaceae*, which is in division *Magnoliophyta*, class *Magnoliopsida*, subclass *Asteridae*, order *Solanales*, and suborder *Solanineae* according to the article of Foolad (2007). The *Solanaceae* family, that is extremely large, includes approximately 2800 species, in summation 96 genera. The family of *Solanaceae* also consists of the following, very important economically, angiosperms, the potato, tomato, pepper, eggplant, petunia and tobacco. This family is the most mutable of all crop species in terms of agricultural usefulness, the 3rd most economically important crop family, exceeded only by the grasses and legumes, and the most precious in terms of vegetable crops. The genus *Lycopersicon* was the focal point for genetic and molecular research. The people used to believe that the tomato was poisonous because it belonged to the nightshade family. Linnaeus placed the tomato in the genus *Solanum*, as *S. lycopersicum*. In 1754, Miller separated tomatoes and defined the genus *Lycopersicon* and the species *esculentum* for the cultivated tomato. This helped with the acceptability of tomato as a food. The genus *Lycopersicon* was initially prominent from the genus *Solanum* by its perspicuous characteristics of anthers and leaves. In biochemistry many alkaloids common to other *solanum* species are conspicuously absent in tomato.

While *Lycopersicon* has anthers that dehisce laterally, and leaves that are mostly pinnate or pinnatifid, *Solanum* has anthers that dehisce from the terminal ends and leaves that tend to be simple. (Tomato leaves are markedly different from any other *Solanum*). Phylogenetic relationships between *Solanum* and *Lycopersicon* have been the subject of a great dissent for a long time. Many researchers placed *Lycopersicon* as a separate genus while others suggesting its fusion with *Solanum* (Foolad 2007). Genetic evidence has now shown that Linnaeus was correct to put the tomato in the genus Solanum, making the *S. lycopersicum* the correct name. Both names, however, will probably be found in the literature for some time (Peralta & Spooner 2001). Hybrids of tomato and diploid potato can be created in the lab by somatic fusion, and are partially fertile, providing evidence of the close relationship between these species (Jacobsen et al. 1994).

## 2.2. Morphological description

The tomato (*S. lycopersicum*, syn. *Lycopersicon lycopersicum*) is a herbaceous, usually sprawling plant in the *Solanaceae* or nightshade family, as are its close cousins tobacco, chili peppers, potato, and eggplant. It is a perennial, often grown outdoors in temperate climates as an annual, typically reaching to 1-3m in height, with a weak, woody stem that often vines over other plants. We can distinguish the cultivated tomato from the wild one, from the red ripe bright colour. The tomato has cultivated in almost all the continents of the earth, with the exception of Antarctica. According to Peralta & Spooner (2001), the leaves of tomato are 10–25 cm long, odd pinnate, with 5–9 leaflets on petioles, each leaflet up to 8 cm long, with a serrated margin; both the stem and leaves are densely glandular-hairy. The flowers are 1–2cm across, yellow, with five pointed lobes on the corolla; they are borne in a cyme of 3–12 together.

The tomato is native to Central, South, and southern North America from Mexico to Argentina. There is evidence that the first domesticated tomato was a little yellow fruit, ancestor of *Lycopersicon cerasiforme*, grown by the Aztecs in Mexico. The fruit shape of the cultivated tomato is commonly round, but thanks to the genes and the new developed genetic tools the fruit shape of the tomato may can surprise us in the future. Tomato loves warm climates and cannot be grown where there is frost. The cultivation of tomato in the northern countries is limited, because of the very low temperatures and confined in greenhouses (http://www.nhm.ac.uk).

## 2.3. Economic importance of tomato

The tomato is a major vegetable crop that has achieves tremendous popularity over the last century. It is grown in practically every country of the world - in outdoor fields, greenhouses and nethouses. Tomato comes second in cultivation and consumption after potato, all over the world, and is undoubtedly the most popular garden crop. By economic view, the tomatoes worth a prodigious amount of money because they give more yield. Tomatoes are also one of the main ingredients in hundreds of dishes and products that are sold in supermarkets throughout the developed world. Furthermore, the tomatoes are eaten directly as raw vegetable, like in many salads, (one common example is the greek salad, that tomato is the main ingredient), also there is a variety of processed products like paste, whole peeled tomatoes, diced products, and various forms of juice, sauces, and soups have gained significant acceptance, according to Foolad (2007). Major tomato producing countries in descending orders include China, USA, India, Turkey, Egypt, and Italy. Other leading countries include Spain, Brazil, Iran, Mexico, Greece, and Russia. Tomatoes, aside from being tasty, are very healthy as they are a good source of vitamins A and C. Lycopene is a very powerful antioxidant which can help prevent the development of many forms of cancer (Foolad 2007).

Tomato yellow leaf curl geminivirus, transferred by whiteflies, is one of the most important factors that can cause derating of tomato up to 100% (Picó et al. 1996). The increasing economic importance of this virus has resulted in the need for accurate detection and identification procedures, stimulating intensive research efforts focused on virus biology, diversity, and epidemiology to develop successful control strategies according to Picó et al. (1996).

## 2.4. Water and soil requirements in greenhouse farming

Many problems arise through the irregular watering of the tomato. Allowed tomatoes to dry out and then deluged them with water causes the fruit to suddenly swell, cracking the skin of the tomato and this allows fungal growth to get a hold, completely ruining the fruit. Worse still it alters the internal calcium balance of the plant and this causes blossom end rot where the base or blossom end of the tomato develops a brown patch. Poor watering practice also contributes to blossom drop, this is where the flowers fall off and no fruit develops at all. Results of experiments that conducted showed that the fruit diameter can increased depending on the amount of the water that will be supplied. Instead of this, lower quantity of water causes the shrinkage of the tomato. Low stem water potentials have an immediate and direct effect on phloem turgor; reducing the driving force for sap flow into the fruit (Johnson et al. 1992).

In greenhouse production, the values of the tomato can increase by using low water inputs and high fertilizer efficiencies. Irrigation system is one of the most significant components affecting the yield and quality of tomatoes from greenhouse farming system. Water should be given in proper amount and exact time application. Consequently, water management is a key to avoid plant moisture stress during the crop growth stages. For cultivation of tomato, the greenhouses preferred than the open farming, because of the possibility of full control in every possible risk, irrigation water productivity and fruit quality. Through experiments that have been conducted the use of drip irrigation and fertigation saves water and fertilizer and gives better plant yield and fruit quality. In greenhouse farming the drip irrigation saves 25% of water compared to the open drip irrigated farming system (Salokhe et al. 2005).

Tomatoes can be grown on many different soil types, but a deep, loamy soil, well-drained and supplied with organic matter and nutrients is most suitable. As with most garden vegetables, tomatoes grow best in a slightly acid soil with a pH of 6.2 to 6.8 (http://www.uri.edu).

## 2.5. Fertilizer requirements of tomato

Chemical determination of the mineral content of a mature, healthy, high-yielding greenhouse tomato plant has shown that the total nutrient absorption is equivalent to 386.4kg/ha of nitrogen, 82.9 kg/ha of phosphorus, 801.9 kg/ha of potassium, 330.4 kg/ha of calcium and 48.2kg/ha of magnesium according to Ward. Conducted experiments, for the uptake of potassium of tomato plants in greenhouse conditions, it was found that the KCL can completely replace the potassium nitrate ($KNO_3$) without damaging effects on plant growth and yield, while significantly ameliorating some important quality parameters. It is resulted that $KNO_3$ can be replaced fully or partially (depending on water quality) by KCl in tomato plants and at the same time improves the quality of tomato fruits (Chapagain et al. 2003). Fertilization with Ca $(NO_3)^2$ in tomato plants seems that has a positive effect on the disease control of leaf grey mould and fruit ghost spots of tomato plants by 70 and 45%, respectively. The fertilizer combination Ca $(H_2PO_4)^2$+ $CaSO_4$ (1 and 3 g/kg soil) applied once to tomato plants grown in soil reduced also the severity of leaf grey mould by 80 % (Elad & Volpin 1993). Phosphorus is very important for the tomato plants, especially in the first stages of its development. Nitrogen fertilizer applications must be added with caution, because in case of overdose, causes extremely spirited vine growth but little fruit production (http://www.uri.edu).

