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RESEARCH ARTICLE

STUDY OF CURRENT STATUS AND FUTURE PROSPECTS OF SOIL DISINFECTION IN SOUSS-MASSA AND GHARB- LOUKKOS (MOROCCO)

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ABSTRACT

This quantitative study to approach the current state of soil disinfection use in understanding the mechanisms and list of the used products via a duly defined questionnaire. The various answers of approached farmers, following surveys in the region of Gharb-Loukkos and Souss-Massa respectively, main areas for strawberries and tomatoes crops, have shown that chemical disinfection is almost universal in both regions (respectively 97% and 98%) and using mainly Metam sodium and Dichloropropene 95% to 70%. The farmers percentage intending using alternatives to chemical disinfection, in the region of Souss Massa (solarization, composts, plant extracts and micro-organisms, especially green organic matter) is 73% while it is only 7% in the region of Gharb and Loukkos. Actually, there is no pressing interest for organic disinfection, only 73% of farmers in the region of Souss Massa think about this issue while those of Gharb-Loukkos do not even know. Thus, the adopted alternative product is Dazitol at 47% in Souss Massa area. 80% of farmers in the Souss-Massa and all those of Gharb and Loukkos are willing to pay the organic product at a price equal to the chemical one.

INTRODUCTION

Morocco, with an agricultural area of almost 8.7 million hectares, is a strong wealth agro climatic system that allows it to produce a wide range of products. In addition to its contribution to the economy by nearly 14%, its socioeconomic impact is important, grace in particular to its ripple effects upstream agricultural inputs and downstream by the agribusiness and through final household consumption. This area is dominated by cereals to 65% and only 3% is for the gardening. Thus, about 15 000 ha are occupied by tomato and 3300 ha by strawberry (Anonymous, 2013). Tomato cultivation occupies an advanced leadership in the agricultural economy export-oriented place with over 5,000 ha under protected greenhouses in the Souss-Massa mainly. The production reached 750,000 tons, of which 350,000 tons were exported in 2011-2012 (Anonymous, 2013). The cultivation of strawberries is well established and developed in the Gharb region and perimeter Loukkos. A study performed by the INRA Kenitra showed that exports rose 5,000 tonnes in 2005 to over 30 000 tonnes in 2008 (El Kharrazi, 2010). Each culture has its phytosanitary constraints: Abiotic and biotic contrains exert significant pressure on the plant health and even on its survival. It is not strange that the majority, if not all fruit and vegetable producers are facing these problems, obliged to treat planting bed culture in advance: either disinfect their soil. This disinfection has experienced several rebounds from the first uses of methyl bromide over 80 years until its banishment in the past decade and its permanent ban recently. The objective of this work is to know the situation of using these disinfectants in areas of Loukkos Gharb and Souss-Massa, studying current chemical uses, and the timid inserts of biological disinfectants then draw a conclusion about the possible trend to replace the chemical by organic in the medium and long term to satisfy the need of the consumer health and protect the environment.

MATERIALS AND METHODS

Geographic data on the two study areas

The two main areas are each known by the practice of the targeted culture. The strawberry plant is grown exclusively in the Gharb region and the perimeter of Loukkos. The tomato cultivation is practiced intensively in the Souss- Massa region Gharb and Loukkos regions are located in the northwest of the country. The agricultural area in the Gharb region is 576 445 ha. The climate is Mediterranean with oceanic influence. The rainfall varies from 430 to 480 mm and average temperatures

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are 13°C in winter and 27°C in summer (Anonymous, 2008). The situation on the Atlantic coast and in the northwest of the country and the variability of its relief give the perimeter Loukkos a Mediterranean climate with a strong oceanic influence. The average annual rainfall varies from 600 mm at the coastal strip and the lower valley of Loukkos to 1800 mm in the high reliefs of Loukkos basin. The average temperature ranges between 16 and 19°C with a minimum in January and maximum in August. The average evaporation is estimated at nearly 1450 mm (Anonymous, 2015a). Souss Massa region was located in the geographical center of Morocco between the Atlantic Ocean and the mountains of the High Atlas and Anti Atlas and covered an area of approximately 23,950 km². The two main plains are the Souss valley (4,150 km²) and the plain of Chtouka (1,260 km²). The climate of the region is arid to semiarid; it varies from wet, cold winter on the peaks of the High Atlas Occidental pre-Saharan with fresh winter in the plains. The proximity to the ocean and the influence of cold Canary Current mitigate climate of the area and the mountainous barrier of the Anti-Atlas contributes to the protection against the southern winds. Average annual temperatures range from 14°C on the High Atlas to the north to 20 °C on the Anti-Atlas in the south. The minimum and maximum daily temperatures respectively reach -3°C and 49°C. Rainfall has high spatial and temporal variability. Averages of rainfall l of the order of 280 mm on the Souss, 265 mm on the Massa, 390 mm in the Tamraght basin and 370 mm in the Tamri basin (Anonymous, 2015b).

