Aristotle University of Thessaloniki

School of Agriculture

Department of Agricultural Economics

Economic assessment of Pendimethalin herbicide use in selective crops (cotton, processing tomato & onion)

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Aristotle University of Thessaloniki, School of Agriculture, Dept. of Agricultural Economics

Corresponding address:

Mattas Konstadinos, Professor of Agricultural Economics,

Dept. of Agric. Economics, School of Agriculture,

Aristotle University of Thessaloniki

Email: mattas@auth.gr

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Executive summary

This work attempts to offer a detailed and informative picture on the use of pendimethalin as a basic herbicide in three crops (cotton, onion, processing tomato) and to assess the economic impacts on farm and regional level. Thus, the economic effectiveness in the farmers' level is thoroughly examined and the economic impacts in regional level are estimated assuming that farmers do not have at their disposal this herbicide to apply. In addition the stakeholders' (farmers, processors, experts) views on the economic effectiveness of pendimethalin were recorded and studied by means of two local surveys.

The primary objective of the survey on weed control use (herbicides and particular pendimethalin) is to gather detailed data on current knowledge, attitudes and beliefs related to herbicide use. In addition, specifically the pendimethalin use is examined in three crops (onion, cotton, processing tomato) investigating the impacts of pendimethalin withdrawal on the crop production, product quality and farmers' revenues.

Local stakeholders (crop consultants, industry experts and agronomists) were engaged in informal conversations about on-farm practices related to the use of pendimethalin in the three selected crops (cotton, onion, processing tomato), to develop essential information for its contribution on the plant viability, crop production and production expenses

The survey design team first interviewed 19 stakeholders in Thessaly prefecture (Larisa, Almiros Volou and Karditsa) and Viotia. The majority of the participants were agronomists and crop consultants, who provide to farmers either advisory for cultivation or procurements. Moreover, experts in cotton processing were interviewed to cast the industry's perspective.

Summarizing the answers of stakeholders' interviews, it can be stated that pendimethalin is valuable and irreplaceable herbicide, especially in cotton and onion crops; whereas in processing tomato crops its use is moderate. **All the stakeholders unanimously stated that pendimethalin cannot be replaced or substituted in those crops by any known herbicide without devastated consequences on the production cost and total production**.

In order to identify farmers' reflection and perceptions towards pendimethalin, 140 farmers in Thessaly prefecture (Larisa, Almiros Volou and Karditsa) and Viotia were interviewed, filling in the appropriate questionnaires. Among this sample, 60.7 percent were cotton farmers, 23 percent onion farmers and 16.3 percent processing tomato farmers, reflecting somehow the respective crop ration in the area. Mainly, participants cultivate wheat as second crop and are self employed. Less than half of respondents employed themselves in non-farm jobs, earning extra income. Furthermore, the majority of the farmers apply carving – hoe and herbicides for weed control.

According to farmers' answers, herbicides are believed to be more effective compared to other weed control techniques and pendimethalin as a herbicide is viewed very effective, used extensively, and irreplaceable. Also, affects farmers' incomes positively. Cotton farmers would increase the use of several less effective substitute herbicides in case of pendimethalin withdrawal, affecting negatively their product and their income.

The second section of the study describes the probable effects of a hypothetical pendimethalin withdrawal from the market and, consequently, no use as a basic weed control herbicide in the three studied crops (cotton, dry bulb onion and processing tomato). For this purpose a comparative analysis performed, building several scenarios which can be followed by farmers to manage weed control. Available data were used and also data for crucial variables were gathered. The most commonly used technique of weed management control serves as the baseline scenario. Furthermore, an attempt was made to measure the probable economic impacts at regional and country level due to a change in weed control management (pendimethalin withdrawal). Therefore, the main aim of this section is to explore the benefit/cost ratio of the several alternative weed control scenarios and to estimate the probable income impacts at regional level.

According to the results, in some crops (processing tomato and cotton) herbicides offer the only practical, cost-effective and selective method of managing weeds although pendimethalin can provide good and acceptable benefit/cost ratios in weed management for all three crops. On the other hand, a hypothetical withdrawal of the use of pendimethalin in these three crops could bear significant

income losses for both farmers and regional economy. Although, the withdrawal effects of pendimethalin per hectare are more important for the growers of domestic dry bulb onion and for the growers of domestic processing tomato, due to extensive cotton cultivation, regional income impacts are extremely high for cotton. Finally, any change in the status of herbicides use in cotton and especially in pendimethalin will cause huge income loss in Greece and particularly in the region of Thessaly. Estimates for income losses, only for the region of Thessaly, after pendimethalin withdrawal, amounts around €7.3 million per year. **And this amount could reach the €14.6 million if the income multipliers effect is considered too** (see Table 2.3). **In addition, it is worth to mention that this amount is a recurring (same amount is gained each year).** At this stage, the main policy and intervention statements from this work can be encapsulated as follows:

- Easy availability of crucial herbicides, and if possible a broader range of weed control chemicals, in the market determines the continuation of cultivating all three studied crops (cotton, onion, processing tomato).
- Pendimethalin use offers unique advantage in managing weeds particularly for onion and cotton crops.
- Pendimethalin use is associated with the highest revenue yielding scenario for all three crops.
- Results derived from technical analysis are fully in line with the results derived from experts/farmers interviews for the cotton and onion cultivation.
- Farmers / experts clearly stated that their crop income is determined largely by pendimethalin availability in the pesticides market. Also, they stated that hardly can vision the possibility to cultivate onion, in the Viotia area, and cotton in Thessaly region without herbicide availability, since cost effective alternatives cannot being foreseen.
- Benefits at regional level are extremely high when pendimethalin use scenario is extrapolated to the whole region. This is mainly because of the income multiplier's effect and the recurring of benefits (at no additional cost).

- See below two abstracted graphs that illustrate the losses per hectare, and regional losses for Thessaly.

Table 2.3. Cotton case in Thessaly

Net benefits at farmers level (per ha)	€67,00
Net benefits at average farm (average farm: 4.6ha)	€241,20
Net benefits at regional level (Thessaly)	€7.3 million
Net benefits after multiplier effects (Thessaly)	€14.6 million

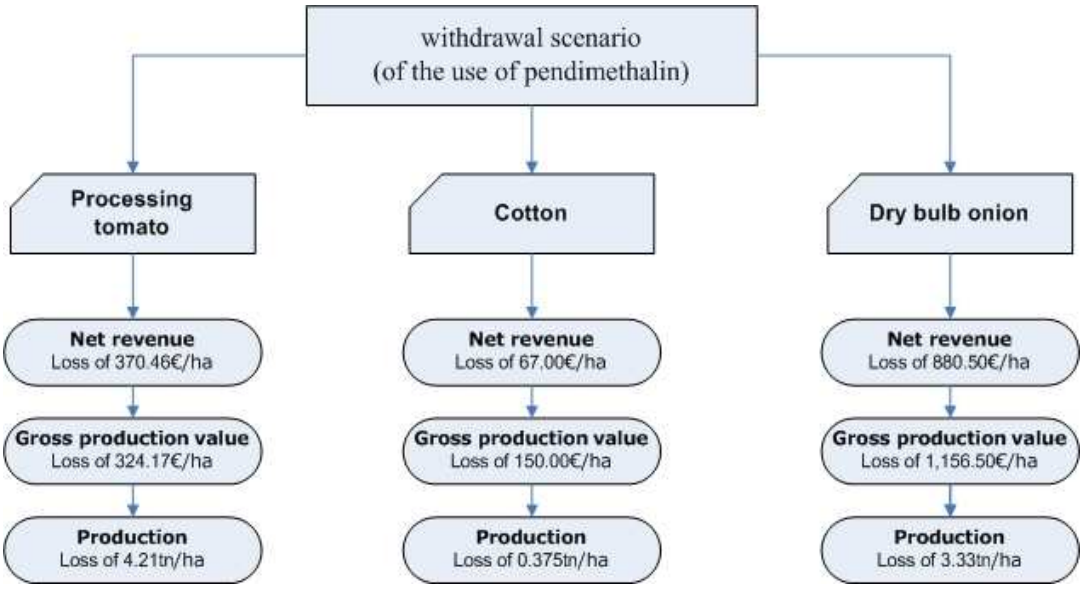


Figure 2.10. Withdrawal effects of the use of pendimethalin

Chapter 1

Stakeholders' and farmers' reflections

1.1. Introduction-objectives

This work aims to determine the current state of experts' knowledge, attitudes and beliefs regarding pendimethalin use in three crops (cotton, onion, processing tomato). The survey is focused on experts' perceptions towards the necessity of pendimethalin in weed control, the advantages and disadvantages of pendimethalin and the probable impacts of pendimethalinwithdrawal due to EU regulation or stoppage in manufacturing. The survey was carried out on the basis of informal conservations with local stakeholders (crop consultants, industry experts, agronomists) covering issues as weed control practices, alternative farm techniques for effective weed control. Also the survey was focused on the use of pendimethalin and its contribution and importance on crop production in those areas. Additionally, farmer's knowledge, attitudes and beliefs regarding herbicides in general and pendimethalin use specifically are measured via an extensive use of questionnaires. The survey was designed also to record farmer's attitudes and perceptions regarding the impacts of pendimethalin use and probable withdrawal from the herbicide market.

The survey area both for stakeholders and farmers covers the prefecture of Thessaly (Larisa, Karditsa, Almiros Volou) and Viotia. In these regions, the most dense cotton, onion and processing tomato is concentrated.

1.2. Stakeholders' reflection on pendimethalin use

1.2.1. Stakeholders' attitudes towards pendimethalin use

Based on stakeholders' answers, Pendimethalin is widely used in cotton (63.8%) and onion (93.8%) crops, whereas its use in processing tomato crops is limited.

Stakeholders believe that compared to weed control practices, Pendimethalin is more effective herbicide, since prevents the crop totally from broadleaf weeds (destroys about 75%), especially in cotton and onion crops. However, its effectiveness becomes stronger when it is combined with other herbicides, which are more effective in narrowleaf weeds, providing an extremely high protection.

According to stakeholders' beliefs, pendimethalin is useful and more appropriate for crops like cotton, onion, vegetables and legumes (though it does not have an authorized license to be applied in all legume crops but only in beans and peas). Stakeholders believe that today pendimethalin is the only authorized herbicide for broadleaf weed control and therefore it is a must for achieving profitable levels of production. They also believe that its application in cotton and onion crops is effective and irreplaceable in terms of making the crop profitable while they do not believe that the chemical improves the quality and appearance of the product.

Regarding the effect of Pendimethalin in the production cost, experts stated that it bears causes a slight increase in production cost (Chart 1), estimating the cost per stremma approximately 4.5 euros (Chart 2) and worth the value.

Chart 1. Effect of Pendimethalin in production cost

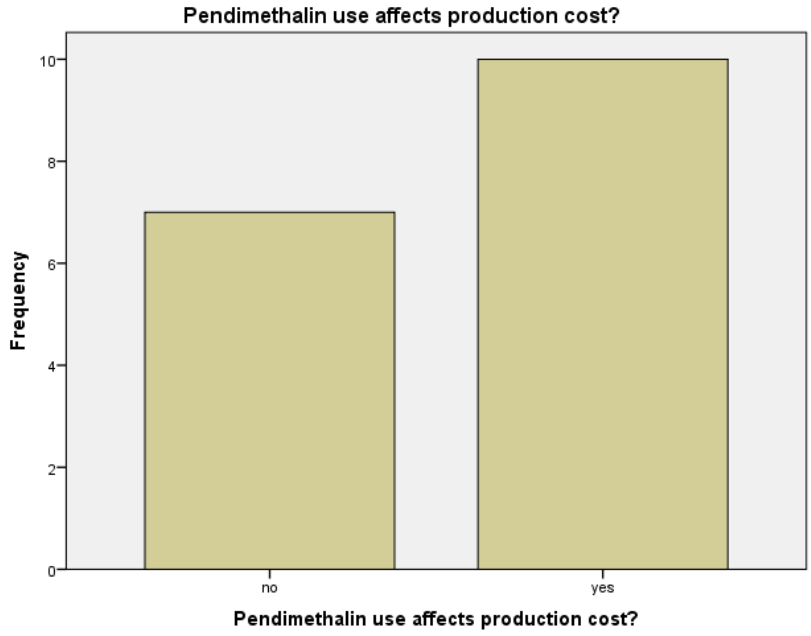
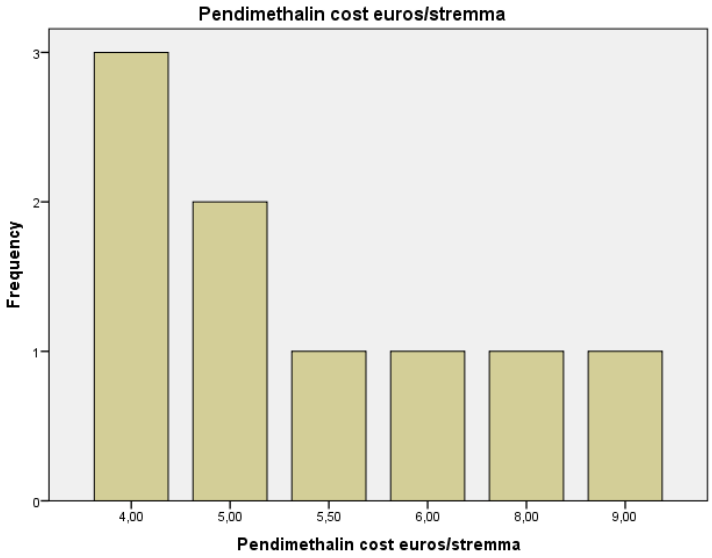


Chart 2. Cost of Pendimethalin use per stremma (euros)



According to the results obtained from stakeholders' interviews, Pendimethalin is not a hazardous chemical herbicide and does not significantly affect the environment and consumers' health. Regarding producers' health, stakeholders believe that it is harmless as long as the appropriate precautions are taken. About 52.6 percent of the respondents stated that in most cases producers do not take all the precautions, especially the older ones (Chart 3).