## 2.6. The most common greenhouse tomato diseases in Poland and Greece

It is approximately estimated that diseases, insects and weeds, every year intrude with the production of, or destroy, the crops produced all over the world in an average of 31-42%. In the more developed countries the losses of the crops are lower compared to the developing countries, namely, countries that need food the most. It has been calculated that of the 36.5% average of total losses of crops, 14.1% are caused by diseases, 12.2% by weeds and 10.2% by insects (Agrios 2005). According to Zitter (1985), bacterial diseases of tomatoes can be some of the most serious and destructive diseases affecting both field- and greenhouse-grown crops. Under moist field conditions they can cause localized epidemics affecting young developing fruit, in the greenhouse can occur total crop losses (Zitter 1985). The diseases of greenhouse tomato in Poland and Greece are similar in both countries. Below we can observe the diseases that they are appear to a greater or lesser degree in both countries.

### 2.6.1. Bacterial canker

Bacterial canker is an important greenhouse disease in all over the world. It first noticed in 1909 (Stephens & Fulbright 1986). The pathogen is *Clavibacter michiganensis* subsp. *michiganensis*. This pathogen can survive in the soil for a long period in dried tomato plant residues. *C. michiganensis* subsp. *michiganensis* is most important as a pathogen on tomato but also can infect other solanaceous plants such as pepper, eggplant, *Nicotiana glutinosa*, and the weeds cutleaf nightshade (*Solanum triflorum*), black nightshade (*Solanum nigrum*) and perennial nightshade (*Solanum douglasii*) (Thompson et al. 1989).

The symptoms of this pathogen are lower foliage and consist of curling of leaves, blighting of leaves and branches, chlorosis of leaves, and brown necrosis of leaf tissue. The internal vascular tissue starts to turn light yellow to tan in color. In advanced stages the pathogen causes the whole plant to grow shabbily, wilt and probably die (Stephens & Fulbright 1986). Fruit symptoms are very characteristic and are a helpful diagnostic trait. The spots that occur on the green fruit firstly are small and round, and white or yellow and later turn to brown centers that remain encircled by the white to cream-colored point. The primary inoculums can come from many sources like diseased transplants, infested seed and infested plant debris in the soil (Chang et al. 1992a). In the last one, the pathogen can survive for a long time, always depending on weather conditions (Chang et al. 1992b). Diseased transplants can carry the bacterial canker, without symptoms until later in their growth, under greenhouse conditions (Chang et al. 1991). When bacterial canker is established on the plants, the bacteria can spread through the splashing water, plant to plant or through infected tools. The disease can develop in warm conditions (24-32ºC) and factors that create sappy growth of tomato (Thompson et al. 1989).

### 2.6.2. Bacterial spot

The impact of this disease is around the whole world, but the most important areas are the tropical and subtropical tomato cultivating areas (Goode & Sasser 1980). The causal agent is *Xanthomonas campestris* pv. *Vesicatoria*, an aerobic, Gram-negative bacterium. It affects the seedlings since is a seedborne bacteria (Gitaitis et al. 1992). This pathogen may host tomatoes and peppers, existing three specific tomato host strains as well as mixed hosting strains, which are named differently (Bouzar et al. 1994). Earlier symptoms give name to this disease, as it is appreciable a variable number of watery spots, of circular to irregular shape and smaller than 5 mm (Gitaitis et al. 1992). It is also possible to appreciate chlorosis on the foliage, but not commonly in the detached spots. As the disease develops, spots become dark brown and may merge causing important necrotic areas in leaves, concluding in defoliation in severe cases (Goode & Sasser 1980). Furthermore, it is observable a production decrease, retardation of the growth and singed-like leaves (Gitaitis et al. 1992).

The main inoculation sources are the plant debris transported by soil, reservoir plant hosts and infested seeds. This latter is especially significant since it emerges the possibility of disease spreading in greenhouse tomatoes (Bashan et al. 1982). Once the disease is transmitted, there exist several propagating means, like the watering (sprinkler irrigation is important as a bacterial spreader), field tools and operators hands (Gitaitis et al. 1992). Moisture and warm temperature stimulate the disease development (Goode & Sasser 1980). The *Xanthomonas* are also able to withstand the winter or persist on infested plant residues (Gitaitis et al. 1992).

### 2.6.3. Late blight

The pathogen that causes late blight tomato disease is very significant as it reemerged long time after the Scottish potato blight famine of 1840s, becoming again a serious problem. The causal agent is *Phytophthora infestans*, a heterothallic oomycete which reproduces sexually by two different mating types (named A1 and A2), resulting in the oospore (Fry & Goodwin 1997). The mating types were initially distributed throughout different areas of the planet, with the major predomination of one of them depending on the country or continent. In the USA sexual recombination was hardly found whilst in some European countries (as Netherlands, Poland or Russia), Canada and Mexico it was more commonly observed (Knapova & Gisi 2002). Low temperatures and a high humidity stimulate the growth and sporulation of the *P. infestans* (Cohen et al. 1997).

Changes in the disease severity have been observed, which correspond with worldwide genetic changes in the late blight pathogen (Fry & Goodwin 1997). In the late 1970s, the main prevalence of the *P. infestans* isolates was of the A1 mating type and especially of the clone form sensitive to the metalaxyl pesticide (Knapova & Gisi 2002). New clone forms are responsible of latest epidemic outbreaks, and their worldwide propagation is probably owing to the international trade of potato seed tubers, tomato fruit and tomato transplants (Goodwin et al. 1994). It is likely to emerge new aggressive and fungicide insensitive lineages in the near future due to the worldwide spreading of both mating types, and hence the increase of the sexual reproduction of this oomycete (Bakonyi et al. 2002). Some investigations have proved the highly aggressiveness of the isolates on potatoes but not of all isolates on tomatoes, which shows a possibility to classify the isolates depending on the virulence presented on tomatoes (positive or negative). Thereby, it is a relevant factor in the disease control strategies (Legard et al. 1995).

First disease symptoms can be appreciated on the leaves as loss of regularity of the shape and intensity of the colour, as well as watery spots. In proper climate conditions, the lower leaf’s surface may be covered with a white velvet layer of the *P. infestans* (Ivors 2008). It is possible the rapidly extension of the spots to bigger areas and the necrosis of the foliage in more severe cases, concluding in plant's death in the worst cases (Henfling 1987). On the other hand, the appreciable features of the disease are in the green fruit, as brownish lesions with variable shape and that may extend to the entire fruit (Ivors 2008). The solid consistency of these lesions produces the fruit not to putrefy until secondary decomposing agents intervene (Griffith et al. 1995).

### 2.6.4. Black mold

The black fungal disease only has an impact on the mature tomato fruit (Reddy et al. 2000). With proper external conditions it is possible to observe the affection in entire fields and its economical consequences (Davis et al. 1997). The causal agent is the fungus *Alternaria alternata*. This pathogen is not a tomato specific host, unlike the subspecies *A. alternata* f. sp. *lycopersici* (responsible for tomato stem canker). Symptoms commence with flecks and stains on the cuticle of the mature fruit, with an irregular contour, tan to brown colour and small-sized. When external conditions are propitious, these signs are rapidly extended into wide, sunken and circular to oval-shaped injuries, and are able to spread deep into the tomato. Black mold's development is increased at 24-28ºC (Koike et al. 2007).