Table 1 Farmers sampling in the two study areas

Area souss massa		
City	**Location**	**Farmers**
Biogra	Takkad	3
	Ouelad essaf	1
	Biogra	7
Ait Melloul	Sidi bibi	5
	Koleaâ	2
	Ouelad dahhou	1
Agadir	Temsia	3
	Sebt ait malek	2
	Khmiss	1
	Taddart	6
Ait amira	Oughras	1
	Ait boutayder	1
	Khmiss	4
	Ait amira	4
Belfaâ	Belfaâ	2
Berhil	Berhil	1
Total		44
Gharb et du Loukkos Areas		
City	Location	Farmers
Moulay Bousselham	Dlalha	5
	Ouelad okayel	10
	Chouafaâ	3
	Gnafda	1
	Laânabssa	6
	Karya	5
	Ksakssa	1
	Zaouia	2
	Drader	1
	Ouelad mesbah	1
Larache	Zlaoula	1
	Ouelad hammou	1
	Laghdira	2
	Boucharen	1
Total		40

Surveys

Between April and June 2013 Surveys were conducted in different locations of the Gharb-Loukkos and Souss Massa regions of covering respectively 40 farmers and 44 farmers. The farmers sampling was done randomly (Table 1).

Quantitative Study

A survey is conducted among farmers about soil fumigation prior to planting Strawberry and Tomato. This quantitative study was based on a questionnaire (Table 2) entitled: "Situation of chemical soil disinfection of two crops tomato and strawberry and search for alternative means in the regions of Gharb- Loukkos and Souss Massa".

Statistical Analysis

The obtained results were processed by the software Excel

RESULTS

The surveys in the Souss-Massa and Gharb Loukkos regions and have achieved quantitative study based on a questionnaire to farmers in both regions. Analysis of the responses was used to assess the state status of chemical soil disinfection of two vegetable crops (tomato and strawberry) and farmers' knowledge about alternative methods and their willingness to use them. In the Souss-Massa three quarters of the visited farms, farmers said their main crop is tomatoes, followed by other crops as beans, peppers and cucumbers (Figure 2A) while farms in the Gharb and Loukkos were almost majority of farms producing strawberries (Figure 2B). Thus, the choice of crops "tomatoes" and "strawberries" was very helpful, and that whatever the choice is random, the representativeness of the two cultures is significant. The previous crop is the same in almost three quarters of the solid investigation objects, the practice of growing tomatoes on tomato in the Souss-Massa (Figure 3A) or the strawberry on strawberry in the Gharb and Loukkos (Figure 3B), which further increases the risk of soil contamination. A quarter of farmers are turning to the bean, melon, pepper, banana, eggplant and zucchini in the Souss - Massa and to potatoes, salads, peanuts and cereals in the Gharb and Loukkos. Disinfecting the soil prior to planting is essential in almost all the surveyed farms: less than 3% of farmers in the two regions considered this non-necessary practice (Figure 4). Indeed, it appears from the investigation of the differences between farmers consideration of both regions on the purpose of disinfection. In the Souss- Massa region, the aim is to counteract the damaging effects of three pathogens types, namely nematodes, bacteria and fungi, while in the Gharb and Loukkos, nematodes and fungi are feared first. However, in both regions nematodes are for farmers the first enemy to treat against. Weeds are not a concern for them (Figure 5). An important result from this study, it is a difference in the approach to the problem of soil disinfection between the two regions, manifested in the identification of the pathogen to treat against. Thus, 39% of farmers in the Souss-Massa region are doing soil tests to determine these pathogens, especially nematodes (Figure 6A), and only 5% of the Gharb- Loukkos region performed these tests (Figure 6B). Disinfection is