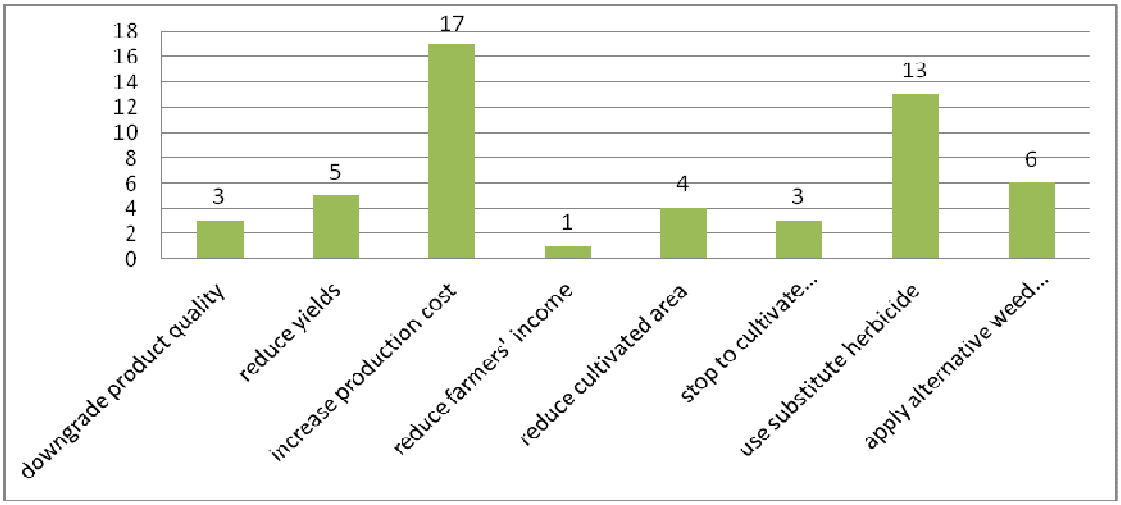
Chart 3. Proper use of Pendimethalin by farmers

The majority of stakeholders express their satisfaction from the cooperation with pendimethalin provider companies, especially in terms of offering helpful payment schemes and particularly after sale support.

1.2.2 SCENARIOS about pendimethalin withdrawal

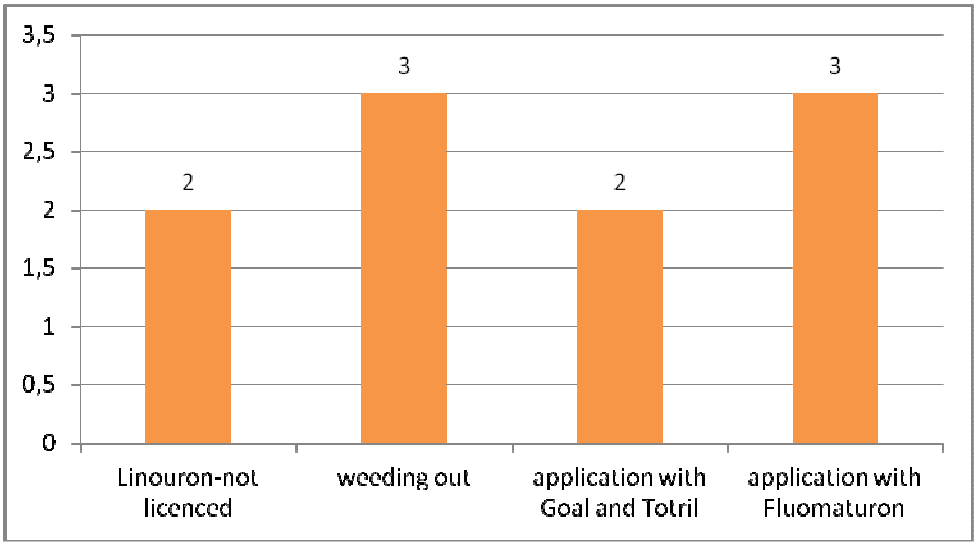
During the conversation with stakeholders, the research team asked them to indicate potential impacts in crops, farmers' income, production cost under a future scenario of probable pendimethalin withdrawal from the herbicide market. Based on their answers, the most significant effects of pendimethalin withdrawal are the increase in production cost (for cotton and onion crops), the massive use of a substitute herbicide, the application of alternative (more costly) weed control techniques and the reduction in crop yields (Chart 4) due to less effective herbicide use.

Chart 4. Scenario: Pendimethalin withdrawal impacts (cotton and onion crops)



Stakeholders believe that the withdrawal of pendimethalin, will cause problems in crop cultivation, since farmers must find alternatives, either in terms of herbicides or in weed control techniques. They suggested the use of Goal, Totril and Fluometuron but expressed doubts about the effectiveness of these herbicides without the combination of pendimethalin (Chart 5).

Chart 5. Pendimethalin alternatives



1.3. Farmers' reflections on Pendimethalin use

1.3.1 Methodology

The survey design team spent several days interviewing farmers in the four areas. The design and implementation of the survey has basically three steps, as follows:

Questionnaire Development

The survey was carried out on the basis of a self-administered questionnaire. The questionnaire was divided in three major sections. The first section included only socio-economic questions for farmers. Questions about farms/enterprises included in the second section. Finally, the last section focused on the use of herbicides, effects of pendimethalin use and impacts of pendimethalin withdrawal.

Survey Sample

The survey covers the four geographical areas namely Larisa, Almiros Volou, Karditsa and Viotia area region, Greece. In these regions, a large number of cotton, onion and processing tomato farmers were notified for the data collection process, which will follow.

Interview

The duration of each interview was about 15-20 minutes, plus the time required for travelling to the interviewing points (cafes, farmer unions, town halls and communities spaces). Farmers were given all basic information needed to answer the questions, assuring them that individual information will remain confidential. Survey team also explained the purpose of the interview, the objectives of survey and any potentially confusing technical terminology.

1.3.2 Results-Discussion

1.3.2.1. Descriptive Statistics

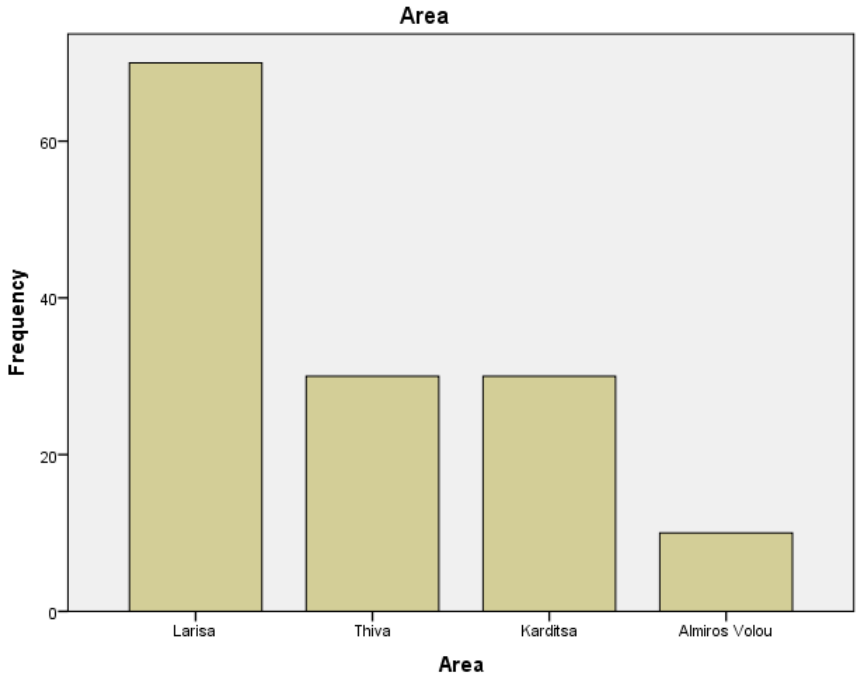
1.3.2.1.1. Socio-economic data of farmers and farms/enterprises

The number of participating farmers in the survey was one hundred and forty (140), among those 132 were males and 8 were females. Seventy (70) of the farms were located in Larisa, thirty (30) in Viotia, thirty (30) in Karditsa and ten (10) farms were cited in Almiros Volou (Table 1 and Figure 1).

Table 1. Distribution of farms along the survey areas**.**

Areas	**Number of farms**	**Percentage %**
Larisa	**70**	**50.0**
Viotia	30	21.4
Karditsa	30	21.4
Almiros Volou	10	7.2
Total	140	100.0

Figure 1. Distribution of farms along the survey areas.



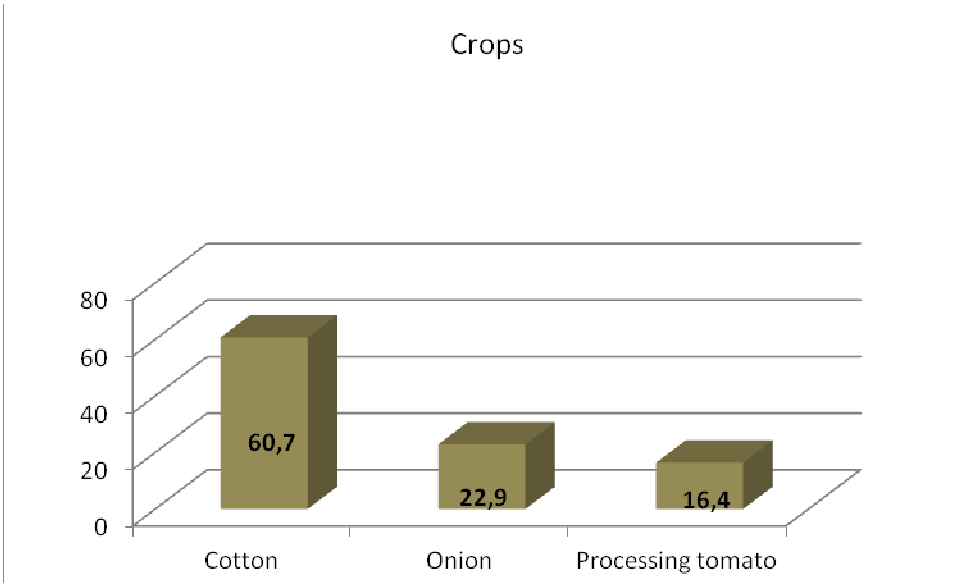
As far as total hectares, 53.6 percent of the farmers cultivated farms less than 101.17 hectares and 11 farmers cultivated farms of 80.94 hectares. 8.6 % of the sample owned farms of 60.70 hectares, 4.3 % of the surveyed farmers possessed farms of 121.41 hectares and the same percentage had farms of 202.34 hectares. 7.1 % of the respondents rented farms of 60.70 hectares and 3.6 % of the participants hired farms of 121.41 hectares. Only a farm of 121.41 hectares was rented to others.

Regarding cultivated crops, 60.7 % of the farmers cultivated cotton as main crop, 22.9 % onion and 16.4 % processing tomato (Table 2 and Figure 2).

Table 2. Distribution of crops along the survey areas

Crops	**Percentage %**
Cotton	**60.7**
Onion	22.9
Processing tomato	16.4
Total	100.0

Figure 2. Distribution of crops along the survey areas



89.9 percent of total farms are irrigated, smaller than 101.17 hectares. Furthermore, 55.7 percent of the respondents cultivated wheat as second crop, 14.3 percent maize, 13.6 percent barley, 5.7 percent potatoes, 4.3 percent carrots, 3.6 percent tobacco, 2.9 percent peppers and 0.7 percent garlic, legumes and chickpeas.