*A. alternata* is a saprophytic microorganism which is able to colonize easily dead organic matter or harmed tissues of other plants (Morris et al. 2000). *A. alternata* grows covering the surface of the injuries, velvety and black-colored (Bartz 1971). It is also possible the growth of different rot fungi in the wide affected areas, such as *Stemphylium, Cladosporium* and *Aspergillus* species (Davis et al. 1997). If the tomatoes are retained for long periods after the harvesting, dissemination of the disease may occur. The fungus is often located on rotting vegetable matter in and around plantations, including the current cultivation in old and dead tomato leaves (Koike et al. 2007). Conidia reach the mature fruit by sprinkled water or winds, and germinate and contaminate the fruit when it is previously spoiled or wet from rains, dew or irrigation (Davis et al. 1997). Fruits are especially sensitive to colonization if previously impaired by sunburn or blossom end rot (Reddy et al. 2000).

### 2.6.5. Gray mold

This fungal disease of tomato is normally observed in diverse ways, particularly in greenhouses since there are indoor high temperatures (O'Neill et al. 1997). The causal agent is the asexual form of the fungus *Botrytis cinerea* (Chastagner et al. 1978). Some cultured strains can sporulate properly only under lights (Sasaki et al. 1985).

The symptoms of the fungus in the invaded petioles and stems are tan to brown injuries with its distinctive velvety, thick, grayish sporulation (Verhoeff 1970). The gray mold can potentially affect the whole petiole or stem and commonly infects the impaired or older structures (O'Neill et al. 1997). There is a particular fruit affection by *B. cinerea*, the 'ghost spots', which consists of the prematurely pathogen's death before the rotting appears. This distinctive affection doesn't produce the rotting of the fruit but produces white-yellowish circles, which is not accepted by consumers (Verhoeff 1970). The most important injuries on greenhouses are the stem infections, and the main sources are the cut remnants and torn or harmed stems (O'Neill et al. 1997).

The fungus may inhabit in different forms: as a pathogen on many plantations, as a saprophyte on cultivation wastes or as sclerotia in the soil (Moorman & Lease 1992). The proper environmental conditions for its fast colonization are absence of moisture on the plant surface (conidia settling on impaired or senescent tomatoes), low vapour pressure deficit (VPD) and cold temperature (O'Neill et al. 1997). When *B. cinerea* has infected the tomato, it will spread into neighboring healthy plant tissues (Chastagner et al. 1978), and is also able to act as a secondary rotting agent in impaired tomato tissues (O'Neill et al. 1997).

## 2.7. Control and protection of diseases

By controlling the plant diseases impact in more food and better quality of food but this have cost implications to consumers. In the last 100 years, the control of plant diseases and other plant pests has depended increasingly on the extensive use of toxic chemicals (pesticides), not only to the food that we consume, but also in the soil that the pathogen microorganisms live and attack to the plant roots. Ruthless use of pesticides has long term effects in the human health and the environment.

The most promising accesses include conventional breeding and genetic engineering of disease-resistant plants, appliance of disease-suppressing cultural practices, RNA and gene-silencing techniques, of plant defense promoting, nontoxic substances, and, if it's possible, use of biological agents antagonistic to the microorganisms that cause plant disease (Agrios 2005).

### 2.7.1. Control of bacterial canker

Get and plant high-quality seed that is free from the pathogen *Clavibacter michiganensis* subsp. *michiganensis*. Sterilize the seeds before the use. Hot water treatments can reduce livableness of the seed. So it's better to use other method like rebaptism of the seeds in hydrochloric acid or calcium hypochlorite. Using of resistance cultivars if it's possible (Fatmi et al. 1991). Normally, bacterial canker symptoms are not appearing to the young transplants, but control them and remove the suspected plants. Reduce the water pressure during the period of irrigation, to avoid damage in the foliage. The mowing of transplants to control their height can disseminate the pathogen. Try to execute growing practices that involve air movement or differential temperature manipulation.

During the irrigation, don't use the sprinkle method over the plants. In the field use sterilize wooden stakes to the shoring of the plants and clean the tools properly in short time (Koike et al. 2007). Copper sprays could supply pathogen control (Hausbeck et al. 2000). When the tomato cultivation finish, incorporate the crop residues to enhance plant decomposition and the dilution of bacteria. Cultivate another crop for a time, that cannot infected by the pathogen and don't keep weed hosts or volunteer tomato to survive (Koike et al. 2007). Soil solarization is useful for the control of bacterial canker of tomato in plastic houses in Greece (Antoniou et al. 2007).

### 2.7.2. Control of bacterial spot

It is important an early control of the seed fields, which can be performed by monitoring regularly. Secondly, it is helpful the utilization of different types of treatments, such as the application of hot water to the seeds (though it may decrease the viability and germination percent), hydrochloric acid, calcium hypochlorite or other advisable substances. Moreover, some contamination testings may be performed (rejecting the highly infested seeds) combined with cleanliness certification programs. Prevent of sprinkler irrigation system (Goode & Sasser 1980).

It is also important to examine and control the transplants and possible infested plants (Gitaitis et al. 1992), as well as all the materials in contact with them (benches, transplant trays and other kinds of equipment like clippers and pruning shears), performing a proper and regular disinfection (Goode & Sasser 1980). Application of preventive fungicides has been recommended (copper combined with mancozed sprays or copper-based substances combined with maneb) although it is not highly effective (Gitaitis et al. 1992). When the tomato growing concludes, integrate the plant wastes to intensify plant decomposition and elimination of the pathogen. Finally, it is advisable to rotate to a non-host crop prior to new tomato cultivation, as well as the removal of weeds and volunteer tomato hosts (Goode & Sasser 1980).

### 2.7.3. Control of late blight

The application of fungicides is very important to control the late blight, where possible before the infection befalls (Tumwine et al. 2002). This fungus has become resistant to some pesticides such as metalaxyl (Fry & Goodwin 1997). Different systems are disposable to forecast the most proper contagion periods, such as the Smith periods, which determine the favorable moments for infection according to the weather conditions. An entire Smith period corresponds to a minimum of 11 hours with a relative humidity value above 90% during two consecutive days, as well as temperatures higher than 10ºC (Koike et al. 2007). On the other hand, it is recommendable not to use a spray irrigation system and the elimination of potential sources of infection; this is potato tubers, tomato fruit debris, volunteer plants, suspicious transplants as well as old tomato cultivations or trays. Some resistant cultivars are available (Tumwine et al. 2002).

### 2.7.4. Control of black mold

The control of the black mold disease can be implemented by antifungal application, before or after harvesting, since the pathogen is able to contaminate the fruit in the crop, become latent in immature tomato and continue growing as the tomato maturates. It is required a strict control of fungicides' application since it involves potential health risks and are not allowed for after-harvesting utilization. Therefore, there is a necessity to use a natural fungicide and host defenses for after-harvesting control (Reddy et al. 2000). Experiments conducted, showed that Chlorothalonil applications on tomato mature fruit have beneficial impacts on the restriction of the fungus. The administration of protectant fungicides must be 4-6 weeks before harvest (Davis et al. 1997). It is also advisable not to use overhead sprinkler irrigation, and to harvest in the appropriate moment so that mature tomatoes are not left more than indispensable in the crop (Koike et al. 2007**).**

### 2.7.5. Control of gray mold

First control action is to prevent the humidity by decreasing the overhead irrigation, improving greenhouses ventilation or applying a proper heating system (O'Neill et al. 1997). Chemical control prior to harvesting is not very usefull since half of the affections are produced by contact of the tomatoes with the soil (Chastagner & Ogawa 1979). Another way to control the spreading of *B. cinerea* is the use of fungicides (Chastagner et al. 1978). Since this pathogen is able to develop resistance to fungicides, it is considerable to apply several types of them with varied functioning modes. For instance, commonly the fungus is resistant to benzimidazole and dicarboximide and therefore their efficiency is diminished (Moorman & Lease 1992). One good election for a fungicide is the utilization of dichlofluanid to control the ghost spot. It has also the attribute of preventing the spore germination, unlike generally the rest of fungicides (Chastagner & Ogawa 1979). Disinfection of affected leaflets can be as efficient as fungicides, since it can decrease the incidence of stem decay in areas with no chemical fungicides (Shtienberg et al. 1998). Other control methods are the elimination of infected plant areas or regular fertilizations (Vakalounakis 1992).