practiced in the fall by 73% of the farms in the Souss-Massa region (Figure 7A) and 98% of farms in the Gharb-Loukkos (Figure 7B). 100% of the interviewed farmers in both regions responded that soil preparation is required prior to disinfection. In addition, the technical route used by all farmers are plowing, spreading manure and irrigation. Thus, the most widespread disinfectant in the Gharb-loukos region is Metam sodium at 95% (Figure 8B) while dichloropropene is used by 70% of farmers in the Souss- Massa region (Figure 8A). The mode of treatment with disinfectants used by 100% of farmers in the Souss-Massa region and 97% in the Gharb-Loukkos is injected into the irrigation system of the plots. A low percentage has used the method of incorporation in the latter region (Figure 9). In the Souss Massa region, for tomatoes production, the soil desinfection cost is between 8000 dirhams and 25 000 Dirhams per hectare with a total income of 70 000 to 500 000 Dirhams per hectare giving a unit cost of 1.00 dirham up to 5.00 Dirhams per kilo of tomatoes. While in the Gharb – Loukkos region, for strawberries, the soil desinfection cost is between 2500 and 20 000 Dirhams , with a total income of 60 000 to 320 000 Dirhams per hectare and a unit production cost of 2,00 to 8,00 Dirhams a Kilo. The sensitivity of the farmers in the region of Gharb and Loukkos regarding the dangers of toxic residues is not widespread, 90% of surveyed farmers are aware of the seriousness of the situation. In the Souss-Massa, 100% of the farmers are aware of the chemical disinfection dangers and the presence of residues and their effects on health and the environment (Figure 10). Thus, the idea of using alternative products for healthy soil disinfection is adoptable in both areas. The use level of alternative techniques to chemical disinfection is very interesting in the Souss-Massa, 73% of farmers have used them to avoid the use of chemicals while it remains low in Gharb region and Loukkos where only 7% of farmers said they have used them. (Figure 11A and 11B) Among the alternative techniques with chemical disinfectants which farmers have used, there are mainly three: solarization, composts- plant extracts and micro-organisms. The use of green organic material made appearance in the Souss-Massa (Figures 12 A and 12B). However, the purpose sought by the use of these alternatives and satisfaction show different farmers opinions between the two areas on the observed diseases and nematodes, while both areas expressed satisfaction on the growth and yield (Figure 13A and 13B). All farmers in the region of Gharb and Loukkos who have previously said they used alternative techniques to chemical soil disinfection found an efficiency of the used method. Satisfaction level of 75% was observed among farmers in the use of alternative techniques in the Souss-Massa (Figure 14). It seems that the desire to find an alternative chemical is present in the minds of farmers in both regions (Figure 15A and 15B). But as for wanting to achieve this, 73% of farmers in the region of Souss-Massa already did, while those in the region of Gharb and Loukkos have not even thought about it yet (Figure 16). Thus, the used products as alternative: Dazitol adopted at 47%, followed by BIOACT product and Nemagold 17% and 12% respectively (Figure 17).

In addition, among farmers who used alternatives, the degree of satisfaction compared to chemicals is 43%. The reasons of the dissatisfaction of other farmers are "limited biological disinfection results" (Figure 18). Also, 86% of farmers in the Souss-Massa area were for biological disinfection, while only four of those surveyed farmers of the Gharb-Loukkos region are aware of the importance of this technique , others were unconcerned (Figure 19). Farmers are aware of the toxical waste dangers by the different actors of the supply chain of tomato and strawberry. Thus, traders, overseas buyers, production and packing stations are top of the list to aware farmers in both regions while the external services of the Ministry of Agriculture and scientists are recessed (Figure 20A and 20B).

Regarding soil disinfection cost, farmers can choose the use of organic products instead of chemical disinfectants as following

- 80% of farmers in Souss-Massa and all those of Gharb and Loukkos are for a price equal to the chemical (Figure 21).
- At a price 25% higher, 67% of farmers in the region of Souss-Massa are for disinfection despite the price difference , while only 7% would accept this difference in the Gharb region and Loukkos .(Figure 22A and 22B)
- At a price 50% more expensive, only 32% of farmers would accept it in the Souss-Massa against 13% in the region of Gharb and Loukkos (Figure 23A and 23B).
- Most of the farmers have shown a general predisposition to conduct trials with organic products, a low percentage would be against these tests (Figure 24A and 24B).
- The preferred method of providing the disinfectant is injected into the irrigation system substantially in the two regions (Figure 25A and 25B).
- 90 days persistence of the product in the soil is required by 64% of farmers in the Souss Massa and 76% in the Gharb-Loukkos, while the 60 days is required by 24% of respondents in Souss-Massa and only 5% in the Gharb-Loukkos , the 30 days can be accepted by 12% of farmers in the Souss-Massa and 19 % for Loukos-Gharb (Figure 26A and 26B).

Only 15% of farmers surveyed in the Souss Massa region said they have already visited organic disinfected farms (Figure 27). Thus, the regions visited by farmers in Morocco are: Ait Baha; Chtouka and Belfaa while Spain is the main foreign visited country. Commercial products used to disinfect the soil are: Dazitol - RMG - Nemassim – biofumigant and Green solution. Among the farmers who visited farms in Morocco and abroad, only 9 % of farmers are met by biological soil disinfection in visited farms.