18.6 percent of the respondents are occupied 30 years in farming, 11.4 percent of 20 years and 10 percent involved 40 years in agriculture.

55 percent of the surveyed farmers were self-employed in a permanent base on their farms and 20.7 percent of them had seasonal assistance by another member of their household. 76.4 percent of the farmers receive an extra help and support by foreign workers in order to complete the cultivated crop period. 51.9 percent of the participants used a employee at a permanent base. 79.4 percent of the farmers employed less than 10 seasonal workers, while 11.8 percent had more than 25 seasonal workers to help them during farming period.

Regarding the marital status of the sample, 73.6 percent were married and 22.1 percent were singles. The size of households consisted mainly of four and three members at a rate of 42.1 percent and 25 percent respectively.

The youngest farmer was 21 years and the oldest 70 years old. 11 farmers were exactly 43 years old, 67 percent was less than 48 years old and 33 percent aged between 49 and 70 years old.

Educational level of the sample was mainly secondary school graduation: 49.3 percent held a high school degree, while 12.1 percent owned a university degree. A very small percent of the respondents have an extra occupation apart from agriculture (17.1 percent).

35 percent of the surveyed farmers stated that have an extra income out of farming (pensions/allowances, rent of houses/stores).

1.3.2.1.2. Perceptions of using herbicides for weed control.

The last part of the questionnaire was dedicated to the use of herbicides and especially pendimethalin. The most common weed control techniques applied on farms are herbicides (96.4 percent) and carving – hoe (86.4 percent). Only 2.1 percent of the respondents covered the soil surface with plastic for weed control (Table 3).

Table 3. Weed control techniques

Weed Control	Farmers %
Carving - hoe	86.4%
Herbicides	**96.4%**
Cover the soil surface with plastic for weed control	2.1%

The main reason for using herbicide products in farms is that herbicides are the most effective weed control technique (72.9 percent), with a relatively small cost (43.6 percent). About 32.9 percent of the participants stated that using herbicides contributed to higher yields, 28.6 percent that herbicides are easier to use and 20 percent that herbicides contribute to the improvement of quality production (Table 4).

Table 4. Reasons of using herbicides and percentage distribution

Reasons of using herbicides	**Farmers %**
Using herbicides is more effective compared to other techniques of weed control	**72.9%**
Using herbicides is a low cost method compared to others	43.6%
Using herbicides contributes to higher yields	32.9 %
Herbicides are easier to use	28.6 %
Using herbicides contributes to the improvement of production quality	20 %

Concerning pendimethalin use, 92.1 percent of the respondents declared that apply it on cotton (68.6%), onion (22.1%), processing tomato (12.1 %), potato (10 %), garlic (1.4 %), legumes (1.4 %), carrots (3.6 %), chickpeas (1.4 %), peppers (2.1 %), tobacco (5 %) and maize (2.1 %).

Farmers participated in the survey stated that the reasons of pendimethalin use on previous crops are that is more effective (53.6 %), controls all the weeds (35.7 %), is easier to use (25 %), improves production quality (25 %), is of lower cost compared to other techniques (18.6 %), contributes to higher yields (17.9 %) and is gentle for the environment (12.9 %) (Table 5).

Table 5. Reasons of using pendimethalin

Reasons of using pendimethalin	**Farmers%**
Pendimethalin is more effective	**53.6 %**
Pendimethalin controls all the weeds	35.7 %
Pendimethalin is easier to use	25 %
Pendimethalin improves production quality	25 %
Pendimethalin is lower cost method compared to other methods	18.6 %
Pendimethalin contributes to higher yields	17.9 %
Pendimethalin is more environmental friendly	12.9 %

Farmers believed that using pendimethalin: does not affect soil quality (51.2 %), the development of the cultivated plant (65.6 %), groundwater (58.9 %), aboveground water (53.2 %), consumers' health (58.3 %), but it affects fauna - flora (50.4 %) and farmers' health (68.8 %) negatively. However, pendimethalin use positively affects farmers' incomes (59.2 %) (Table 6).

Table 6. Impacts of Pendimethalin use.

Pendimethalinaffects	**Negatively %**	**Zero %**	**Positively %**
Soil quality	47.2 %	**51.2 %**	1.6 %
Development of the cultivated plant	22. 1 %	**65.6 %**	12.2 %
Groundwater	41.1 %	**58.9 %**	-
Aboveground water	46.8 %	**53.2 %**	-
Fauna and flora	**50.4 %**	49.6 %	-
Farmers' health	**68.8 %**	31.3 %	-
Consumers' health	40.2 %	**58.3 %**	-
Farmers' incomes	16.9 %	23.8 %	**59.2 %**

Under the scenario of pendimethalin withdrawal from the market, farmers stated that: 45.7 percent would take advice from a consultant agronomist about alternative weed control techniques,45 percent stated will use a substitute herbicide, 33.6 percent believe that will reduce farmers' income, 30 percent believe it will cause reduction in yields, 18.6 percent believe that will cause reduction of cultivated farm's hectares, 15.7 percent that could cause degradation of product quality, 12.9 percent

abandonment of crops and 12.9 percent increased use of weed control techniques (Table 7).

Table 7. Impacts of Pendimethalin withdrawal

Impacts of pendimethalinwithdrawal	**Farmers%**
Degradation of product quality	15.7 %
Reduction of yields	30 %
Reduction of cultivated farm's hectares	18.6 %
Abandonment of crops	12.9 %
No impact of crops	4.3 %
Increased used of substitute herbicide	45 %
Increased manual weed control with carving – hoe	20.7 %
Increased use of others weed control techniques	12.9 %
Increased production costs	33.6 %
Reduced agricultural income	33.6 %
Guidance and advice from specialist agronomists on alternative weed control techniques	**45.7 %**

1.3.2.2. Correlation Statistics

A way of studying the relationship of pendimethalin use and farmers' socioeconomic profile and beliefs is correlation statistics. The Correlation Coefficient indicates both the existence of a relation and also the significant of these relations.

The statistical analysis of the variable pendimethalin use with socioeconomic data and farmers' beliefs resulted in the following findings (Table 8):

a) there are two negative correlations with variables: seasonal employment of household members and employed in non farm job. This means that pendimethalin is used to a lesser extent by farmers who occupy household members at a seasonal base and by farmers who are also employed in a non farm job. Specifically, the limited use of pendimethalin by farmers who occupy household members in their enterprise can be attributed to the use of alternative weed control methods and reduce the use of chemicals. Farmers who are employed also in non-farm jobs may use pendimethalin to a lesser extent in order to reduce total production cost as they gain additional income from non farm occupation.

b) there are three marginal positive correlations with variables: pendimethalin affects soil quality, pendimethalin affects the development of the cultivated plant. According to these findings, pendimethalin is used more intensively by farmers who believe that it improves soil quality and plant development.

c) there is one positive correlation with variable pendimethalin affected farmers' incomes, meaning that farmers who believe that pendimethalin use can result in a higher income, use it more intensively (Table 8).

Table 8. Correlation between variables.

Use of pendimethalin	**Pearson Correlation**	**Sig.***
Area	-,069	,418
Product	-,030	,724
Gender	-,042	,618
Age	-,109	,198
Educational level	,008	,926
Marital status	,067	,429
Persons of household	-,017	,842
Years engaged in agriculture	,026	,764
Total hectares	,011	,901
Owned hectares	-,073	,768
Hectares rented from others	-,008	,933
Permanent employment of household members	,018	,836
Seasonal employment of household members	**-,264**	**,096***
Employ foreign workers	,046	,590
Foreign workers in a seasonal base	,035	,730
Foreign workers in a permanent base	,121	,557
Income out of farming	-,005	,951
Employed in other job apart from farm	**-,148**	**,082***
What percentage of family's income is derived from agriculture	-,106	,219
Pendimethalin affects soil quality	**,160**	**,073***
Pendimethalin affects the development of the cultivated plant	**,150**	**,086***
Pendimethalin affects groundwater	,188	,360
Pendimethalin affects aboveground water	,062	,490
Pendimethalin affects fauna and flora	,052	,572
Pendimethalin affects farmers' health	-,007	,938
Pendimethalin affects consumers' health	,084	,346
Pendimethalin affects farmers' incomes	**,219**	**,012***

*N=140, *correlation is significant at the 0.05 and 0.01 level.*

1.3.2.3. Regression Statistics

Binary logistic regression was used to analyze relationships between a dichotomous dependent variable and metric or dichotomous independent variables. The value produced by logistic regression is a value between 0.0 and 1.0. Statistical analysis, utilizing SPSS, (version 20.0) and the collected and calibrated data from the questionnaires, was conducted to derive particular estimates.

The statistical analysis focused on two groups, as shown on table 9. The dependent variable is cotton farmers (first group) and the independent variables referred to pendimethalin withdrawal effects (second group). There are two significant statistical results between variable cotton farmers and variables: reduction of cultivated farm's hectares and increased used of substitute herbicide (Table 9). Based on these findings it is important to highlight that cotton farmers express the opinion that a probable withdrawal of pendimethalin from the market will limit the total cotton cultivated area, and in parallel increase the use of pendimethalin substitutes, which however are not very effective in broadleaf weeds.

Table 9. Regression between variable cotton farmers and pendimethalin withdrawal effects

Cotton	**B**	**Sig**
Degradation of product quality	,014	,980
Reductionof yields	,016	,973
Reductionof cultivated farm's hectares	**-1,485**	**,007***
Abandonment of crops	-,410	,499
No impact on crops	-,045	,964
Increased used of substitute herbicide	**,747**	**,063***
Increased manual weed control with carving – hoe	,392	,447
Increased use of other weed control techniques	-,552	,345
Increased production costs	-,322	,455
Reduced agricultural income	-,536	,235
Guidance and advice from agronomist/consultant on alternative (more costly) weed control techniques	,381	,352

*N=140, *regression is significant at the 0.05 and 0.01 level.*

-2 Log likelihood=163,542, Cox & Snell R^2=,158, Nagelkerke R^2=,214.

Furthermore, there is one significant statistical result between variable pendimethalin use by onion farmers and variable: reduction of cultivated farm's hectares (Table 10).

Table 10. Regression between variable onion farmers and pendimethalin withdrawal effects

Onion	**B**	**Sig**
Degradation of product quality	,072	,911
Reduction of yields	,274	,619
Reduction of cultivated farm's hectares	**1,373**	**,013***
Abandonment of crops	,381	,556
No impact of crops	,257	,833
Increased used of substitute herbicide	,181	,693
Increased manual weed control with carving – hoe	,010	,987
Increased use of other weed control techniques	-,438	,548
Increased production costs	,390	,426
Reduced agricultural income	,252	,627
Guidance and advice from agronomist/consultant on alternative (more costly) weed control techniques	-,630	,199

*N=140, *regression is significant at the 0.05 and 0.01 level.*

-2 Log likelihood=129,406, Cox & Snell R^2=,140, Nagelkerke R^2=,212.

Finally, there are two significant statistical results between variable processing tomato farmers and variables: increased used of substitute herbicide and increased used of other weed control techniques (Table 11). These findings are similar with the case of cotton farmers' beliefs on probable pendimethalin withdrawal from the herbicide market.

Table 11. Regression between variable processing tomato and pendimethalin withdrawal effects

Processing tomato	**B**	**Sig***
Degradation of product quality	-,134	,853
Reduction of yields	-,324	,599
Reduction of cultivated farm's hectares	,500	,445
Abandonment of crops	,168	,827
No impact of crops	-,244	,843
Increased used of substitute herbicide	**-1,532**	**,009***
Increased manual weed control with carving – hoe	-,761	,262
Increased use of other weed control techniques	**1,336**	**,051***
Increased production costs	,088	,876
Reduced agricultural income	,675	,241
Guidance and advice from agronomist/consultant on alternative (more costly) weed control techniques	,006	,992

*N=140, *regression is significant at the 0.05 and 0.01 level.*

-2 Log likelihood=110,493, Cox & Snell R^2=,099, Nagelkerke R^2=,167.

1.4. Conclusions

The experts discussions and interviews and the farmers survey reveal very intriguing results regarding the use of pendimethalin as a major herbicide in the crops of cotton and onion. We present first the experts postulates and then the farmers' results.

1.4.1 Stakeholders' interviews

The main points highlighted from the discussions with the experts are summarized as follows:

- Regarding the current status in Greece's herbicide market, there are only a few licensed herbicides that can be applied in cotton and onion crops. Especially before spearing, pendimethalin is the most appropriate for broadleaf weeds. Its use accompanied with another one against resisted narrowleaf weeds can reach a rate of weed control effectiveness almost one hundred percent.