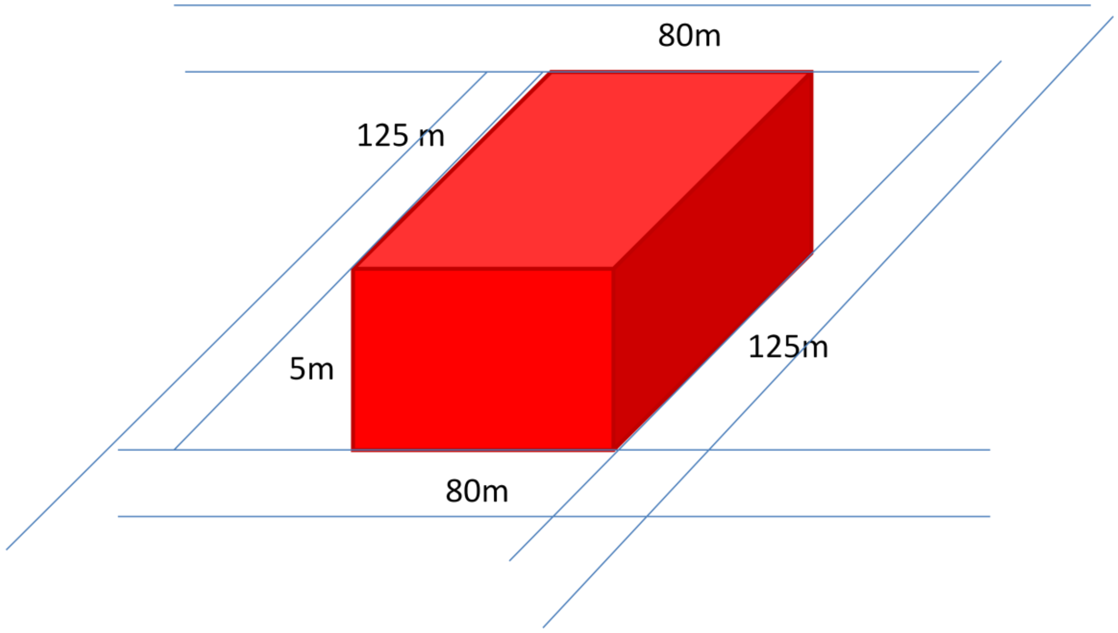
# 3. Practical part of the project

In this part, it will be compared, two greenhouse facilities. The first is located near Wroclaw of Poland and the other in Alexandria of Greece. We will try to compare two greenhouses with the same systems and cultivation methods to be able to be as objective as possible. We are going to see the differences between their technical issues of both greenhouses. Additional, it would be considered and compared all the data about the costs of tomato production and the climatic conditions. It will be a comparison of plant protection against to the most common greenhouse tomato disease the Gray Mold (*Botrytis cinerea*). So, we will have a clear aspect, and we will try to give an answer to the question of where there is a greater benefit of tomato production. Below is quoted all the necessary data.

## 3.1. Place of cultivation of polish greenhouse

- The greenhouse of Poland is located in the village of Tokary, Dlugoleka municipality, Dolnoslascie voivodship, 12 km from Wroclaw.
- Geographic coordinates : Longitude $51^{o}$ 13’ 58’’
  Latitude $17^{o}$ 8’ 32’’
- Surface of greenhouse : 1.00 ha
- Is a glass, Venlo type greenhouse.
- On the north side, along the greenhouse extends a wall which protect also from the strong winds.
- On the eastern side is extended a rural road.
- On the other sides and around the greenhouse are undeveloped fields.

➢ Size and shape :




### 3.2. Climatic conditions of Poland

The climate in Poland is typically temperate with cold, cloudy, moderately severe winters with frequent precipitation; mild summers with frequent showers and thundershowers. The terrain: mostly flat plain mountains along southern border. The climate is continental, with a light oceanic influence which causes climatic instability. Winter is very cold from December to February (between -5°C and -15°C) and very snowy. Spring is mild and sunny with hoar frosts in mid-May. Summer is mild with rains and frequent storms in July. Autumn (September and October) is dry and sunny.

Annual average high temperature is 13.1$^{o}$ C

Annual average low temperature is 3.7$^{o}$ C

Average temperature is 8.4$^{o}$ C

Average annual precipitation is 599 mm

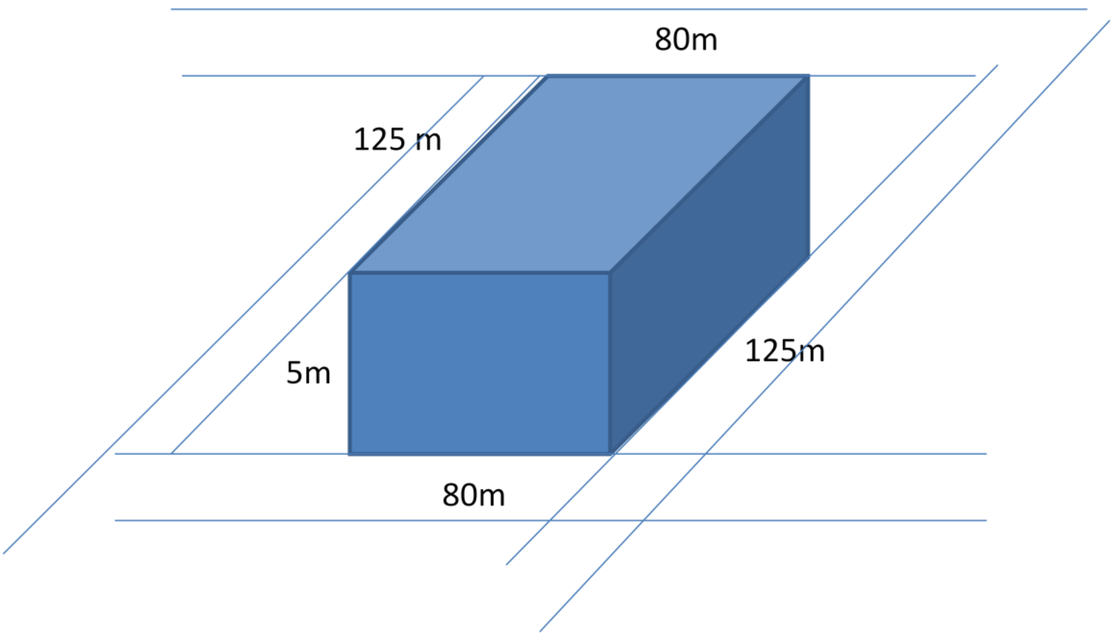
Days per year with precipitation are 169 d.

Average annual hours of sunshine are 1495 h.

## 3.3. Place of cultivation of Greek greenhouse

- The Greek greenhouse is located in the city of Alexandria, county of Imathia, the north geographical region of Greece, Macedonia.
- Geographic coordinates: Longitude 40$^{o}$ 62”79

  Latitude 22$^{o}$ 67”45
- Surface of greenhouse : 1.00 ha
- It is a Venlo, glass greenhouse.
- In the west side, is extended a rural road.
- In the east side, 500 m, from the greenhouse, is a field of grain.
- Circumferentially of the greenhouse there are undeveloped fields.
- Size and shape:



## 3.4. Climatic conditions of Greece

The climate of Greece is typically Mediterranean climate: mild and rainy winters, relatively warm and dry summers and, generally, extended periods of sunshine throughout most of the year. In climatological terms, the year can be divided into two main seasons: The cold and rainy period lasts from mid-October until the end of March and the warm and dry season lasting from April to October. The climate in Alexandria is continental, with harsh winters and hot summers.