Figure 1 Geographical situation of two study areas (A) Gharb-Loukkos (B) Souss-Massa

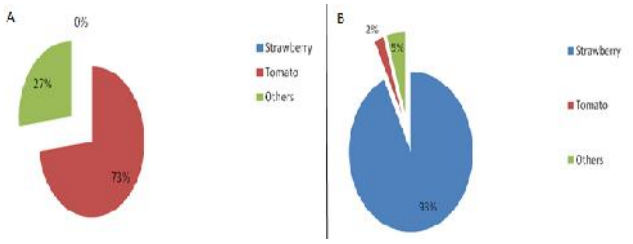

Figure 2 Crops in the visited farms in Souss-Massa (A) and Gharb-Loukkos (B) in 2013

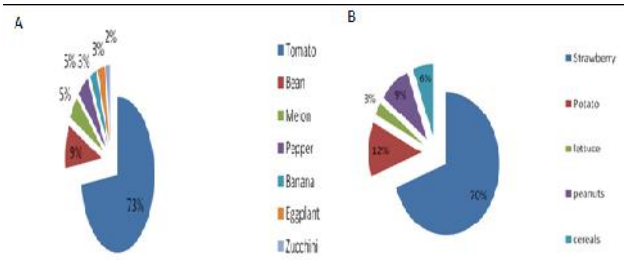

Figure 3 Previous crops in the visited farms in Souss-Massa (A) and in Gharb-Loukkos (B) in 2013.

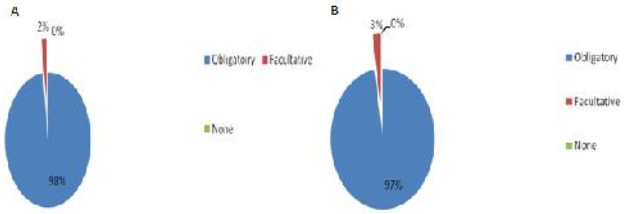

Figure 4 Chemical soil disinfection in the visited farms in Souss-Massa (A) and in Loukkos-Gharb (B).

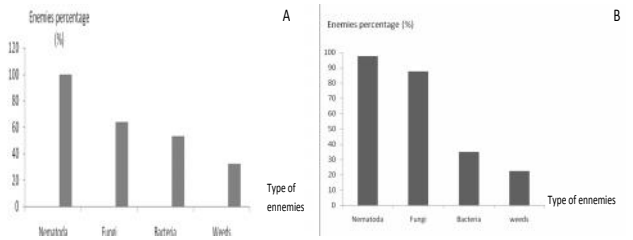

Figure 5 Targeted crop enemies in Souss-Massa (A) and in Gharb-Loukkos (B).

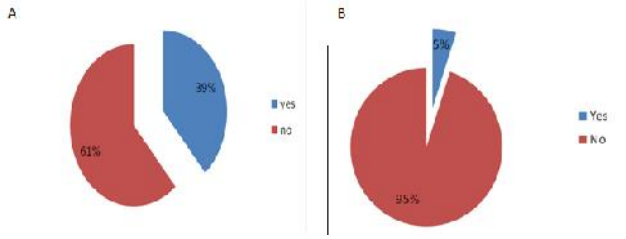

Figure 6 Soil analysis prior to disinfection in Souss-Massa (A) and Gharb-Loukkos (B).

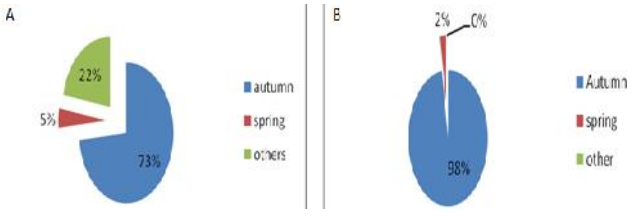

Figure 7 Period of disinfection in the year in Souss-Massa (A) and Gharb-Loukkos (B).

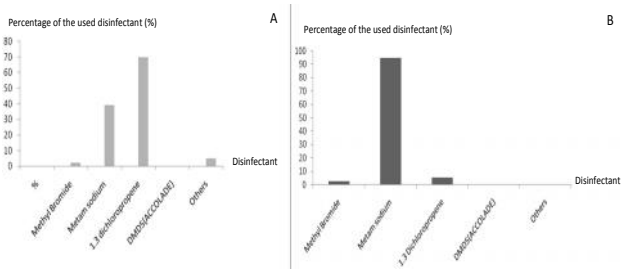

Figure 8 Percentage of the used disinfectants in SoussMassa (A) and Gharb –Loukkos (B).

