

SOIL SOLARIZATION IN SPAIN

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Abstract

The Mediterranean coast of Spain enjoys a mild climate with heavy sunstroke in summer, this makes it a suitable area for soil solarization.

The first experiments on soil solarization begun by the year 1980, with uncertain results, either because a misuse of the technique, or because frequent storms which appeared in mid-August and September, producing temporal decrease of solar radiation. There are two reasons for the fact that growers did not easily accept the new technique. One is the long time of exposure required, the other is the fact that in summer most of crops are still in progress.

We tried to improve the application by using small amounts of fumigants with solarization as early as the summer of 1982. The results encouraged us to perform new experiments for reducing dosages and time of exposure. The use of double sheet, under tunnel, or combining with fumigants, improved effectiveness as was expected.

At the same time, research on Solarization was conducted in other areas in Spain, like Catalonia, Murcia, Andalucia and Canary Islands. This studies covered several horticultural and ornamental crops, and included temperature prediction, and control of soilborne pests - fungi, nematodes and weeds.

Technology Transfer was encouraged by government institution, Generalitat Valenciana (GV) as a result of a demonstration of the spectacular effects on a carrots crop. The Agricultural Department offered the plastic sheet free to those farmers belonging to cooperatives specialized in horticultural products, for applying soil solarization. Combination with small doses of fumigants were recommended for those farmers which required security in their results or shorten the exposure time. Also, courses sponsored by the GV for qualified farmers in horticulture, biological growers, and Integrated Production for Agronomists, included a lesson about Soil Solarization.

As a result of this campaign, most farmers begun to use Solarization combined with fumigants, but after several trials some of them returned to soil solarization without fumigants for certain crops. Young farmers, specially those concerned with environmental quality employ soil solarization without institutional help.

1. Introduction

The Mediterranean coast of Spain enjoys a mild climate with heavy sunstroke in summer, this makes it a suitable area for soil solarization.

The first experiments on soil solarization begun by the year 1980, with uncertain results, either because a misuse of the technique, or because frequent storms which appeared in mid-August and September, producing temporal decrease of solar radiation. There are two reasons for the fact that growers did not easily accept the new technique. One is the long time of exposure required, the other is the fact that in summer most of crops are still in progress.

Organic farming easily accepts solarization as a means to disinfest soil even with a long solarization period because this is a non contaminant technique. For non organic farmers it is necessary to shorten the solarization time to adapt it to their crop rotation

2. About Research developed in Spain:

Research teams from all Mediterranean regions, Catalonia, Valencia, Murcia and Andalucia have studied solarization, also the Canary Islands and Aragón, Castilla and Extremadura have contributed to the study and spread of this technique.

Most of works tend to compare soil solarization with standard soil disinfestation techniques by fumigation with Methyl bromide, Metham Na. or D-D Also the combination with herbicides, have

been studied for improving the results. The effect of exposition time ranging from 15 days up to 2 months on the survival of pathogens have also been analyzed.

2.1. Temperature

Some studies allow to forecast the time needed to control diseases based on temperature prediction by Fourier analysis (Cabello S, Verdu AMC. 1995), (Cenis, JL. 1989) (Lopez Cosme, E., et al 1996) as well as forecast efficacy against mortality of larvae of *M. javanica* (Cenis, J, Argemi, J. 1988). It was thus possible to calculate the number of days of solarization needed to reach a given level of nematode population.

Temperatures reached vary according to the authors and methodology as shown in Table 1.

Table 1. Temperatures °C reached at different depths (cm) in Spanish regions

Regions and Authors	0cm	5cm	10cm	15cm	20cm	25cm	30cm
Aragon (Lopez Garcia MC et al, 1991)	60		48				42
Andalucia (Gonzalez Torres R.,1993)			48			42	
Andalucia(Lopez Herrera CJ. Et al, 1994)		46.8		40.3	36.4		
Valencia (Busto, A del,et al, 1989)*	60						
Valencia (Cebolla V. et al, 1995)**		47			43		
Murcia (Cenis, JL., 1989)			+2.2	+1.3	+1.4		

+ means an increment of temperature °C as compared with non solarized soil

* maximum absolute temperature reached

** temperatures kept for periods longer than 1 hour under double cover sheet (tunnel)

2.2 Control of Fungi

Most Spanish teams working on soilborne fungi have tried solarization as a disinfection practice. According to (Melero, JM, et al. 1995) Solarization reduces wilt produced by *Fusarium oxysporum* f. sp. *Niveum* on Watermelon to very low levels and crop diseases can be controlled for at least one year. In other research Solarization for 2 months completely controlled wilt in watermelon(Gonzalez Torres R, et al 1993) and gave a fruit yield almost 5 times that of plants in untreated soil. Solarization for 1 month only slowed disease development slightly but gave a yield more than twice that in untreated soil. Fumigation with metham-sodium retarded disease development considerably and tripled fruit yield. Plant performance was better in soil solarized for 2 months than in uninfested control soil, suggesting beneficial effects of this treatment in addition to wilt control.