- Aside from herbicides, farmers normally apply hoeing methods for weed control just after spearing, and mainly focusing on the row.
- Pendimethalin is normally used by approximately 85 percent of cotton and onion farmers, but to a lesser extent by processing tomato farmers.
- Pendimethalin is perceived as a gentle herbicide for the environment and the producer health, as long as the recommended use instructions are followed, though the majority of old age farmers do not take the required precautions during applications.
- Companies and agencies selling pendimethalin to the farmer have developed excellent relations and cooperations with agronomists/consultants and farmers. In addition, they offer very good sale support and smooth payment schemes.
- Any action of stoppage or withdrawal of pendimethalin from the market will bring about devastated effects on the farmers and crops, mainly due to lack of effective substitutes or herbicide combinations. The most significant impact, in case of pendimethalin withdrawal, would be a surge in production cost, since farmers must apply more costly and perhaps less effective weed control techniques (hoeing, covering land with plastic and using other combinations of herbicides).

1.4.2 Farmers' survey

As personal interviews are a highly demanding and time-consuming way of obtaining information they cannot be employed in large number of individuals. Thus, a survey performed covering a large numbers of cotton and onion farmers in the selected areas. One of the tasks of the survey was to record attitudes and perceptions of farmers on using herbicides and particular pendimethalin, and also to record what could be the probable impacts in case of pendimethalin withdrawal from the herbicide market. Personal interviews are ideally suited for this purpose. Thus, 140 personal interviews from the studied areas were conducted. Analyzing farmers' survey data the following conclusions are derived:

- 60.7 % of the participants were cotton farmers, 22.9 % onion farmers and 16.4 % processing tomato farmers.

- The most common techniques farmers used at the four studied areas for weed control were herbicides (96.4 %) and carving – hoe (86.4 %). The most unusual method of weed control for cotton, onion and processing tomato crops is to cover the soil surface with plastic (2.1%).
- The main reason participants use herbicide products in farms, is the high effectiveness in weed control (72.9 %). According to the respondents, pendimethalin is the most effective technique (53.6 %) and is applied on 11 crops for weed control.
- Respondents believe that pendimethalin does not affect the growth of the cultivated plant (65.6 %), but has negative effects on farmers' health (68.8 %) if application instructions are not followed. Also pendimethalin use has a positive effect on farmers' income (59.2 %).
- Under the scenario of pendimethalin withdrawal, farmers would consult the agronomists about alternative herbicides and other weed control techniques (45.7 %), though that at the moment they do not foresee any effective alternative use.
- Statistical analysis derived some useful points regarding the effects of pendimethalin withdrawal and farmers reactions. Farmers, who cultivate cotton, would not reduce cultivated hectares because of pendimethalin withdrawal but were tended to increase quantities and combinations of substitute herbicides. On the other hand farmers who cultivated onion would only reduce cultivated hectares because of pendimethalin withdrawal. Finally, farmers who cultivated processing tomato would not increase the use of substitute herbicide but they will increase the use of other weed control techniques.

Chapter 2
Sectoral indirect effects of Pendimethalin use in crops

2.1 Introduction

Cotton generally does not represent a very important crop for EU, and only for two EU members (Greece and Spain) constitutes a significant crop, since a whole region totally depends on the cultivation and production of this crop (Thessaly). On the other hand, dry bulb onions over the last five years demonstrate a continuous upward trend. Finally, the cultivation of processing tomato, both in Greece and in other European countries, is usually carried out under contract farming agreements and to a relative small area, and under some certain conditions can ensure significant benefits and satisfactory income to farmers.

2.2 Cotton

2.2.1 Weed control

According to Cotton Incorporated (2013), cotton is a poor competitor against many of the weeds that infest fields in Greece. Thus, a Greek farmer hardly can harvest cotton (Nalayini et al., 2013) without chemical weed control. However, during the last decade, the number of approved herbicides is drastically decreasing, leaving farmers with less choices and higher herbicide prices.

Weed control in cotton could be based not only on solely chemical methods but also on integrated approaches including cultural, mechanical and biological techniques (Ali et al., 2013). However, the cost of a complete hand weeding practice elevates very much labor cost (Giannopolitis, 2012; ABAF, 2013). Therefore solely hand weeding practice is not included in the following cost effectiveness analysis.

2.2.2 Cost effectiveness

This section presents the cost effectiveness of Greek cotton cultivation. The required data collected, updated to year 2012, from several sources. In particular: a) for weed control costs used the data from the briefing document of Giannopolitis (2012) while b) for other costs used survey data from the accounting monitoring of several Greek

cotton farms, gathered over time by our own Department of Agricultural Economics (ABAF, 2013). For the purposes of this analysis representative farms from all geographical regions were selected.

The several scenarios analyzed below are the following (Giannopolitis, 2012):

Scenario 1: Inter-row cultivations plus hand weeding on rows

Scenario 2: Pre-seeding incorporated pendimethalin

Scenario 3: Pre-emergence fluometuron

Scenario 4 (basic): Pre-seeding incorporated pendimethalin plus Pre-emergence fluometuron (lower rates)

Scenario 5: Pre-emergence fluometuron plus Post-emergence clethodim twice

Scenario 6: Post-emergence clethodim twice

Table 2.1 presents the costs and the benefits of cotton production, as well as the net revenues and the benefit/cost ratios, for the several selected scenarios of weed control assuming that all cost items, excluding the cost of weed control, remain exactly the same.

Table 2.1. Cost-Effectiveness of cotton (Scenarios Analysis / per ha)

	Scen.1	**Scen.2**	**Scen.3**	**Scen.4**	**Scen.5**	**Scen.6**
Expenses						
Rent	500.00	500.00	500.00	500.00	500.00	500.00
Crop care	200.00	200.00	200.00	200.00	200.00	200.00
Seed	110.00	110.00	110.00	110.00	110.00	110.00
Labor (+depreciations)	180.00	180.00	180.00	180.00	180.00	180.00
Weed control	650.00	116.00	73.00	156.00	261.00	188.00
Fertilization	250,00	250,00	250,00	250,00	250,00	250,00
irrigation (+electricity network)	200,00	200,00	200,00	200,00	200,00	200,00
Chemical control (prevention of pests & diseases)	250,00	250,00	250,00	250,00	250,00	250,00
Foreign labor (10 salaries/ha)	190.00	190.00	190.00	190.00	190.00	190.00
Harvesting	75.00	75.00	75.00	75.00	75.00	75.00
Defoliants, Pix, sprays	60.00	60.00	60.00	60.00	60.00	60.00
Total expenses	***2,665.00***	***2,131.00***	***2,088.00***	***2,171.00***	***2,276.00***	***2,203.00***
Revenues						
Gross Production Value	700.00	850.00	850.00	1,000.00	900.00	850.00
Coupled aid (strengthening)	800.00	800.00	800.00	800.00	800.00	800.00
Single payment (strengthening)	950.00	950.00	950.00	950.00	950.00	950.00
Denitrification program	500.00	500.00	500.00	500.00	500.00	500.00
V.A.T. recursion	200.00	200.00	200.00	200.00	200.00	200.00

Total Gross Revenues	***3,150.00***	***3,300.00***	***3,300.00***	***3,450.00***	***3,350.00***	***3,300.00***
Net revenues	***485.00***	***1,169.00***	***1,212.00***	***1,279.00***	***1,074.00***	***1,097.00***
Benefit/Cost Ratio	***1.182***	***1.548***	***1.580***	***1.589***	***1.472***	***1.498***
Ranking	*(6)*	*(3)*	*(2)*	*(1)*	*(5)*	*(4)*

Scenario 1 (weed control): *200€/ha for two cultivations + 450€/ha for two hand weedings*
Scenario 2 (weed control): *66€/ha (herbicide value) + 50€/ha for application (spray +incorporation)*
Scenario 3 (weed control): *43€/ha (herbicide value) + 30€/ha for application (spray +incorporation)*
Scenario 4 (weed control): *66€/ha (pendimethalin value) + 50€/ha for application of pendimethalin (spray +incorporation) + 40€/ha (fluometuronvalue + application)*
Scenario 5 (weed control): *43€/ha (herbicide value) + 30€/ha for application (spray +incorporation) + 2x94€/ha (clethodim value + application)*
Scenario 6 (weed control): *188€/ha (herbicide value + application)*
**Assuming that the efficiency of the basic scenario is 1000€/ha (2.5tn/ha x 400€/tn). According to Papageorgiou (2009) and ABAF (2013) the weed control of the first scenario has resulted in a product reduction of around 30%, the weed control of second, third and last scenario has resulted in a product reduction of around 15% and the weed control of fifth scenario has resulted in a product reduction of around 10%. The herbicides values and their cost of application have been calculated according to the report of Giannopolitis (2012).*

Generally, total expenses of domestic cotton production (excluding the expenses of weed control) are equal to 1,515€/ha, namely: crop care (200€/ha), seed (110€/ha), labor + depreciations (180€/ha), fertilization (250€/ha), irrigation + electricity network (200€/ha), 10 salaries/ha non-own labor (250€/ha), harvesting (190€/ha), fuel expenses (75€/ha) and defoliants, sprays (60€/ha). The above estimates refer to farmland that the farmer owns, while in case of non-owned farmland a rent of 500€/ha can be added to the total cost.

On the other hand, as revenues (benefits) have included: a) the 800€/ha, coupled aid, b) the 950€/ha single payment, c) the 500€/ha participation in the program of denitrification, d) the 200€/ha reimbursement of VAT and fuel, and e) the gross value of the sold product which ranges from 700 to 1,000€/ha (depending on the weed control method).

Then, the results of several scenarios of net revenues can be generated (Table 2.2) at country level (the total domestic cotton area harvested amounts to 285,351 hectares) (OPEKEPE, 2012).

Table 2.2. Generalization of net revenues at country level

Scenarios	**Net Revenue**
1. Inter-row cultivations plus hand weeding on rows	138,395,235€
2. Pre-seeding incorporated pendimethalin	333,575,319€
3. Pre-emergence fluometuron	345,845,412€
4. Pre-seeding incorporated pendimethalin plus Pre-emergence fluometuron (lower rates)	364,963,929€
5. Pre-emergence fluometuron plus Post-emergence clethodim twice	306,466,974€
6. Post-emergence clethodim twice	313,030,047€

From Tables 2.1 and 2.2 can be observed that the baseline scenario (scenario 4) proved the most beneficial. In this scenario probably the added value comes from the uses of pendimethalin clearly (Table 2.1). All the scenarios show positive net revenues although smaller than the basic one (scenario 4). The second best scenario is the third one, where as chemical weed control practice pre-emergence fluometuron is applied. **This scenario could be the best in case of pendimethalin withdrawal, meaning that farmer will lose 67 €/ha (1279-1212) and country will miss around €20 million every year.**

Since the most important cotton production areas in Greece are Thessaly, Macedonia, Easter Sterea Greece, Thrace and Western Greece, the generalization results of farmers' net revenues by geographic region are shown in Figure 2.1. In this figure, the benefits of chemical weed control, and especially of pendimethalin, which are higher for Central and Northern Greece are clearly demonstrated.

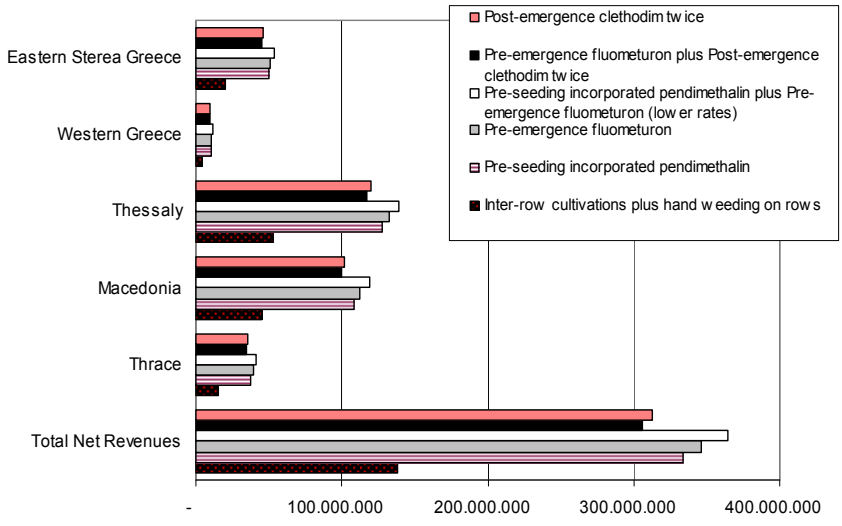


Figure 2.1. Generalization of net revenues by geographic region (€/kg)

Also, in the case of pendimethalin withdrawal the best alternative scenario, based on the economic results, is the third one. **According to this scenario (withdrawal of pendimethalin), a loss of the net revenue by 67 €/ha, a loss of the gross production value by 150 €/ha and a loss of the production quantity by 0.375 tn/ha occurs (figure 2.2.).**