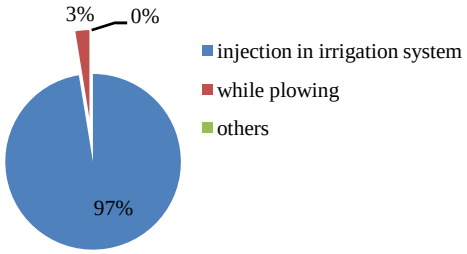

Figure 9 Way of disinfectant application in Gharb-Loukkos

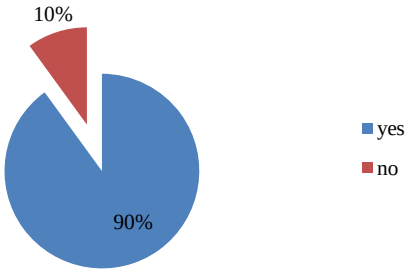

Figure 10 Knowledge of chemical threats in Gharb-Loukkos

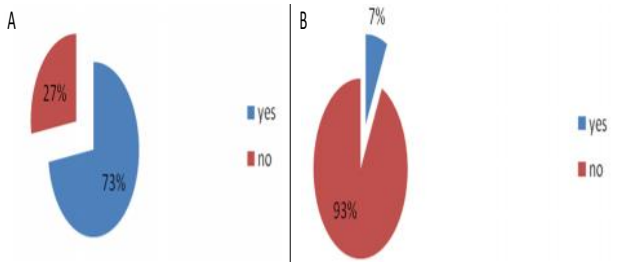

Figure 11 Intention to use alternatives to chemical disinfectants Souss-Massa (A) and in Gharb-Loukkos (B).

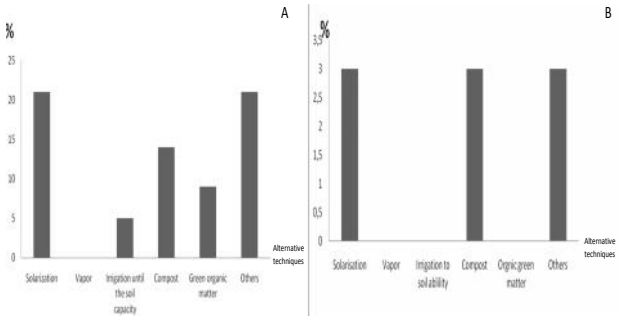

Figure 12 Percentage of technical alternatives to chemical soil disinfection in Souss-Massa (A) and in Gharb-Loukkos (B).

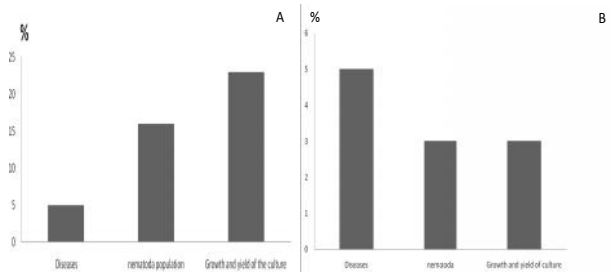

Figure 13 Efficiency of alternatives in use on crop enemies in Souss-Massa (A) and Gharb-Loukkos (B).

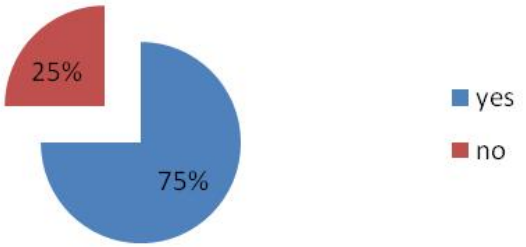

Figure 14 Efficiency of alternatives satisfied farmers in Souss-Massa

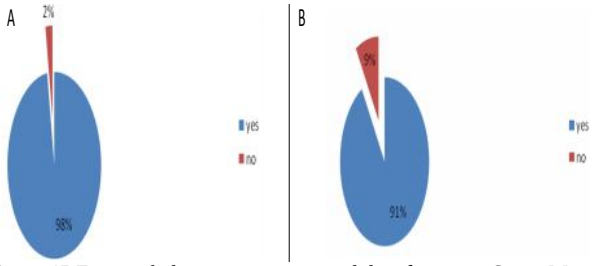

Figure 15 Farmers believing in organic soil disinfection in Souss-Massa (A) and Gharb – Loukkos (B).