Annual average high temperature is $29^{o}$ -$35^{o}$ C.

Annual average low temperature is $5^{o}$C.

Average temperature is $10^{o}$ - $19{,}7^{o}$ C.

Average annual precipitation is 400mm.

Days per year with precipitation are 117 d.

Average annual hours of sunshine are 2700 h.

### 3.5. Production

- The total area of the Greek Greenhouse is 10 ha and the Polish one, 8 ha.
- Prices of production in 1 ha of greenhouse cultivation are going to be analyzed.

#### 3.5.1. Characteristics of tomato cultivars

- Initially we have to compare the different characteristics of the variety of tomato. It is very important the kind of cultivar that is used, and its disease resistance.

Table 1: Characteristics of tomato cultivars and disease resistance.

| | GREECE | POLAND |
|---|---|---|
| **Cultivars** | Brilliant | Admiro |
| **Height** | 2.00-2.20m | 1.80-2.40m |
| **Spacing** | 50-55 cm | 45-60 cm |
| **Sun Exposure** | Full sun | Full sun |
| **Growing habit** | Very open | Indeterminate |
| **Days to maturity** | 70-80 | 69-80 |
| **Fruit colour** | Red | Red |
| **Fruit weight** | 135-150gr | 150-200gr |
| **Fruit size** | 5 fruits per cluster | Medium |
| **Usage** | Fresh, salad, slicing | Fresh salad, slicing, canning |
| **Disease resistance** | Botrytis cinerea, Fusarium wilt, Verticillium wilt, Cladosporium wilt, Fusarium crown, Root rot, tomato mosaic virus, tomato spotted wilt virus | Tobacco mosaic virus |

### 3.5.2. Cost of transplants

Table 2: Cost of transplants of both tomato cultivars in Greece and Poland.

| | **GREECE**<br><br>**Brilliant** | **POLAND**<br><br>**Admiro** |
|---|---|---|
| **Transplants density**<br><br>**(November-February)** | $1.8/m^2$ | $2.5/m^2$ |
| **Transplants density**<br><br>**(March- October)** | $3.2/m^2$ | $2.5/m^2$ |
| **Transplants in 1 ha** | 25.000 | 25.000 |
| **Cost of each transplant** | 0,70€ / 2,80 zł | 1€ / 4zł |
| **Cost of transplants for 1 ha** | 17.500€ / 70.000 zł | 25.000€ / 100.000 zł |
| **TOTAL** | **17.500€**<br><br>**70.000 zł** | **25.000€**<br><br>**100.000 zł** |

## 3.6. Hydroponics production

Both greenhouses in Poland and Greece are adopted the modern method of cultivation of hydroponics.

The **advantages** of this method are the following:

- Allows immediate change root environment
- Economy in water and fertilizers.
- Increase in production due to brightness.
- Relief from soil diseases and the cost of decontamination, which is usually important.
- Facilitate automation of irrigation and fertilization.
- Saving water and nutrients because it eliminates losses from surface spills and deep water penetration in the soil
- Simplify the work program of the production company, why not require the creation of special soil mixtures for the growth of young plants and
- Limitation of hard manual labor that is needed on soil cultivation, such as tillage, planting, weeding.

### 3.6.1. Estimation of hydroponics equipment.

Table 3: Cost of Rockwool and water gutters of both greenhouses.

| | GREECE | POLAND |
|---|---|---|
| **Rockwool slabs in 1 ha** | 17.000 €<br>68.000 zł | 15.000 €<br>60.000 zł |
| **Water gutters in 1 ha** | 5.000 €<br>20.000 zł | 4.000 €<br>16.000 zł |
| **TOTAL** | **22.000 €**<br>**88.000** zł | **19.000 €**<br>**76.000** zł |

### 3.6.2. Cost of different lubrication systems

There are several types of hydroponic systems. Broadly divided into open and closed (revolving) systems:

- **Greece applying the close system:**

In closed systems, the solution of the effluent is recycled and reused in a large proportion. In this way we save in fertilizer consumption (up 50%) and significantly reduce pollution.

- **Poland applying the open system**

These systems are the simplest and the first developed. They are widespread and have fewer requirements. In open systems, fluid drainage are not recycled but disposed. This has resulted in increased losses fertilizer runoff and contamination of soil and groundwater, as is the territorial culture.

- Rockwool contains practically no nutritious matter, therefore continuous dripping with a nutrient solution is required. The content of the nutrients is the same in both countries. The basic composition of the nutrient solution, specialized for the greenhouse tomato is as follows:

Table 4: The content of nutrients of the basic nutrient solution.

| **Macro (main) elements** | **Quantity** |
|---|---|
| $NO_3^-$ | 13.5 mmol/l |
| $H_2PO_4^-$ | 2.0 mmol/l |
| $SO_4^-$ | 3.5 mmol/l |
| $NH_4^+$ | 0.5 mmol/l |
| $K^+$ | 9.5 mmol/l |
| $Ca^{++}$ | 4.75 mmol/l |
| $Mg^{++}$ | 1.5 mmol/l |
| Fe | 20-25 μmmol/l |
| Mn | 10 μmmol/l |
| Zn | 5 μmmol/l |
| B | 25 μmmol/l |
| Cu | 0.75 μmmol/l |
| Mo | 0.5 μmmol/l |

### 3.6.2.1. Cost of the different lubrication systems

- Cost lubrication for annual tomato cultivation using water conductivity 1200 μS/cm due mainly to carbonates and sulphates of calcium and magnesium :

Table 5: Cost of the nutrient solution depending on the lubrication system

| | **GREECE** | **POLAND** |
|---|---|---|
| | **Close system** | **Open system** |
| **Nutrient solution** | 700€/acre | 1500€/acre |
| **Nutrient solution per ha** | 7.000€/ha | 15.000€/ha |
| **Water consumption per acre** | 700 $m^3$ /acre | 980 $m^3$ /acre |
| **Water consumption per ha** | 7.000 $m^3$/ha | 9.800 $m^3$ /ha |
| **Price of water/$m^3$** | 1.36€ /$m^3$ | 1.24€ /$m^3$ |
| **Cost of water** | 9.520€ | 12.152€ |
| **TOTAL** | **16.520€**<br>**66.080** zł | **27.152€**<br>**108.608** zł |

## 3.7. Cost of heating in the greenhouse

Table 6: Cost of the different heating methods.

| | **GREECE** | **POLAND** |
|---|---|---|
| **Heating method** | Geothermal method | Coal burning |
| **Price/ unit** | 1.66 € /$m^2$ | 450 zł / ton<br>(400 ton/ha/year) |
| **TOTAL (1ha)** | **16.600 €**<br>**66.400** zł | **45.000 €**<br>**180.000** zł |

- It is worth noting that the initial cost of installing geothermal heat pumps are great but makes quick damping, is ecological, with 0 emissions, silent and it's the unique completely renewable energy source. According to scientific research, geothermal energy is inexhaustible source of energy for the human prospect. As long as there is sun, there will be geothermal energy.

## 3.8. The comparison of coping with Gray mold between Greece and Poland

- The **Greek greenhouse** does not use pesticides against Gray mold (*botrytis cinerea*) because the climate does not allow flares, so the management of infected plants is to remove them from the plantation. It is possible in conditions of prolonged high humidity (due to cloud and precipitation) can be sedating effect by SIGNUM 26,7 / 6,7 WG. In any case, if is necessary interference with chemicals, are selected very mild products to do not disturb the insects that are unleashed in the greenhouse (bees for pollination of plants and beneficial insects for the treatment of pests and diseases).