Reduction of *Fusarium oxysporum* population was observed on potato (Bello, A, et al. 1993). *F. oxysporum* f. sp. *dianthi* population studies (Cebolla V, et al. 1995) and effects on carnation (Cebolla V, et al. 1993) with artificial inoculation show the interest of soil solarization for the control of this disease. It significantly improves the plant health and flowers harvest. Solarization with the addition of small doses of fumigants allows a normal crop up to the next summer.

White rot *Sclerotium cepivorum* on garlic (Melero, JM, et al. 1989) is controlled, (Basallote Ureba, MJ, Melero Vara, JM 1993.) by soil solarization during the summer. This provides a reliable and convenient method of control of white rot of garlic. (Basallote, MJ, et al.1994), the populations of this pathogen was reduced to negligible levels and a high control was achieved

Solarization did not reduce the number of sclerotia (Lopez Rivera, S.,et al 1996) of *Sclerotium rolfsii* on sugar beet, but sclerotia were less active and produced less secondary sclerotia

Verticillium wilt on Cotton (Melero, JM, et al. 1989) is controlled,(Gil Ortega R, et al. 1990) The results showed that soil solarization controlled *V. dahliae* infection and increased precocity, total yield and fruit weight,(Melero Vara JM, et al. 1995) The final incidence of Verticillium wilt in the cotton crop following solarization was reduced in solarized plots (Gonzalez Torres R,et al. 1993) . Good control with natural infestation of *V. dahliae* on eggplant was observed by (Cenis, JL, et al. 1988)

Solarization produced a whole loss of viability (Lopez Herrera, C.J et al . 1996) of *Phytophthora cinnamomi* and *Dematophora necatrix* . Also *Phytophthora parasitica*, *P. cactorum*, (Cebolla V. et al, 1995) *Pythium spp* inocula were reduced by solarization. Also good control of *Pythium spp*. was carried out on a carrot infested field, but combining with very low dosages of Methyl bromide (7g/m²) increases drastically the yield.

One of the initial studies on solarization was done on a field infested by *R. solani* (Cebolla V., M. García. 1984) Solarization increased strawberry yield but combination with fumigants Metham Na and

Methyl bromide at low doses gave control at the same level than standard Methyl bromide disinfection. Other research (Cebolla V. et al, 1995) on artificial inocula confirm the results. Nevertheless (Cenis, JL, et al. 1988) reported no differences found on faba-bean crop.

The effects on *Botrytis cinerea* (Lopez Herrera CJ, et al. 1994) induce complete loss of viability of mycelium at depths of 5-25 cm, as well as of sclerotia buried at 5 cm, this was observed after 2 days in solarized plots. Viability of sclerotia at 15- and 25-cm depth decreased linearly with temp.-time (degree-hour).

Olpidium radicale (Gomez J, et al. 1993) on melon and *Polymyxa betae* (Lopez, J., García P., 1991) on beet as vectors of virus transmission. In both cases the fungal population was reduced but the disease was not eliminated.

2.3. Control of weeds

Soil Solarization is rather a good treatment to control weeds on several crops, at least from the agronomic point of view, but combination with fumigants assures very good control (Cebolla V., et al 1990,1991,1995,1996). Weeds like *Solanum nigrum*, *Sonchus spp*, *Lolium spp*, *Plantago lanceolata*, *Asphodelus fistulosus*, *Euphorbia exigua*, *Euphorbia prostrata*, *Malva spp*, *Medicago spp* (Cebolla V, et al. 1995) *Portulaca oleracea*, *Euphorbia prostrata*, *Urtica dioica*, *Sonchus tenerrinus*, *Chenopodium album*, *Poa annua*, *Convolvulus arvensis*, *Oxalis pes-caprae*, *Amarantus retroflexus*, *Lamium amplexicaule*, *Mercurialis annua*, *Amaranthus blitoides*, *Setaria verticillata*, *Capsella bursa-pastoris*, *Digitaria sanguinalis*, *Erodium malacoides*, *Cirsium arvense*, *Fumaria officinalis*, *Papaver rhoeas*, *Misopates orontium* are well controlled, *Conyza canadensis*, reproduces fast because seeds are easily disseminated by wind. According to (Bello, A, et al.1993) complete weed control was also achieved, for at least 1 month.