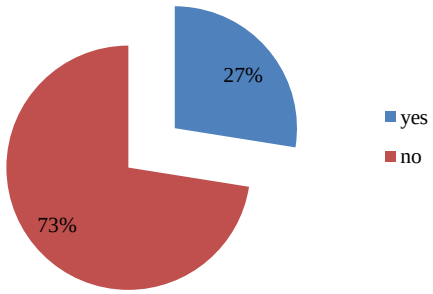

Figure 16 Farms tried using organic disinfection in Souss-Massa

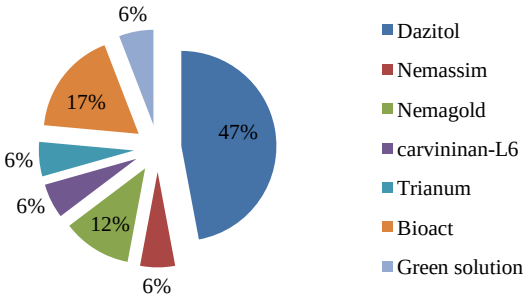

Figure 17 Common organic products used in Souss-Massa

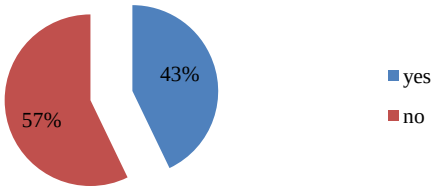

Figure 18 Level of satisfaction in Souss-Massa

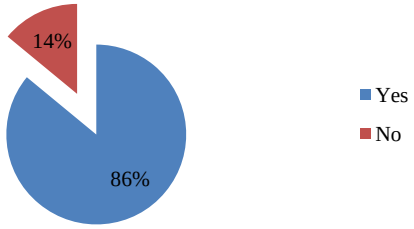

Figure 19 Intention to use organic alternatives in Souss-Massa

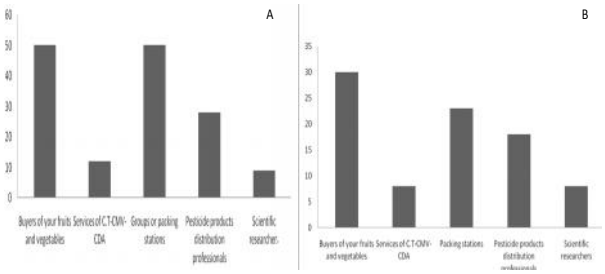

Figure 20 Advertising people visiting farms in Souss-Massa (A) and Loukos-Gharb (B).

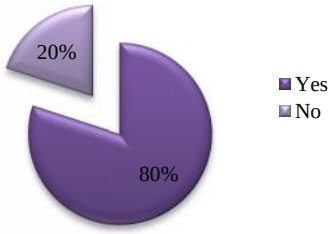

Figure 21 Paying an organic alternative at price equal to the chemical disinfection in Souss-Massa

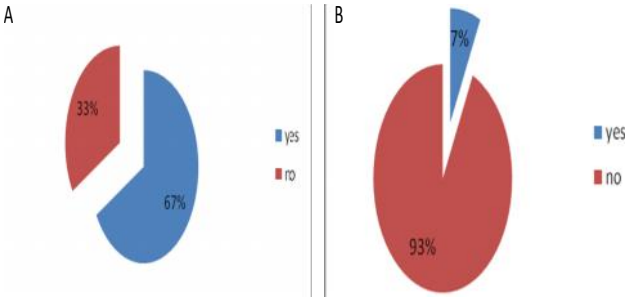

Figure 22 paying an organic alternative at 25 % more expensive in Souss-Massa (A) and Gharb- Loukkos (B)

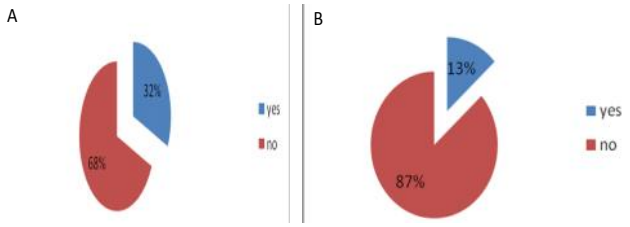

Figure 23 Paying an organic alternative at 50 % more expensive in Souss-Massa (A) and Gharb-Loukkos (B)

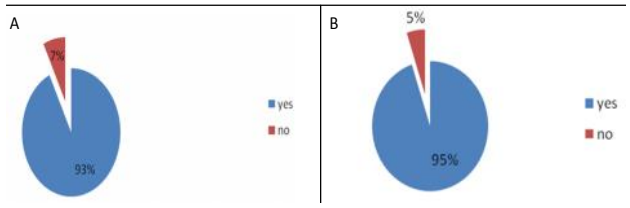

Figure 24 Agreement to do trials with alternatives in Souss-Massa (A) and Gharb-Loukkos (B)