- The **Polish producers** face a serious problem of Gray mold in their greenhouses. Mainly because of cool and wet (high humidity) conditions. These conditions also stress the plants, making them susceptible to disease. Condensation occurs when the plant surfaces are colder than the surrounding air. The chance of condensation forming increases with high humidity of the air and when the air temperature decreases quickly. For this reason are made frequent controls of the tomato plants and the use of a complex of pesticides. Preventively, they are making foliar applications of calcium.

Table 7: Cost of Greek pesticides against the fungus *Botrytis Cinerea.*

| **GREECE** | | | | |
|---|---|---|---|---|
| ***Botrytis cinerea*** | | | | |
| **Pesticides** | **Dosage** | **Price /ha** | **Mode of action** | **Application** |
| **SIGNUM 26,7/6,7 WG** | 1.5 kg /ha | 132.63 € | Preventative non-systemic | Since the start of flowering to the ripening of fruits. Maximum three applications at intervals of 7-10 days. |
| **TRICHODERMA HARZIANUM** | 833 g/ha | 1370.29 € | Preventative-biological | Foliar sprays can be used for leaf coverage and they are applied through irrigation to nutrient solution. |
| **TOTAL** | | **1.502,92 €** **6.011,68** zł | | |

Table 8: Cost of polish pesticides against *Botrytis Cinerea*.

| **POLAND** | | | | |
|---|---|---|---|---|
| ***Botrytis cinerea*** | | | | |
| **Pesticides** | **Dosage** | **Price /ha** | **Mode of action** | **Application** |
| **SWITCH 62,5 WG** | 1 kg/ha | 460zł / 115€ | Preventative- locally systemic | Begin applications at or before bloom and continue on 7 to 10 day intervals. Pre-harvest interval is one (1) day. |
| **ROVRAL AQUAFLO** | 2 L/ha | 420zł / 105€ | Preventative non-systemic | Spray at 14-day intervals from transplanting and throughout the period of disease pressure. |
| **SIGNUM 33 WG** | 2 kg/ha | 920 zł / 230€ | Preventative non-systemic | Since the start of flowering to the ripening of fruits. Maximum three applications at intervals of 7-10 days. |
| **DECREE 50 WDG** | 1.5 kg/ha | 1800 zł /450€ | Preventative non-systemic | Use preventatively, do not exceed 3 applications per year, apply at 7-10 day intervals, treated tomatoes cannot be used for processing |
| **TELDOR 50 WG** | 1.5 kg / ha | 868 zł /217€ | Preventative non-systemic | Preventive spraying from the appearance of the first fruits, and where conditions favor disease development |
| **TOTAL** | | **4468 zł** **1117 €** | | |

## 3.9. Tomato crop productivity between Greece and Poland

Table 9: Productivity of tomato cultivation in both greenhouses.

| | GREECE | POLAND |
|---|---|---|
| **Cultivation productivity** | 55 kg / $m^2$ | 50 kg / $m^2$ |
| **Productivity per 1ha** | 550 ton / ha | 500 ton/ha |
| **Price producer** | 1.10€ / kg<br>4.40 zł / kg | 0.75€ / kg<br>3 zł / kg |
| **TOTAL** | **605.000 €**<br>**2.420.000 zł** | **375.000 €**<br>**1.500.000 zł** |

## 3.10. Concentration of all the cost data of production in Greece and Poland

Table 10: Comparison of total prices of all the greenhouses costs.

| | GREECE | POLAND |
|---|---|---|
| **TRANSPLANTS** | 17.500 €<br>70.000 zł | 25.000 €<br>100.000 zł |
| **ROCKWOOL & WATER GUTTERS** | 22.000 €<br>88.000 zł | 19.000 €<br>76.000 zł |
| **NUTRIENTS** | 16.520 €<br>66.080 zł | 27.152 €<br>108.608 zł |
| **HEATING** | 16.600 €<br>66.400 zł | 45.000 €<br>180.000 zł |
| **PESTISIDES** | 1.152,92 €<br>6.011,68 zł | 1117 €<br>4468 zł |
| **TOTAL** | **74.122,92 €**<br>**296.491,68 zł** | **117.269 €**<br>**469.076 zł** |

Figure 1: Breakdown of costs in Greek greenhouse.

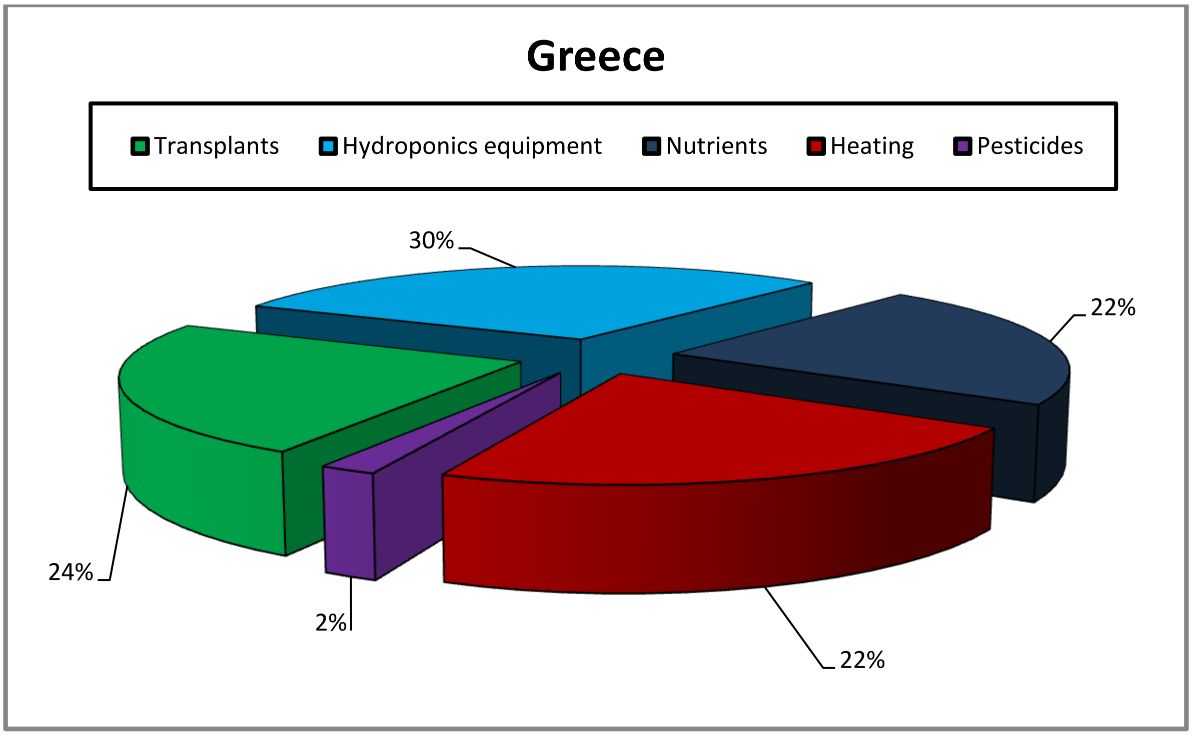
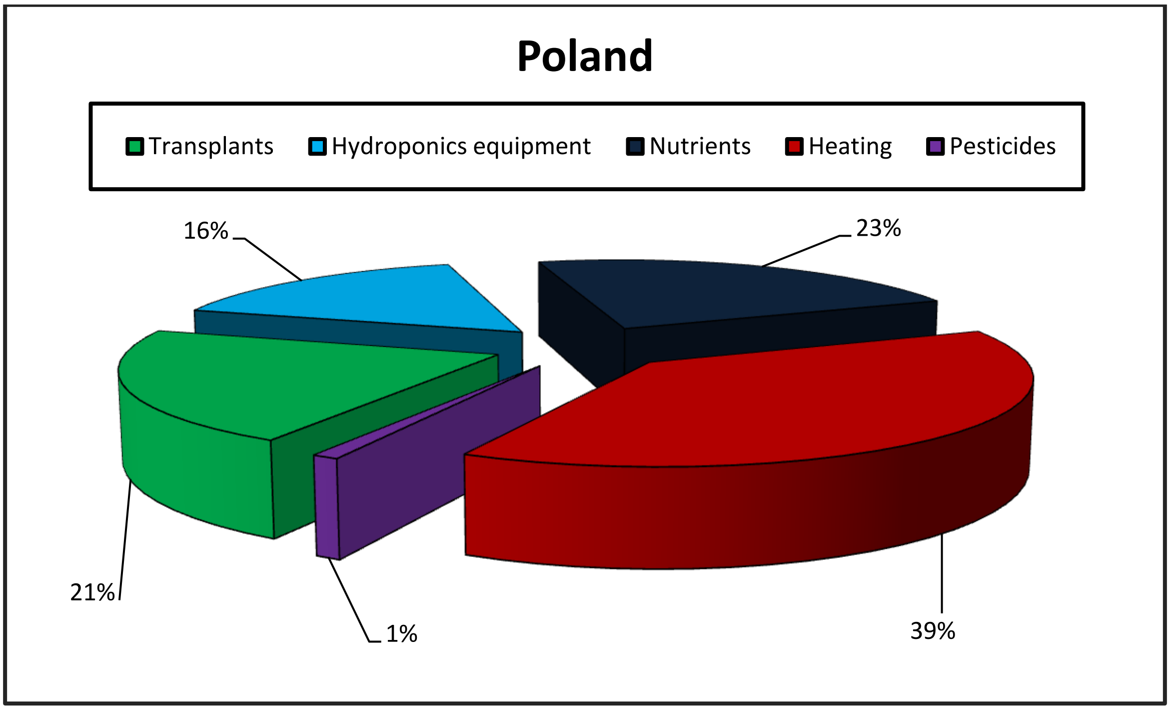