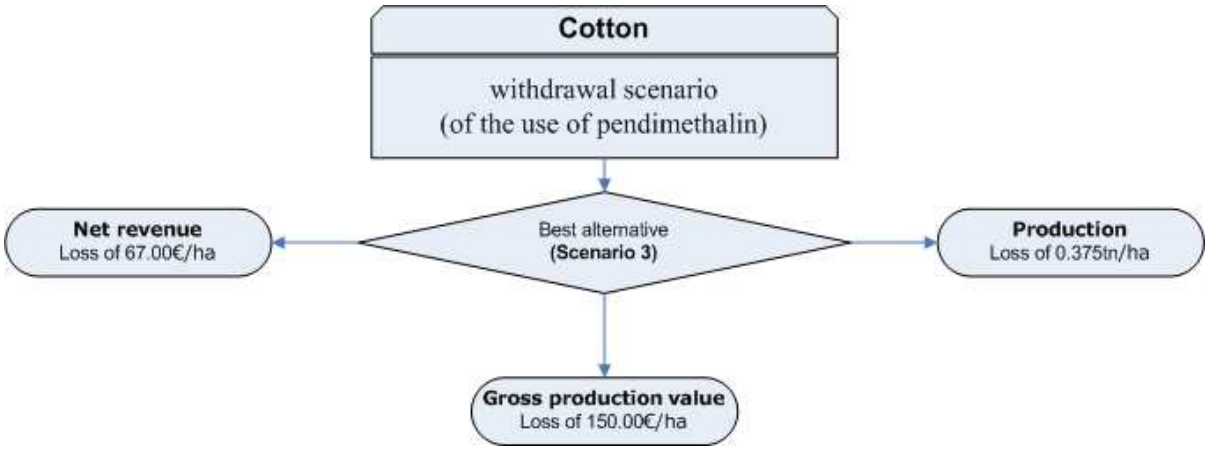


Figure 2.2. Withdrawal effects of the use of pendimethalin

Then, considering the withdrawal effects of the use of pendimethalin in a regional level, the growers of cotton in Thessaly will lose a total of approximately €16.4 million of their gross production value and a total of approximately €7.3 million of their net revenues (figure 2.3). Additionally, the growers of cotton in Macedonia and Eastern Sterea Greece will lose approximately €14 million and €6.4 million respectively of their gross production value and approximately €6.2 million and €2.8 million respectively of their net revenues (income). Finally, in a national level the growers of cotton in whole Greece will lose a total of approximately €42.8 million of their gross production value and a total of approximately €19.1 million of their net revenues.

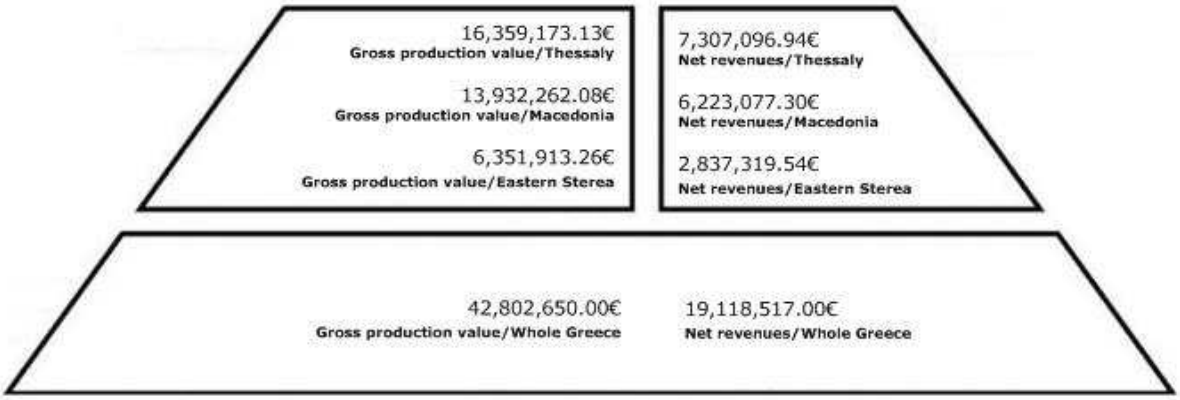


Figure 2.3. National and regional effects of pendimethalin withdrawal

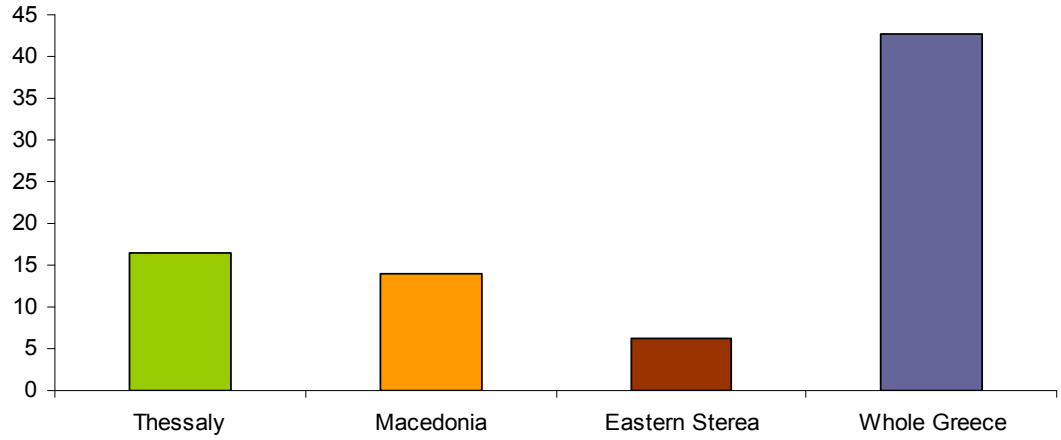


Figure 2.4. Effects of pendimethalin withdrawal on Gross Production Value (million €)

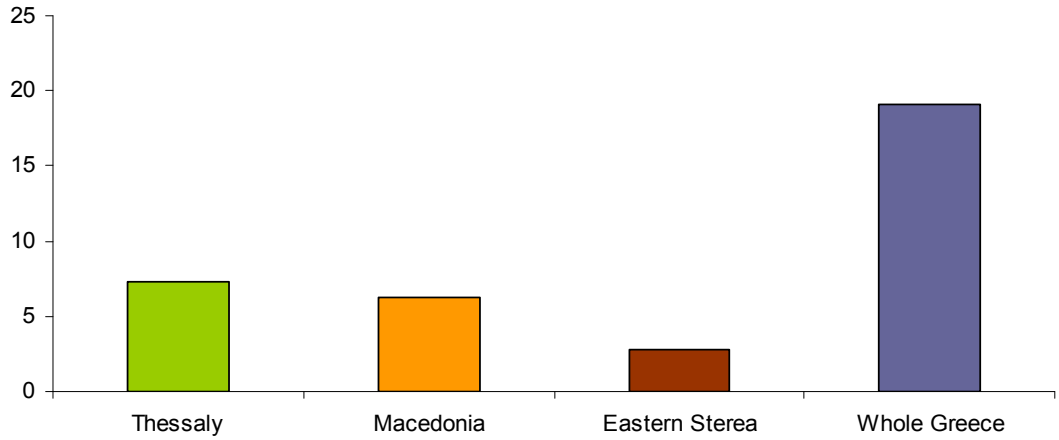


Figure 2.5. Effects of pendimethalin withdrawal on Net Revenues (million €)

Those loss, in practice, are not huge when two additional factors are incorporated, the multipliers effect and the recurring dimension. **The multiplier's effect is the total benefit garnered by the Thessaly society, if this additional income will spend within the regional economy. In this case, with an average income multiplier equal to two, the whole benefits are doubled €14.6 million. Therefore, any change in the status of herbicides use in cotton and especially in pendimethalin, will cause huge loss of income in the region of Thessaly (Table 2.3).**

Table 2.3. Cotton case in Thessaly

Net benefits at farmers level (per ha)	€67,00
Net benefits at average farm (average farm: 4.6ha)	€241,20
Net benefits at regional level (Thessaly)	€7.3 million
Net benefits after multiplier effects (Thessaly)	€14.6 million

2.2.3 Conclusions

Conclusively, cotton is a crop which can ensure significant benefits to producers. Thus, the net income per hectare can ideally exceed the 1,250€. However, it is worth noting that the expenses of herbicides are only a small part of the total production cost (from 3.5% to 11.5%). On the other hand, the benefits of chemical weed control are so significant that cotton cultivation without chemical weed control is impractical and unprofitable (Nalayini et al., 2013). Especially in the basic scenario of "Pre-seeding incorporated pendimethalin plus Pre-emergence fluometuron" (Scenario 4), the net benefits are increased even more. In the following figures 2.6 and 2.7 have been distinguished graphically the comparisons of the several economic results and the benefit/cost ratios of the selected scenarios.

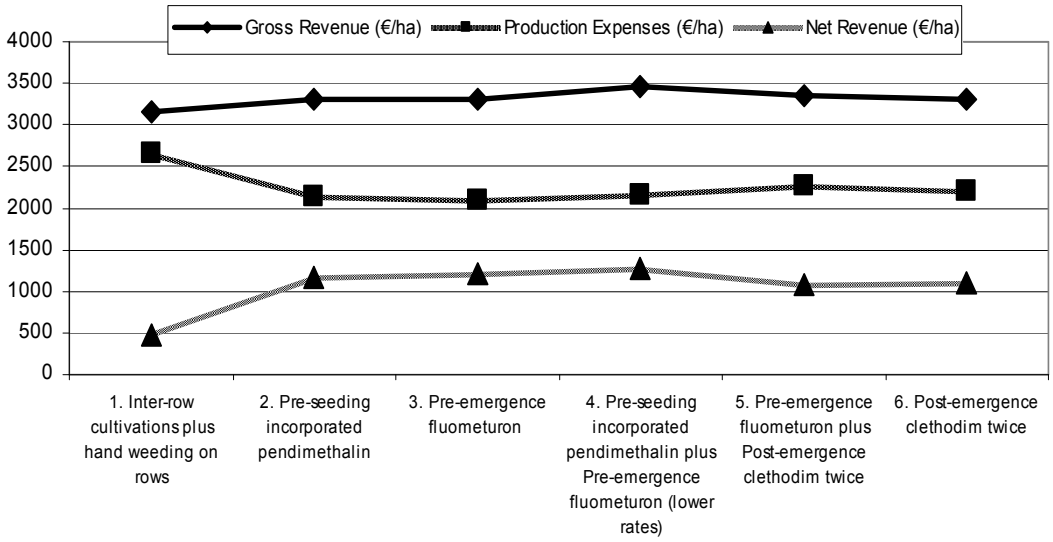


Figure 2.6. Illustration of economic results of cotton production

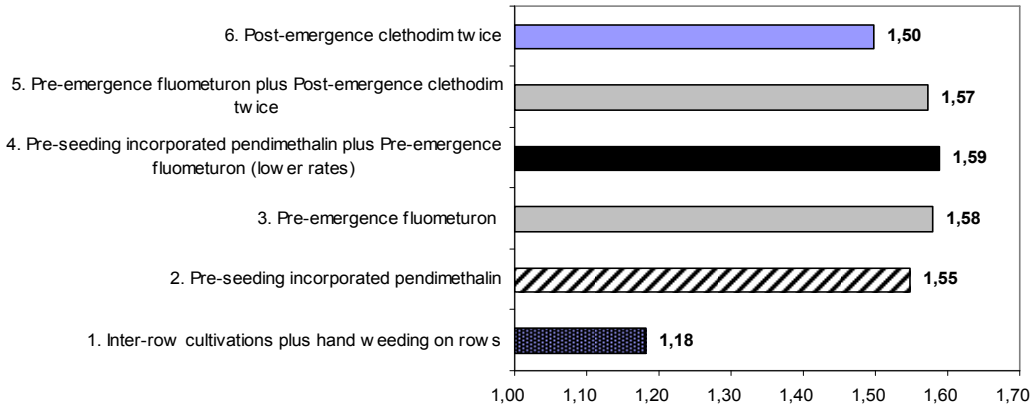


Figure 2.7. Benefits/costs ratios of several scenarios of cotton weed control

2.3 Dry bulb onion

2.3.1 Weed control

Onion (always referring to dry bulb onion) cultivation is concentrated mainly in Viotia area (Central Greece) and offers high income to farmers. In cultivated onion weed management is very important since onion is very sensitive to invaded weeds. Today, the most common practice of weed control is the application of pendimethalin (SEMINIS, 2010), followed by some other chemicals like oxyfluorfen, oxadiazon, ioxynil and quizalofop (Giannopolitis, 2012). Pendimethalin can be applied as a pre-emergent herbicide, since the others can temporarily stop plant development (sometime for 2 weeks). According to Griepentrog and Dedousis (2010), mechanical weed control is also necessary during the season (with also secondary goal: to cultivate the soil layer for water management). 2-3 times of machine cultivation, and, if needed, 1-2 times of manual weeding (often before harvest to pull out the large weeds not to block the harvest machines) is generally necessary (SEMINIS, 2010).