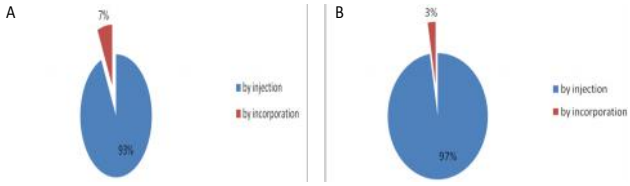

Figure 25 Preferred way to provide the disinfectant in Souss-Massa (A) and Gharb-Loukkos (B)

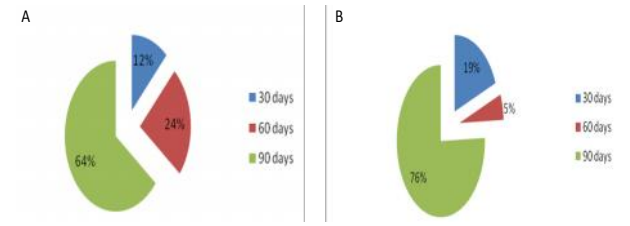

Figure 26 Expected protecting time by organic disinfectant in Souss-Massa (A) and Gharb-Loukkos (B)

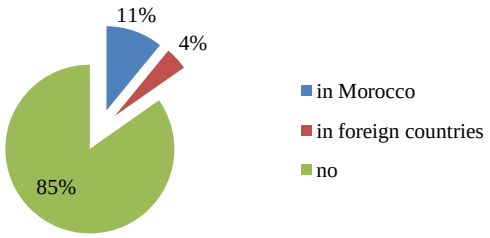

Figure 27 Visiting farms organic disinfected in Souss-Massa

DISCUSSION

Strawberry plants are susceptible to nematodes such as root-knot, foliar, stem, and lesion nematodes (Bleve-Zecheo *et al.*, 1980; Tacconi and Lamberti, 1987) and soilborne pathogens such as *Phytophthora cactorum, P. fragariae, Verticillium dahliae, and Colletotrichum acutatum*. The use of biocidal chemical compounds such as MB has long been regarded as a necessary pre-planting practice for strawberries and other small fruits, vegetables, orchards and nursery stock. Soil fumigation is a central tool in the strawberry production system because soil disinfestations maximize yield and fruit quality (Duniway, 2002a, b). Currently, only three MB alternative fumigants are registered and available for strawberry fruiting fields, and intensive research is being conducted to optimize application technologies to improve the performance and to reduce the cost. The registered chemical alternatives are chloropicrin (Pic), 1,3-dichloropropene (1,3-D), and methyl isothiocyanate generators such as metam sodium and Dazomet (Lamberti *et al.*, 2003). Although the alternative fumigants can be applied into soil by shank injection, new technologies were developed recently to apply fumigants through the drip irrigation systems (Ajwa and Trout, 2000; Ajwa *et al.*, 2001; Ajwa *et al.*, 2002a, b).

The nematoda pests in strawberry are the root-knot nematodes (Meloidogyne). Their damage is very important. For this reason, a nematicide treatment is necessary. Fumigation with nematicides was used by 17 producers in 20, or 85%. The other three producers (15%) felt no need to treat their ground because their land receives strawberries for the first time (Anonymous, 2014). Methyl bromide has been used as a pre-plant soil fumigant for over 40 years. It has activity in soil against a wide spectrum of plant pathogens and pests, including fungi, nematodes, insects, mites, rodents, weeds, and some bacteria. In addition, methyl bromide is sufficiently volatile to penetrate soils for some distance from the points of application (Duniway, 2002).

Fumigating soil with methyl bromide and chloropicrin has been an integral part of strawberry cultivation in California since about 1960 (Wilhelm and Paulus, 1980). Fumigation has minimized losses to root diseases caused by *Verticillium dahliae* and *Phytophthora* spp. and has controlled weeds sufficiently to allow the use of clear polyethylene mulch to increase crop earliness and reduce fruit rots (Hartz *et al.*, 1993). The obtained results showed that disinfection is required in both areas with the main goal to eliminate nematodes and fungi in the first place, Bacterial are in a smaller place, only the region of Souss-Massa resorted to an analysis before disinfection. Both regions converge on the disinfection time: autumn. Methyl bromide has been replaced by the Metam sodium in the Gharb region and Loukkos while it is replaced by the dichloropropene in the Souss- Massa region with injection into the irrigation system for both areas.