Figure 2: Breakdown of costs in Polish greenhouse.



## 3.11. Comments

In Greece, the greatest cost is due to the hydroponic equipment installation and to acquisition of transplants from reliable producers, which provide a guarantee of free from diseases.

In Poland, the greatest cost is due to the heating gases, namely, coal burning heating, which is at the same time a major polluting factor, compared with the sophisticated greenhouse of Greece, which is an ecological heating method and operates the lucrative geothermal energy. The advantages of geothermal energy are: a high efficiency (low power usage), low maintenance costs and no external machines. Nonetheless, the initial cost of installation is high, but its amortization is rapid.

The comparison of the Gray mold disease and the responses of both countries lead us to the following conclusion: in Greece, the occurrence of the fungus *Botrytis cinerea* in tomato plants is decreased because of the hot climate and the highly equipped and modern greenhouse. For this reason no pesticides are used, but preventively, the plants are provided with anti-fungus soft medicine like 'Signum'. Generally, the management of infected plants performed is to remove them from the plantation. Additionally, during overcast and rainy days, mild products are applied to prevent the appearance of the fungus, which is the best option to avoid the disturbance of the unleashed beneficial insects in the greenhouse. On the other hand, to face the habitual presence of the fungus in Poland, due to the high relative humidity and overcast months, a combination of plant protection products is used for the suppression of the gray mold.

Also should be noted that the variety of tomato plays an important role in the occurrence of *B. cinerea.* The Greek greenhouse cultivates a resistant variety of tomato, and this is important in the lower incidence of the fungus. An effective solution to reduce the occurrence of the disease in the Polish greenhouse would be the substitution of the cultivated specie for another more resistant.

Below, net income of both greenhouses is indicated, obtained by deducting the greenhouse costs from the tomato's productivity:

**NET PROFITS**

**GREECE:** 605.000 - 74.122,92 = **530.877,08 €**

**POLAND:** 375.000 - 117.269 = **257.731 €**

As we can observe, Greece spends less money for the greenhouse requirements, and this is due to the heating method applied for the cultivation.

Furthermore, Poland earns less money from the tomato production, and spends more in the total needs of the greenhouse. But this does not mean that the quality of the tomato production is poorer. It should be emphasized that the values are associated to the policy and the interests of each country.

# 4. Bibliography

1) http://en.wikipedia.org/wiki/Tomato

2) Olympios, C. M. (2004). Protected cultivation in Greece. In *First Coordinating Meeting of the FAO Regional Working Group on Greenhouse Crops in the SEE Countries, October*, 20-22.

3) Kalbarczyk, R., Raszka B., & Kalbarczyk, E. (2011). Variability of the Course of Tomato Growth and Development in Poland as an Effect of Climate Change. *Climate Change – Socioeconomic Effects*. InTech, 279-306.

4) Strange, R. N., & Scott, P. R. (2005). Plant disease: a threat to global food security. *Annu. Rev. Phytopathol.*, *43*, 83-116.

5) Peralta, I. E., & Spooner, D. M. (2001). Granule-bound starch synthase (GBSSI) gene phylogeny of wild tomatoes (Solanum L. section Lycopersicon [Mill.] Wettst. subsection Lycopersicon). *American Journal of Botany*, *88*(10), 1888-1902.

6) Jacobsen E. Daniel, M. K. Bergervoet-van Deelen, J. E. M. Huigen, D. J. Ramanna M. S. 1994. The first and second backcross progeny of the intergeneric fusion hybrids of potato and tomato after crossing with potato". TAG Theoretical and Applied Genetics 88(2), 181–186.

7) Foolad, M. R. (2007). Genome mapping and molecular breeding of tomato. *International Journal of Plant Genomics*, *vol. 2007*, Article ID 64358, 52 pages. doi:10.1155/2007/64358

8) http://www.nhm.ac.uk/research-curation/research/projects/solanaceaesource/taxonomy/description-detail.jsp?spnumber=3601

9) Picó, B., Díez, M. J., & Nuez, F. (1996). Viral diseases causing the greatest economic losses to the tomato crop. II. The Tomato yellow leaf curl virus—a review. *Scientia Horticulturae*, *67*(3), 151-196.

10) Salokhe, V. M., Babel, M. S., & Tantau, H. J. (2005). Water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment. *Agricultural Water Management*, *71*(3), 225-242.

11) Johnson, R. W., Dixon, M. A., & Lee, D. R. (1992). Water relations of the tomato during fruit growth. *Plant, Cell & Environment*, *15*(8), 947-953.

12) http://www.uri.edu/ce/factsheets/sheets/tomato.html

13) Ward, G. M. (1964). Greenhouse tomato nutrition—A growth analysis study. *Plant and Soil*, *21*(1), 125-133.

14) Chapagain, B. P., Wiesman, Z., Zaccai, M., Imas, P., & Magen, H. (2003). Potassium chloride enhances fruit appearance and improves quality of fertigated greenhouse tomato as compared to potassium nitrate. *Journal of plant nutrition*, *26*(3), 643-658.

15) Elad, Y., & Volpin, H. (1993). Reduced development of grey mould (Botrytis cinerea) in bean and tomato plants by calcium nutrition. *Journal of phytopathology*, *139*(2), 146-156.

16) http://www.uri.edu/ce/factsheets/sheets/tomato.html

17) Zitter, T. A. (1985). Bacterial diseases of tomato. *Fact Sheet*, 735.

18) Agrios, G. N. (2005). Plant pathology. *Elsevier Academic Press*, 4-5.

19) Chang, R. J., Ries, S. M., & Pataky, J. K. (1992a). Effects of temperature, plant age, inoculum concentration, and cultivar on the incubation period and severity of bacterial canker of tomato. *Plant disease*, *76*(11), 1150-1155.