2.3.2 Cost effectiveness

This section presents the cost effectiveness analysis of onion cultivation. Data gathered from several sources as for cotton (Giannopolitis, 2012, ABAF, 2013).

The studied scenarios are the following (Giannopolitis, 2012):

Scenario 1: Hand weeding

Scenario 2: Pre-seeding or pre-emergence incorporated Pendimethalin or early post-emergence Pendimethalin

Scenario 3: Later post-emergence Oxyfluorfen (or Linuron or Trifluralin orOxadiazon or Ioxynil or Quizalofop)

Scenario 4: Pre-seeding incorporated Pendimethalin or pre-emergence Pendimethalin plus post-emergence Oxyfluorfen

Scenario 5 (basic scenario): Pre-seeding incorporated Pendimethalin or pre-emergence Pendimethalin plus post-emergence Oxyfluorfen plus hand weeding

Scenario 6: Mechanical weed control

Table 2.4 presents the expenses and the benefits of onion production, as well as the net revenues and the benefit/cost ratios, for the selected scenarios of weed control assuming that all weed control scenarios have the same expense items besides the weed control cost which variates.

Table 2.4. Cost-Effectiveness analysis of dry bulb onion (Scenarios Analysis / per ha)

	Scen.1	**Scen.2**	**Scen.3**	**Scen.4**	**Scen.5**	**Scen.6**
Expenses						
Rent	500.00	500.00	500.00	500.00	500.00	500.00
Crop care	200.00	200.00	200.00	200.00	200.00	200.00
Seed (plantlets / seedlings)	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00
Labor (+depreciations)	180.00	180.00	180.00	180.00	180.00	180.00
Weed control	450.00	51.00	92.00	143.00	368.00	225.00
Fertilization (basic)	500.00	500,00	500,00	500.00	500.00	500.00
Fertilization (surface - nitrate)	500.00	500.00	500.00	500.00	500.00	500.00
irrigation (+electricity network)	250.00	250,00	250,00	250.00	250.00	250.00
Chemical control (prevention of pests & diseases)	500.00	500.00	500.00	500.00	500.00	500.00
Foreign labor (10 salaries/ha)	250.00	250,00	250,00	250.00	250.00	250.00
Harvesting	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00
Total expenses	***7,530.00***	***7,131.00***	***7,172.00***	***7,223.00***	***7,448.00***	***7,305.00***
Revenues						
Total gross revenues	***8,158.50***	***9,906.75***	***10,498.50***	***10,498.50***	***11,655.00***	***8,158.50***
Net revenues	***628.50***	***2,775.75***	***3,326.50***	***3,266.50***	***4,207.00***	***853.50***
Benefit/Cost Ratio	***1.08***	***1.39***	***1.46***	***1.45***	***1.56***	***1.12***
Ranking	*(6)*	*(4)*	*(2)*	*(3)*	*(1)*	*(5)*

Scenario 1 (weed control): *450€/ha for two hand weedings*

Scenario 2 (weed control): *51€/ha for the pre-seeding or pre-emergence or early post-emergence application*

Scenario 3 (weed control): *92€/ha (mean price) for the later post-emergence Oxyfluorfen (or Linuron or Trifluralin or Oxadiazon or Ioxynil or Quizalofop)*

Scenario 4 (weed control): *51€/ha for the pre-seeding or pre-emergence or early post-emergence application + 92€/ha (mean price) for the later post-emergence Oxyfluorfen (or Linuron or Trifluralin or Oxadiazon or Ioxynil or Quizalofop)*

Scenario 5 (weed control): *51€/ha for the pre-seeding or pre-emergence or early post-emergence application + 92€/ha (mean price) for the later post-emergence Oxyfluorfen (or Linuron or Trifluralin or Oxadiazon or Ioxynil or Quizalofop) + 225€/ha for one hand weeding*

Scenario 6 (weed control): *250€/ha application cost (including depreciations)*

[*] *Assuming that the efficiency of the basic scenario (scen. 5) is 11,655.0€/ha (33.3tn/ha x 350€/tn). According to ABAF (2013), the weed control of the first and last scenario has resulted in a product reduction of around 30%. The weed control of the second scenario has resulted in a product reduction of around 15% and the weed control of third and fourth scenario has resulted in a product reduction of around 10%. The herbicides values and their cost of application have been calculated according to the report of Giannopolitis (2012).*

Hence, total expenses of onion production (excluding the expenses for weed control) are equal to 6,580€/ha, namely: crop care (200€/ha), seed (1,200€/ha), labor + depreciations (180€/ha), fertilization (1,000€/ha), irrigation + electricity network (250€/ha), 10 salaries/ha non-own labor (250€/ha) and harvesting (3,000€/ha). Revenues (benefits) are coming mainly from the gross value of the product which ranges from 8,158.5 to 11,655.0€/ha (depending on the weed control method). Scenario differences extrapolated at country level for a cultivation of 7,300 hectares (FAOSTAT, 2013) and are shown in Table 2.5.

Table 2.5. Generalization of net revenues at country level (scenarios analysis)

Scenarios	**Net Revenue**
Scenario 1: Hand weeding	4,588,050€
Scenario 2: Pre-seeding or pre-emergence incorporated Pendimethalin or early post-emergence Pendimethalin	20,262,975€
Scenario 3: Laterpost-emergenceOxyfluorfen (orLinuronorTrifluralinorOxadiazonorIoxynilorQuizalofop)	24,283,450€
Scenario 4: Pre-seeding incorporated Pendimethalin or pre-emergence Pendimethalin plus post-emergence Oxyfluorfen	23,845,450€
Scenario 5 (basicscenario): Pre-seedingincorporatedPendimethalinorpre-emergencePendimethalinpluspost-emergenceOxyfluorfenplushandweeding	30,711,100€
Scenario 6: Mechanical weed control	6,230,550€

Clear the baseline scenario (scenario 5) proved the best one as net revenues exceed all the other cases. Pendimethalin use offers spectacular differences comparing the scenario five with the second best scenario three. Pendimethalin use can increase farmer's income by 881euros per ha.

Thus, in the case of pendimethalin withdrawal the best alternative scenario, based on the economic results, is the third one. According to this scenario the withdrawal of pendimethalin use could cause: a) a loss of the net revenue by 880.50€/ha, b) a loss of the gross production value by 1,156.50€/ha and c) a loss of the production quantity by 3.33tn/ha. And this means that the whole area loose €6.5 million (880.5 €/ha x 7,300 ha ≈ €6.5).

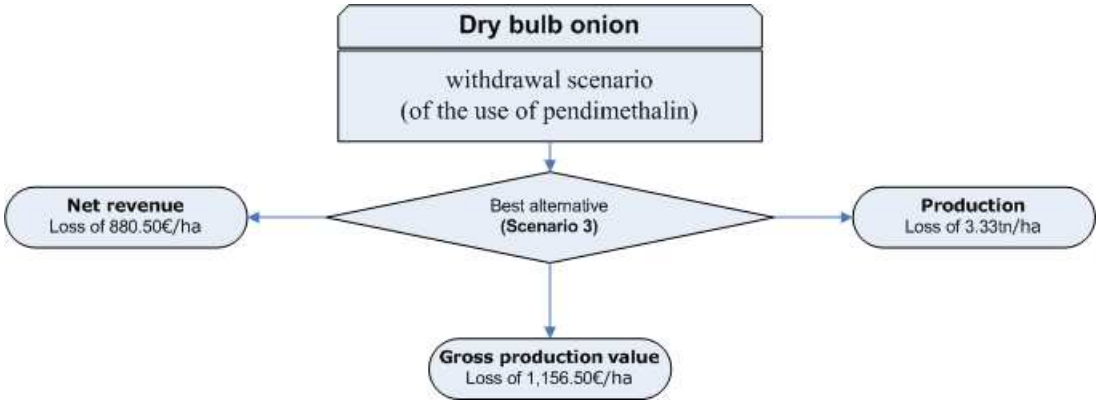


Figure 2.6. Withdrawal effects of the use of pendimethalin

2.3.3 Conclusions

Conclusively, onion is a vegetable crop which can ensure significant benefits to farmers. Thus, the net income per hectare can exceed 4,000€ (Table 2.3 – Scenario 5), a sum which, under conditions, could be considered as very satisfactory. However, it is worth noting that the costs of herbicides are only a small part of the total production costs (1%-6%). **The use of Pendimethalin as weed control herbicide offers to the farmer a net additional income of €880.5 per ha while the net additional revenues to the farmers of the Prefecture of Viotia are equal to €2.6 million (880.5 €/ha x 2,900 ha ≈ €2,6) an amount significant huge for the small area of Viotia. In other words, withdrawal of pendimethalin will cause loss to the small area of Viotia around €2.6 million.** This amount will more than doubled, if multiplier's effect and recurring dimension will measured.

2.4 Processing tomato

2.4.2 Weed control

Processing tomato cultivation, a labor intensive crop (Petro-Turza, 1986) requires large amounts of fertilizer, frequent irrigation, specific climatic conditions, which favor the development of weeds, and well planned weed management. Among many weeds, the broadleaf weeds constitute a major weed control problem (Giannopolitis, 2007). International and Greek sources (Patrap et al., 1997; Viggiani and Dellacecca, 1998; Kati et al., 2012) suggest that failure of weed control can cause a loss of agricultural production ranging from 30% to 70% and a loss of around 50%-60% can be expected.

2.4.3 Cost effectiveness

This section will focus on evaluating the cost analysis of processing tomato based on the same sources of data as for onion and cotton (Giannopolitis, 2012, ABAF, 2013). The weed control scenarios for processing tomato are the following (Kati et al., 2012; Giannopolitis, 2012; ABAF, 2013):

Scenario 1: Pre-transplanting broadleaf herbicide (oxadiazon) plus post transplanting grass herbicide (fluazifop)

Scenario 2 (basic scenario): Pre-transplanting residual broad spectrum herbicide pendimethalin

Scenario 3: Cultivation without weed control

Scenario 4: Inter-row cultivations plus hand weeding on rows (organic production)

Scenario 5: Weed control with mulch on rows plus post transplanting (metribuzin+rimsulfuron)

Scenario 6: Post transplanting: two herbicide applications (rimsulfuron and metribuzin+rimsulfuron)

Table 2.6 presents expenses, revenues, net revenues and the benefit/cost ratios, for the several selected scenarios of weed control assuming that all weed control scenarios maintain same cost (excluding the cost of weed control), for all non-weed control expenses.

Table 2.6. Cost-Effectiveness analysis of processing tomato (scenarios analysis / per ha)

	Scen.1	Scen.2	Scen.3	Scen.4	Scen.5	Scen.6
Expenses						
Rent	500.00	500.00	500.00	500.00	500.00	500.00
Crop care	200.00	200.00	200.00	200.00	200.00	200.00
Seed (plantlets / seedlings)	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00
Labor (+depreciations)	180.00	180.00	180.00	180.00	180.00	180.00
Weed control	143.50	81.00	0.00	650.00	476.00	215.80
Fertilization (basic)	500.00	500,00	500,00	500.00	500.00	500.00
Fertilization (surface - nitrate, crystalline, amino acids or humics)	500.00	500.00	500.00	500.00	500.00	500.00
irrigation (+electricity network)	250.00	250,00	250,00	250.00	250.00	250.00
Chemical control (prevention of pests & diseases)	500.00	500.00	500.00	500.00	500.00	500.00
Foreign labor (10 salaries/ha)	250.00	250,00	250,00	250.00	250.00	250.00
Harvesting	1,010.40	1,010.40	1,010.40	1,010.40	1,010.40	1,010.40
Transport (+ depreciation)	585.00	585.00	585.00	585.00	585.00	585.00
Impairment due to quality defects and impurities (5%)	307.96	324.17	162.08	291.80	307.96	307.96
Total expenses	***5,926.86***	***5,880.57***	***5,637.48***	***6,417.19***	***6,259.36***	***5,999.16***
Revenues						
Gross Production Value	***6,159.23***	***6,483.40***	***3,241.70***	***5,835.96***	***6,159.23***	***6,159.23***
Net revenue	***232.36***	***602.83***	***-2,395.79***	***-581.24***	***-100.13***	***160.06***
Benefit/Cost Ratio	***1.04***	***1.10***	***0.58***	***0.91***	***0.98***	***1.03***
Ranking	*(2)*	*(1)*	*(6)*	*(5)*	*(4)*	*(3)*

Scenario 1 (weed control): *46€/ha for the pre-transplanting herbicide, 37.5€/ha for the post-transplanting herbicide plus 60€/ha for the application of both herbicides*

Scenario 2 (weed control): *51€/ha for the pre-transplanting herbicide plus 30€/ha for the application*

Scenario 3 (weed control): *no weed control*

Scenario 4 (weed control): *200€/ha for two cultivations plus 450€/ha for two hand weedings*

Scenario 5 (weed control): *350 €/ha (mulch value), 96€/ha for the post-transplanting herbicide plus 30€/ha for application*

Scenario 6 (weed control): *155.8€/ha for the two post-transplanting herbicides plus 60€/ha for the application of both herbicides*

**Assuming that the efficiency of the basic scenario (scen.2) is 6,483.4€/ha (84.2tn/ha x 77€/tn). According to ABAF (2013); Patrap et al. (1997); Viggiani and Dellacecca (1998) & Kati et al. (2012) the weed control of the third scenario has resulted in a product reduction of around 50%. The weed control of first, fifth and sixth scenarios (ABAF, 2013; Masiunas et al., 1995; Schonbeck, 1999) has resulted in a product reduction of around 5% and the weed control of fourth scenario (ABAF, 2013; Masiunas et al., 1995; Schonbeck, 1999) has resulted in a product reduction of around 10%. The herbicides values and their cost of application have been calculated according to the report of Giannopolitis (2012).*

Based on the used data and authors calculations, total expenses of processing tomato production (excluding weed control and impairment expenses) are equal to 4,975.4€/ha, namely: crop care (200€/ha), seed (1,000€/ha), labor plus depreciations (180€/ha), fertilization (1,000€/ha), irrigation plus electricity network (250€/ha), 10 salaries/ha foreign labor expenses (250€/ha), transportation (585€/ha), harvesting (1,010,4€/ha) and chemical control (500€/ha). Also in the category of revenues (benefits) has been included only the gross commercial value of the product, which ranges from 3,241.7€/ha to 6,483.4€/ha (depending on the weed control method).