In Morocco, Metam sodium is the most widely used nematicide (94%). Use rates ranged from 750 to 1000 L / ha at a price of 10 Dh / kg, or 7,500 to 10,000 DH / ha, while 6% of farmers used dichloropropene + chloropicrin at 40 L / hr, with a price of 75 Dh / liter, 18000 Dh / ha. The treatment is done by injection into the irrigation system 3 weeks before transplanting strawberry (Anonymous, 2014). The tendency to opt for an organic disinfectant is still present, only the price which may be more expensive or having lower efficacy compared to chemical leaves hesitant farmer. The term of protection is required between 60 and 90 days in most cases, across all regions.

It seems that for organic alternatives disinfection techniques, Souss-Massa far outstrips Gharb and Loukkos, whatever these two regions do not seem to be really involved to find these alternatives, while accentuating the stress on eliminating nematodes. Metam sodium and 1,3 - D were tested in

combination with soil solarization for their impact on root-rot nematodes, weeds and yield performance in strawberry production systems in Morocco. These combined treatments suppressed nematodes, and weed densities and resulted in fruit yield similar to MB (Ammati *et al*., 2002). A drawback of these fumigants was that they undergo accelerated biodegradation after only one application. Soil solarization was proposed to support the pesticidal effects of these fumigants in the long-term by eliminating the specific soil microflora generated by repeated application of these pesticides.

Soil solarization is a disinfection technique that employs solar radiation during summer months to increase the soil temperature under a polyethylene-tarped field in which the soil-water content is brought to field capacity (Medina-Mínguez, 2002). This methodology has been used as a pathogen control strategy at least since 1976 (Katan *et al*., 1976) and has worldwide applications (Chellemi, 2002). Successful solarization requires 30–45 days and soil temperatures exceeding 50°C. Soil heating was reported to be lethal or sub-lethal for many pathogenic fungi, bacteria, and weeds (Katan, 1981; Katan, 2000), and very effective against the stem nematode (Greco *et al*., 1985), but was less effective on nematodes that are able to move in the soil over longer distances.

The awarened farmers on the topic of toxic residues that can leave chemicals is poor. Only commercial circuits initiate with them about it. Sellers have an important role to play in the supervision of farmers in terms of pesticide use. The illiteracy rate is high in rural areas (Thiam *et al*., 2008). Oudebji *et al*. (2012) noted in a survey which was conducted in the Gharb region and Loukkos that respectively only 47% and 50% of farmers could read the instructions on pesticide etiquettes packaging.

Biofumigation is based on the release of volatile compounds that suppress pathogens during biodegradation of organic amendments or crop residue (Bello *et al*., 1999). Materials that hold potential as biofumigants are livestock manure, refuse from waste paper bins, fishing factory waste, agricultural and food industrial waste and plant residuals with allelopathic compounds (Hoitink, 1988). The biocidal effect of these materials is caused by the release of nitrogen compounds like ammonium and nitrate, organic acids, and various volatile substances (Mian *et al*., 1982). However, high rates of organic matter amendments may produce phytotoxicity or increase the risk for ground water contamination (Cebolla, 2002).

The application of alternative fumigants through subsurface drip irrigation systems is the most practical and safest strategy for greenhouse conditions. Pesticide application by shank injection is limited due to the narrow working spaces in Italian greenhouses. However, the drip irrigation technology is becoming popular for greenhouse crops because it can easily be adapted to any greenhouse size. Moreover, drip fumigation has been demonstrated to reduce emissions when compared to shank injection (Gan *et al*., 2000). Furthermore, this technique does not require the presence of workers in the greenhouse, and thus reduces worker exposure.

CONCLUSIONS

The quantitative survey was conducted among farmers on the state of soil fumigation to install respectively strawberry cultivation in the region of Gharb and Loukkos and culture of tomato in Souss Massa and opportunities using alternative techniques and biofumigation. The responses were used to draw the following conclusion: cultural practices: the study shows intensive monoculture whether for tomato or strawberry, the fact that the majority of farmers do not practice rotation.

The cost of disinfection / production cost in their maximum and minimum ratio is:

+ 11.42% to 5% tracing a cost variance from 5% to 11.5% for the region of Souss-Massa

+ 4.17% to 6.66% and the minimum to the maximum, giving a variation of 4.17% to 6.66% for the region Gharb-Loukkos.

The change in cost per kilogram of the product showed a large margin, which could be explained by the final product quality (1.00 to 5.00 DH for tomato and 2.00 to 8.00 for DH strawberry). Cost to export is unknown to farmers. The tendency to opt for an organic disinfectant is still present, only the price which may be more expensive or lower efficacy compared to chemical leaves hesitant farmer. The term of protection is required between 60 and 90 days in most cases, across all regions.

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