20) Chang, R. J., Ries, S. M., & Pataky, J. K. (1991). Dissemination of Clavibacter michiganensis subsp. michiganensis by practices used to produce tomato transplants. *Phytopathology*, *81*(10), 1276-1281.

21) Chang, R. J., Ries, S. M., and Pataky, J. K. (1992b). Local sources of Clavibacter michiganensis ssp. michiganensis in the development of bacterial canker on tomatoes. *Phytopathology*, *82*(5), 553–560.

22) Fatmi, M., Schaad, N. W., & Bolkan, H. A. (1991). Seed treatments for eradicating Clavibacter michiganensis subsp. michiganensis from naturally infected tomato seeds. *Plant Disease*, *75*(4), 383-385.

23) Hausbeck, M. K., Bell, J., Medina-Mora, C., Podolsky, R., & Fulbright, D. W. (2000). Effect of bactericides on population sizes and spread of Clavibacter michiganensis subsp. michiganensis on tomatoes in the greenhouse and on disease development and crop yield in the field. *Phytopathology*, *90*(1), 38-44.

24) Thompson, E., Leary, J. V., and Chun, W. W. C. (1989). Specific detection of Clavibacter michiganensis subsp. michiganensis by homologous DNA probe. *Phytopathology*, *79*(3), 311–314.

25) Antoniou, P. P., Tjamos, E. C., & Panagopoulos, C. G. (1995). Use of soil solarization for controlling bacterial canker of tomato in plastic houses in Greece. *Plant pathology*, *44*(3), 438-447.

26) Stephens, C. T., & Fulbright, D. W. (1986). *Bacterial Canker of Tomato*. Cooperative Extension Service, Michigan State University.

27) Koike, S. T., Gladders, P., & Paulus, A. O. (2007). *Vegetable diseases: a color handbook*. Gulf Professional Publishing.

28) Bashan, Y., Okon, Y., & Henis, Y. (1982). Long-Term Survival of Pseudomonas syringae pv. tomato and Xanthomonas campestris pv. vesicatoria in Tomato and Pepper Seeds. *Phytopathology*, *72*(9), 1143-1144.

29) Bouzar, H., Jones, J. B., Stall, R. E., Hodge, N. C., Minsavage, G. V., Benedict, A. A., & Alvarez, A. M. (1994). Physiological, chemical, serological, and pathogenic analyses of a worldwide collection of Xanthomonas campestris pv. vesicatoria strains. *Phytopathology*, *84*(7), 663-671.

30) Gitaitis, R., McCarter, S., & Jones, J. (1992). Disease control in tomato transplants produced in Georgia and Florida. *Plant disease*, *76*(7), 651-656.

31) Goode, M. J., & Sasser, M. (1980). Prevention-the key to controlling bacterial spot and bacterial speck of tomato. *Plant Disease*, *64*(9), 831-834.

32) Obradovic, A., Mavridis, A., Rudolph, K., Janse, J. D., Arsenijevic, M., Jones, J. B., Minsavage, G. V., & Wang, J. F. (2004). Characterization and PCR-based typing of Xanthomonas campestris pv. vesicatoria from peppers and tomatoes in Serbia. *European journal of plant pathology*, *110*(3), 285-292.

33) Ivors, K. L. (2008). Tomato – Late Blight. *Department of Plant Pathology North Carolina State University*.

34) Bakonyi, J., Láday, M., Dula, T., & Ersek, T. (2002). Characterisation of isolates of Phytophthora infestans from Hungary. *European Journal of Plant Pathology*, *108*(2), 139-146.

35) Cohen, Y., Farkash, S., Reshit, Z., & Baider, A. (1997). Oospore production of Phytophthora infestans in potato and tomato leaves. *Phytopathology*, *87*(2), 191-196.

36) Fry, W. E., & Goodwin, S. B. (1997). Re-emergence of potato and tomato late blight in the United States. *Plant Disease*, *81*(12), 1349-1357.

37) Goodwin, S. B., Cohen, B. A., Deahl, K. L., & Fry, W. E. (1994). Migration from northern Mexico as the probable cause of recent genetic changes in populations of Phytophthora infestans in the United States and Canada. *Phytopathology*, *84*(6), 553-558.

38) Griffith, G. W., Snell, R., & Shaw, D. S. (1995). Late blight (Phytophthora infestans) on tomato in the tropics. *Mycologist*, *9*(2), 87-89.

39) Henfling, J. W. (1987). Late blight of potato. *Technical information bulletin*, *4*, 1-24.

40) Knapova, G., & Gisi, U. (2002). Phenotypic and genotypic structure of Phytophthora infestans populations on potato and tomato in France and Switzerland. *Plant Pathology*, *51*(5), 641-653.

41) Legard, D. E., Lee, T. Y., & Fry, W. E. (1995). Pathogenic specialization in Phytophthora infestans: Aggressiveness on tomato. *Phytopathology*, *85*(11), 1356-1361.

42) Tumwine, J., Frinking, H. D., & Jeger, M. J. (2002). Integrating cultural control methods for tomato late blight (Phytophthora infestans) in Uganda. *Annals of applied biology*, *141*(3), 225-236.

43) Bartz, J. A. (1971). Studies on the causal agent of black fungal lesion on stored tomato fruit. *Ann Meet Fla State Hort Soc*, *84*, 117-119.

44) Davis, R. M., Miyao, E. M., Mullen, R. J., Valencia, J., May, D. M., & Gwynne, B. J. (1997). Benefits of applications of chlorothalonil for the control of black mold of tomato. *Plant disease*, *81*(6), 601-603.

45) Morris, P. F., Connolly, M. S., & St Clair, D. A. (2000). Genetic diversity of *Alternaria alternata* isolated from tomato in California assessed using RAPDs. *Mycological Research*, *104*(3), 286-292.

46) Reddy, M. B., Angers, P., Castaigne, F., & Arul, J. (2000). Chitosan effects on blackmold rot and pathogenic factors produced by Alternaria alternata in postharvest tomatoes. *Journal of the American Society for Horticultural Science*, *125*(6), 742-747.

47) Chastagner, G. A., Ogawa, J. M., and Manji, B. T. (1978). Dispersal of conidia of Botrytis cinerea in tomato fields. *Phytopathology, 68*(8), 1172–1176.

48) Chastagner, G. A. & Ogawa, J. M. (1979). A fungicide-wax treatment to protect and suppress Botrytis cinerea on fresh market tomatoes. *Phytopathology*, 69, 59–63.

49) Moorman, G. W., & Lease, R. J. (1992). Benzimidazole-and dicarboximide-resistant Botrytis cinerea from Pennsylvania greenhouses. *Plant disease*, *76*(5), 477-480.

50) O'Neill, T. M., Shtienberg, D., & Elad, Y. (1997). Effect of some host and microclimate factors on infection of tomato stems by Botrytis cinerea. *Plant Disease*, *81*(1), 36-40.

51) Sasaki, T., Honda, Y., Umekawa, M., & Nemoto, M. (1985). Control of certain diseases of greenhouse vegetables with ultraviolet-absorbing vinyl film. *Plant disease*, *69*(6), 530-533.

52) Shtienberg, D., Elad, Y., Niv, A., Nitzani, Y., & Kirshner, B. (1998). Significance of leaf infection by Botrytis cinerea in stem rotting of tomatoes grown in non-heated greenhouses. *European journal of plant pathology*, *104*(8), 753-763.

53) Vakalounakis, D. J. (1992). Control of fungal diseases of greenhouse tomato under long-wave infrared-absorbing plastic film. *Plant disease*, *76*(1), 43-46.

54) Verhoeff, K. (1970). Spotting of tomato fruits caused by Botrytis cinerea. *Netherlands Journal of Plant Pathology*, *76*(3), 219-226.