Taking into account that the mean size of a typical Greek processing tomato farm is almost 8ha (ABAF, 2013), some economies of scale have been expected that may reduce the average cost to some extent (Guenthner et al., 1999). However, these economies of scale are not taken into account in this analysis and they do not affect comparative analysis as among different scenarios no difference was assumed (Fuguitt and Wilcox, 1999). Thus, Table 2.7 illustrates gained revenues at country level (around 4,882ha).

Table 2.7. Generalization of net revenues at country level

Scenarios	**Net Revenue**
Scenario 1: Pre-transplantingbroadleafherbicide (oxadiazon) pluspostransplantinggrassherbicide (fluazifop)	1,134,381.52
Scenario 2 (basic scenario): Pre-transplanting residual broad spectrum herbicide pendimethalin	2,943,016.06
Scenario 3: Cultivation without weed control	-11,696,246.78
Scenario 4: Inter-row cultivations plus hand weeding on rows (organic production)	-2,837,613.68
Scenario 5: Weed control with mulch on rows plus post transplanting (metribuzin+ rimsulfuron)	-488,834.66
Scenario 6: Post transplanting: two herbicide applications (rimsulfuron and metribuzin+ rimsulfuron)	781,412.92

Having a look at both tables (2.6 and 2.7), intriguingly only three out of six scenarios yield a positive revenue manifesting how pivotal is a well designed weed control plan. However, still the use of pendimethalin may bring about substantial benefits (scenario 2). In addition, the first and the last scenarios also show positive net benefits although much smaller than the basic scenario (scenario 2), while all the rest scenarios yield negative outcome.

According to the Map 3 (see Appendix) for the most important cotton production areas in Greece (Central Greece, Northern Greece and Western Peloponnese) generalization results of farmers' net revenues by geographic region can be calculated (Figure 2.7). In this figure, benefits of chemical weed control, and especially of pendimethalin, which are higher for Central and Northern Greece are clearly illustrated.

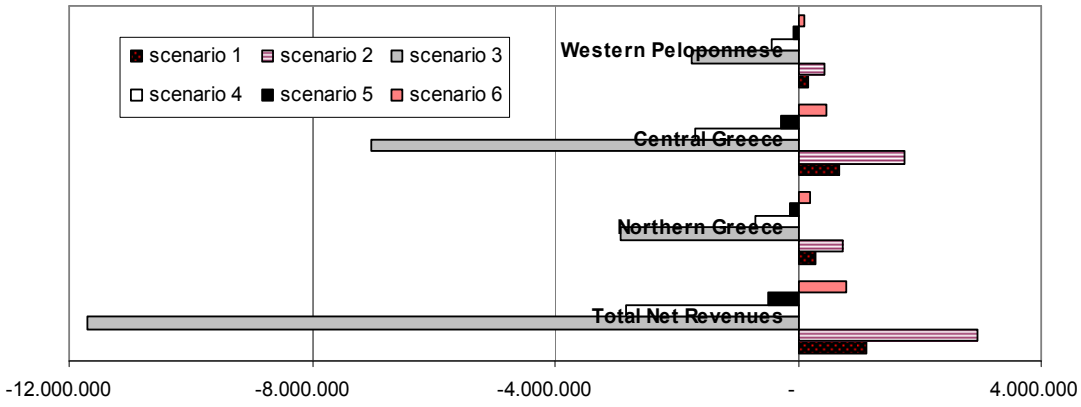


Figure 2.7. Generalization of net revenues (€) by geographic region

The only one of the scenarios which includes the application of pendimethalin in the cultivation of processing tomato is the second one (basic). In an attempt to quantify the withdrawal effects of the use of pendimethalin the data of the following figure 2.8 have been calculated per hectare. Thus, in a hypothetical case of pendimethalin withdrawal the best alternative scenario, based on the economic results, is the first one. **According to this scenario the withdrawal of pendimethalin use could cause: a) a loss of the net revenue by 370€/ha, b) a loss of the gross production value by 324.17€/ha and c) a loss of the production quantity by 4.21tn/ha.** And this means that the whole Greece a loss of €6.5 million (370 €/ha x 4,882 ha ≈ €1.8).

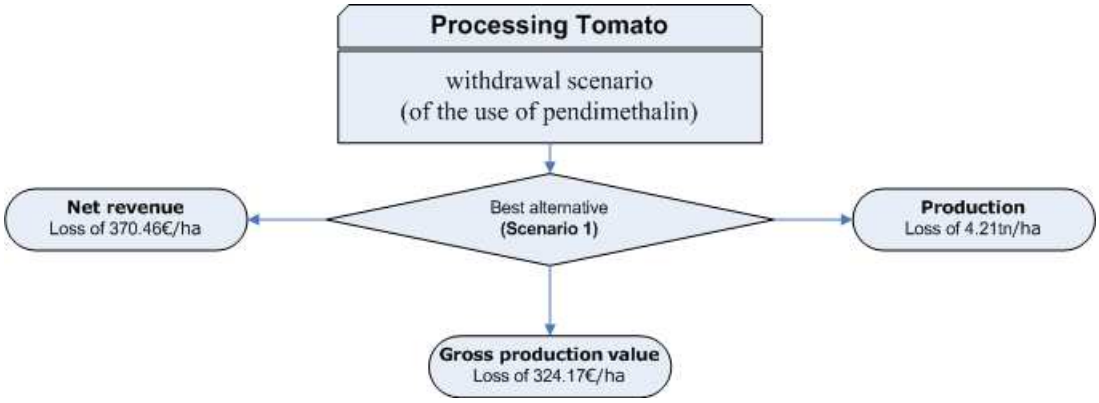


Figure 2.8. Withdrawal effects of the use of pendimethalin

Same methodology, used in onion and cotton, can be used to extrapolate benefits at regional and country levels incorporating the multiplier's effect. Nevertheless, someone can argue that a) truly benefit in this cultivation have reached at the lower level mainly if non-attractive and trending downwards, b) the level of occurred benefits and the allocation of the crop, small region, would restrict the validity of a multiplier's effect.

Conclusively, it can be stated that under those conditions availability of pendimethalin and other effective herbicides support very much the crop to be turned to a profitable one.

It is also worth noting that the expenses for herbicides are only a small part of the total production expenses (around 2%). On the other hand, under the existing conditions the processing tomato cultivation without chemical weed brings no net revenues (Creamer et al., 1996). Especially in the second scenario (basic), of using pendimethalin, the net benefits are increased even more.

Chapter 3

Concluding remarks / highlights

From the above analysis it is clear that the withdrawal effects of pendimethalin per hectare are more important for the growers of domestic dry bulb onion and subsequently for the growers of domestic processing tomato than for the growers of domestic cotton (figure 2.10). However, considering the extensive cultivation of cotton and the use of pendimethalin, the multiplier's effect in cotton cultivation, is much higher for the economy of the whole Greece and the regional economies (especially for the regions of Thessaly, Macedonia and Easter Sterea).

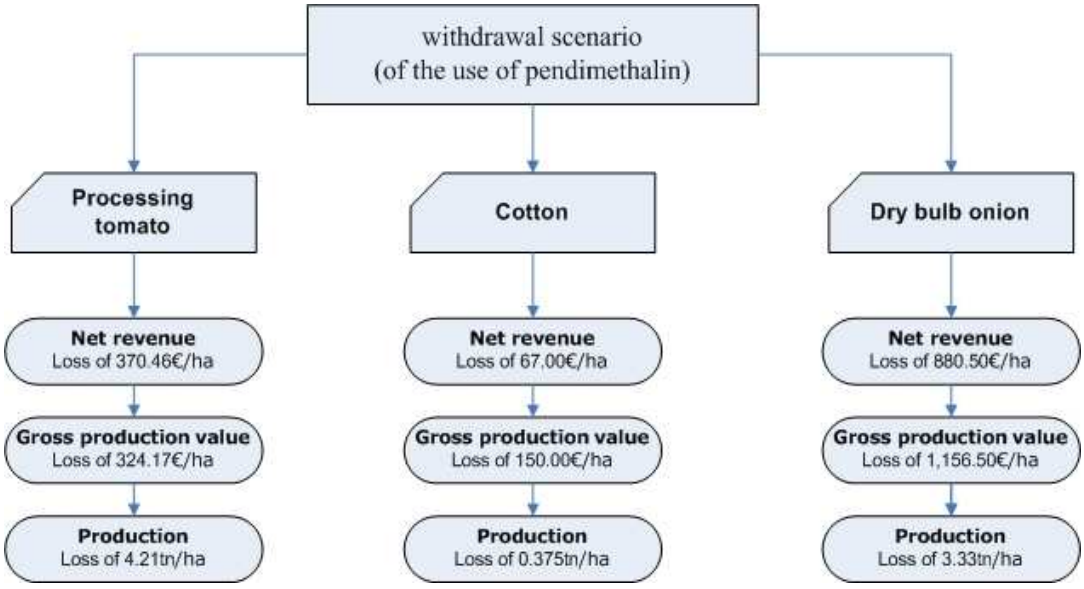


Figure 2.10. Withdrawal effects of the use of pendimethalin

Additionally, some important conclusions from this analysis are the following:

- Although the use of chemicals is not always unique, herbicides are important and effective components of any weed control program.
- In the examining crops (cotton, onion and processing tomato) herbicides offer the only practical, cost-effective and selective method of managing weeds.
- Pendimethalin is a unique low cost herbicide especially effective (pre-emergence or pre-seeding).

- In all three crops pendimethalin can provide good and acceptable benefit/cost ratios in weed management efforts.
- Pendimethalin use is associated with the highest revenue yielding scenario for all three crops.
- Pendimethalin use offers unique advantage in managing weeds particularly for onion and cotton crops.
- A hypothetical withdrawal of the use of pendimethalin in these three typical crops in Greece could bear significantly losses both for farmers and regional economy.
- Benefits at regional level are extremely high when pendimethalin use scenario is extrapolated to the whole region. This is mainly because of the income multiplier's effect and the recurring of benefits (at no additional cost).
- Results derived from technical analysis are fully in line with the results derived from experts/farmers interviews for the cotton and onion cultivation.

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APPENDIX

1. Stakeholders' questionnaire

2. Farmers' questionnaire

3. Maps

1.

Questionnaire on stakeholders' reflections, beliefs and attitudes towards Pendimethalin herbicide

(addressed to specialists, agronomists, and consultants in cotton and processing tomato industry)

1. To what extent Pendimethalin is used by farmers?

.....

2. Do you believe that Pendimethalin is more effective compared to other weed control practices?

.....

3. Do you believe that Pendimethalin is more effective compared to other herbicides?

.....

4. In which of the following crops you think is more effective?

- ☐ Cotton
- ☐ Industrial tomato
- ☐ Onion
- ☐ Other ....

5. In which of the following crops you think is most appropriate?

- ☐ Cotton
- ☐ Industrial tomato
- ☐ Onion
- ☐ Other ....

6. Do you believe that Pendimethalin can be used effectively in other crops?

.....

7. Why do you think Pendimethalin is widely applied to these crops?

.....

8. Do you believe that the use of Pendimethalin affects crop yields?

- ☐ Too much
- ☐ Much
- ☐ Moderate
- ☐ Little
- ☐ Not at all

9. The use of Pendimethalin affects / improves production by:

- ☐ Quality
- ☐ Appearance
- ☐ Yield
- ☐ Flavor
- ☐ Uniformity
- ☐ Quantity
- ☐ Other .....

10. The use of Pendimethalin affects production costs? YES NO

11. The use of Pendimethalin affect the environment? YES NO

If YES , how? .....

12. Do you believe that it is dangerous for producers' health? YES NO

If YES, why? .....

13. Do you believe that it is dangerous for consumers' health? YES NO

If YES, why? .....

14. What percentage of farmers use Pendimethalin in cotton crops / industrial tomato / onion ?

.....

15. Do you believe that farmers use it properly , taking the appropriate precautions?
YES NO

.....

16. Do you believe that farmers are satisfied with the use of Pendimethalin;
YES NO

.....

17. Is there a good collaboration between you and pendimethalin provider company, concerning:

- ☐ Addressing potential problems / questions use of Pendimethalin
- ☐ Directives / Clarifications on the use of Pendimethalin
- ☐ After Sales Support
- ☐ Promotions
- ☐ Payment facilities
- ☐ Other .....

18. SCENARIOS

A. Suppose Pendimethalin herbicide withdrawn from the market. What do you think will be the impact on cotton crop.

- ☐ Downgrade quality
- ☐ Reduction in yields
- ☐ Increase in production costs
- ☐ Decrease agricultural income
- ☐ Reduction in cultivated area
- ☐ Abandonment of cultivation
- ☐ No effect on crop
- ☐ Using other herbicide (substitute)
- ☐ Application of other weed control techniques
- ☐ Other .....

B. What are the alternatives for weed control in cotton crops after withdrawal of Pendimethalin;

……
……
……
……
……

C. Suppose Pendimethalin herbicide withdrawn from the market. What do you think will be the impact on processing tomato crop.

- ☐ Downgrade quality
- ☐ Reduction in yields
- ☐ Increase in production costs
- ☐ Decrease agricultural income
- ☐ Reduction in cultivated area
- ☐ Abandonment of cultivation
- ☐ No effect on crop
- ☐ Using other herbicide (substitute)
- ☐ Application of other weed control techniques
- ☐ Other .....

D. What are the alternatives for weed control in processing tomato crops after withdrawal of Pendimethalin;

……
……
……
……
……
……
……..

E. Suppose Pendimethalin herbicide withdrawn from the market. What do you think will be the impact on onion crop.

- ☐ Downgrade quality
- ☐ Reduction in yields
- ☐ Increase in production costs
- ☐ Decrease agricultural income
- ☐ Reduction in cultivated area
- ☐ Abandonment of cultivation
- ☐ No effect on crop
- ☐ Using other herbicide (substitute)
- ☐ Application of other weed control techniques
- ☐ Other .....

F. What are the alternatives for weed control in onion crops after withdrawal of Pendimethalin;

……
……
……
……
……

2.

Questionnaire on farmers' reflections, beliefs and attitudes towards Pendimethalin herbicide

(addressed to cotton, onion and processing tomato farmers)

A. Personal Data

1. Gender: Male☐Female☐
2. Age:……..
3. Education
   - ☐ No formal education
   - ☐ Primary school graduate
   - ☐ High school graduate
   - ☐ Technical school graduate
   - ☐ University graduate
   - ☐ Other (specify)……..
4. Marital status
   - ☐ Married
   - ☐ Single
   - ☐ Divorced
   - ☐ Widow
   - ☐ Other (specify)……..
5. Household size:.....……

B. Farm/enterprise data

1. How many years are you involved in agriculture? …….
2. How many acres do you cultivate? ……..
   Owned ……..
   Rented ……..

3. Which crops you cultivated during 2012-2013?

Crop	Total area (ha)	Irrigated area (ha)	Non irrigated area (ha)

4. How many and which members of your household are employed in the farm?

Permanent	Seasonal

5. Do you employ foreign workers in your farm?

YES☐NO☐

6. If YES: how many are employed seasonally and how many permanently?

Seasonally…… Permanently……..

7. Do you receive income from out of farm activities?

YES☐NO☐

8. IfYES: what activities?

☐employment in another farm
☐non-agricultural employment
☐land rental
☐house/shop rental
☐pensions
☐Other (specify)……

9. What percentage of your family income comes from agriculture?

☐over 50%

☐ under 50%
☐ 50%

C . Attitudes and beliefs towards herbicides use

1. Which weed control methods do you apply in your farm?

☐ carving-hoe
☐ cover the soil surface with plastic
☐ use of herbicides
☐ other (specify)……..

2. Which are the main reasons you use herbicides in your farm?
☐ is more effective compared to other methods of weed control
☐ is easier to use
☐ contribute to the improvement of production quality
☐ contribute to higher yields
☐ is of a lower cost compared to other methods of weed control
☐other (specify)……..

3. Do you use the herbicide Pendimethalin?

YES☐NO☐

4. If YES, in which crops?

Crop

5. Which are the main reasons for using Pendimethalin?

☐ is more effective
☐ controls all the weeds
☐ is easier to use
☐ improves production quality
☐ contributes to higher yields
☐ is cheaper compared to other herbicides
☐ is friendly to the environment
☐ other (specify)……..

6. Which are the main reasons for not using Pendimethalin?

☐ is more expensive compared to other herbicides
☐ is not very effective
☐ has an impact on the environment
☐other (specify)……..

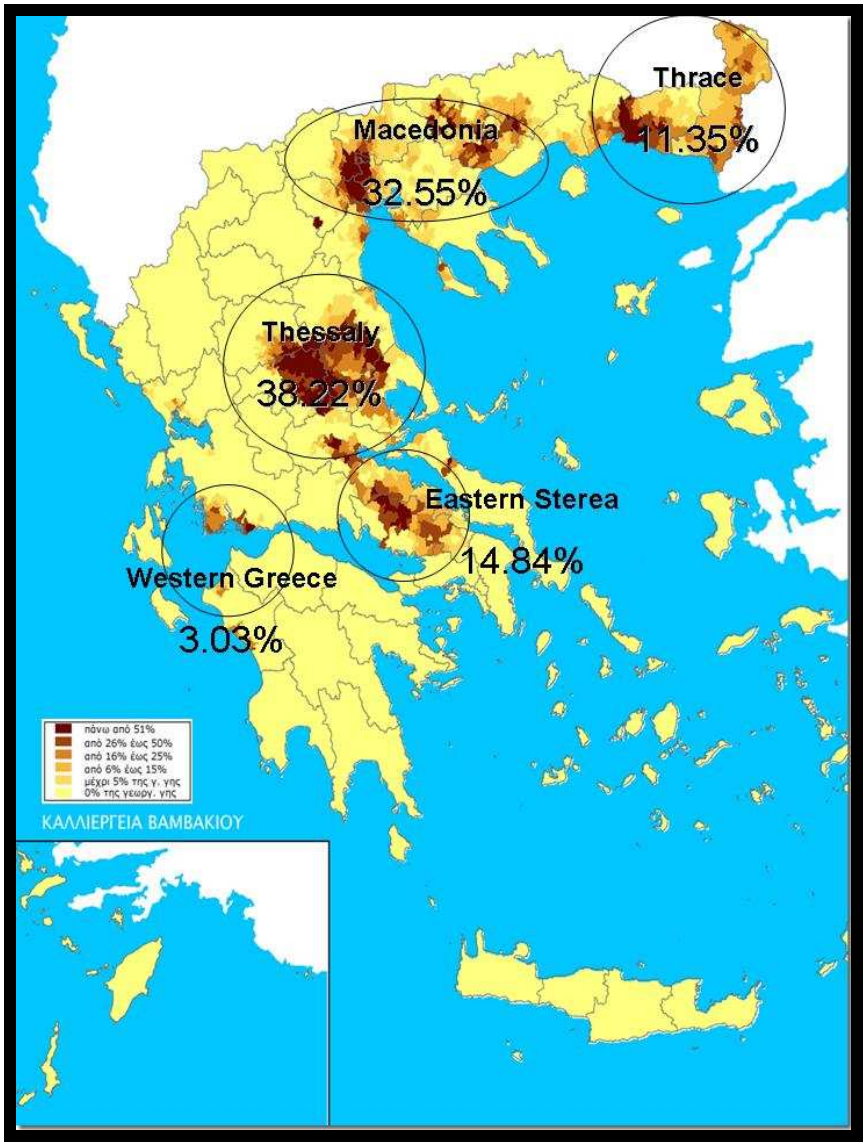
7. Do you believe that Pendimethalin use affects:

	negatively	no effect	positively
Soil quality			
Development of cultivated plant			
groundwater			
Aboveground water			
Fauna and flora			
Farmers' health			
Consumers' health			
Farmers' income			

8. SCENARIO
Suppose there is a lack of herbicide Pendimethalin in the market and you cannot use it in your crops for weed control. What do you think will be the consequences?

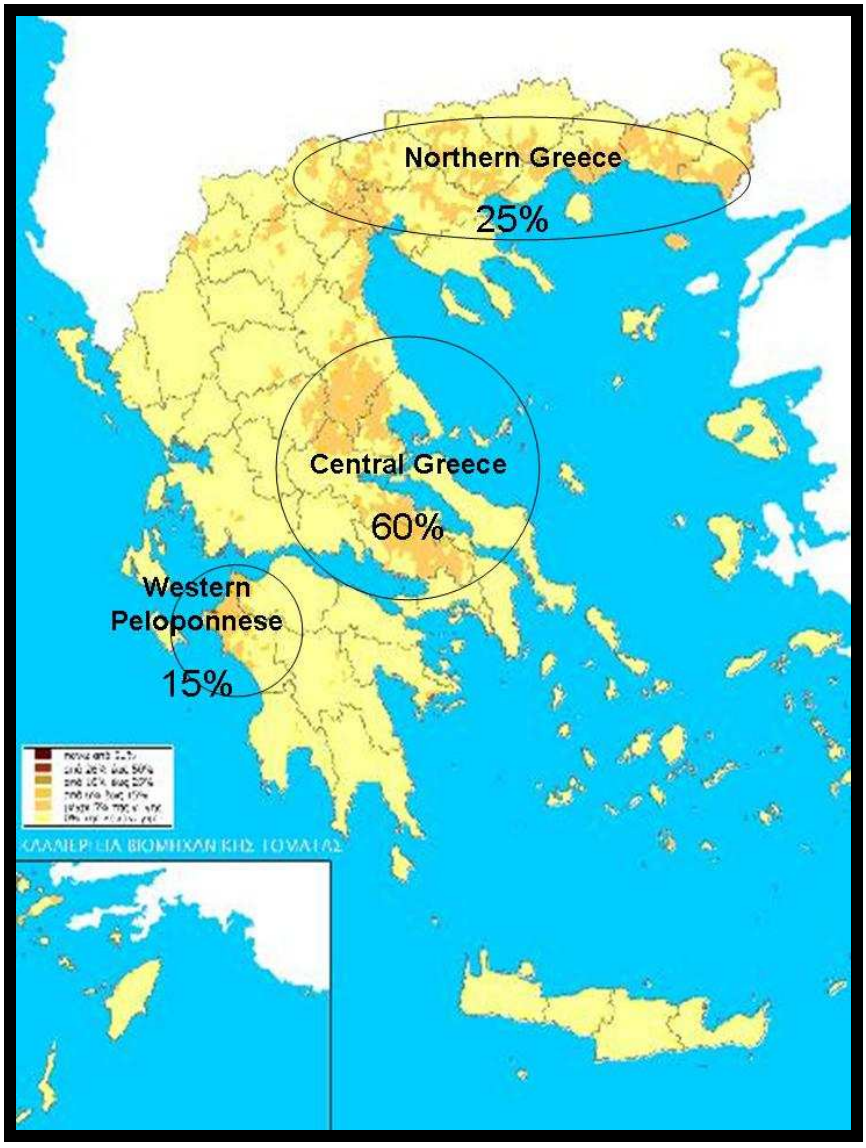
☐ downgrade product quality
☐ reduction in yields
☐ reduction in cultivated area
☐ crop abandonment
☐ no effect on crop
☐ use a substitute herbicide
☐ weed control by hoeing
☐ use alternative weed control methods
☐ increase production cost
☐ reduce farmers' income
☐ consult of agronomists about alternative weed control methods
☐other (specify)…….

3. MAPS



Map 1. Map of domestic cotton cultivation (OPEKEPE, 2012)

Map 2. Map of domestic dry bulb onion cultivation (ELSTAT, 2007)



Map 3. Map of processing tomato cultivation (ELSTAT, 2007)

WP 14-03

Aristotle University of Thessaloniki

School of Agriculture

Department of Agricultural Economics