In a research comparing solarization with both mouldboard or chisel ploughing (Dalmau L, Plana E, Verdu AM. 1993.) found that weed control was similar but significantly better than with soil solarization in an assessment 38 days after polyethylene removal for *Chenopodium album*, *Poligonum aviculare*, *P. convulvulus*, *Xanthium spinosum*, *Paspalum distichum* and *Amaranthus retroflexus*.

Soil solarization is able to control many common summer weeds, but not *Cyperus rotundus*. (Lopez Garcia, MC, et al 1991). This weed is partially controlled and its remaining propagules are weakened, making them susceptible to a low dose of glyphosate. (Lopez Cosme E, et al. 1995) Although solarization alone failed to control *C. rotundus*, it was found that solarization for 2.5 months, followed by 0.72 kg glyphosate/ha led to a sharp decline in *C. rotundus* populations the following summer. Other authors (Gonzalez Torres R, et al. 1992) show that Soil solarization reduced by a factor of 3 and 6 the number of tuberous rhizomes that resulted from an initial plantation combined with glyphosate. No significant difference was found between 6 and 10 weeks solarization; both substantially reduced *C. rotundus* amount.

2.4. Control of Nematodes

Nematodes like *Ditylenchus dipsaci*, *Nacobbus aberrans*, *Rothylenchulus reniformis*, (Bello A, Gonzalez JA. 1994) are controlled. Other genera like *Globodera rostochiensis*, *G.Pallida* are not absolutely controlled but reduced in population

A forecast of mortality rates of *Meloidogyne javanica* larvae at soil temp. typical of soil solarization (30 to 48 °C) (Cenis, J, et al.1988) were expressed in 2 equations. These were used in a computer program to calculate the number of surviving larvae at hourly intervals on the basis of temp. data fed in hourly. It was thus possible to calculate the number of days of solarization needed to reach a given level of nematode population.

Also solarization into a glasshouse achieved a substantial reduction in numbers of *M. incognita* larvae (Mejias Guisado A, et al.1993) to a level where lettuce and melons could be grown with minimal injury Solarization was also found effective in the control of *M. incognita* by (Mejias A, et al.1995)

Solarization and D-D were compared in a research on *Heterodera schachtii* (Lopez, J., García P. 1991) both treatments reduced population on beet but don't eliminate the problem.

2.5. Control of virus

Control of virus spread by controlling its vector is a general idea that has been tried to control Melon Necrotic Spot Virus MNSV (Gomez J, Cuadrado I, Velasco V. 1993.) transmitted by *Olpidium radicale* Nevertheless, although the vector population was reduced, Solarization treatment did not reduce disease severity. Other virus disease tried was Beet Necrotic Yellow Vein Virus BNYSV (Lopez, J., García P. 1991) none of treatments compared Solarization or D-D did not eliminate the problem.

2.6. Other Useful results.

Soil solarization was also as effective as soil fumigation in the control of replant disease of rose (Basallote, MJ, et al.1994) It is suggested that soil solarization should be integrated with the use of tolerant cotton cultivars. Other results showed that soil solarization decreased *Agrotis spp*(Gil Ortega R, et al. 1990).

Soil solarization prevented upward capillary movement of the soil solution, in a saline water table, and its concentration by evaporation on the surface. As a result, the electrical conductivity in the solarized plots was a quarter of that in the unsolarized ones (Lopez Cosme E, Gonzalez Torres R. 1995.)

Most of authors found the cost of solarization treatment lower than the fumigants methyl bromide or Metham-Na treatments.

3. Application Techniques and plastic sheet

The type of plastic used is polyethylene film of a thickness ranging from 25 to 100 micron. This sheet is considered the most convenient as cover material, because its price, strenght and transparency to radiation. To choose the sheet thickness some reasons like risk of wind or whether the treatment is in or out of a greenhouse have to be considered.

The soil must be tilled and well shred by deep ploughing and subsequent harrowing up to the soil is properly crumbled to avoid to tear the sheet when placed on the soil. These practices allow a deep and uniform water penetration to keep the soil wet along solarization. Moisture improves soil thermal conductivity and increases sensitivity of soil microorganisms to the heat.

3.1.Improving the technique

A number of methods are used to improve the efficacy of Solarization. Double cover sheet is used to reach higher temperatures on the soil surface, and then transmitted in depth. This double cover can be done by mulching under tunnel, or in greenhouse (Cebolla V, et al 1991,1995), (Lopez, J., García P. 1991.). In this case there is a drawback for the farmers, because plastic cover on greenhouse shortens in one year its life, due to the high temperatures reached into the sealed enclosure.

Combination with tolerant cultivars was tried on cotton (Melero Vara JM,et al. 1995) as a mean to ensure the control of soil diseases.

3.2. Combination with chemicals at low dosages to improve solarization

Soil solarization in combination with fumigants like Metam Na,(Cebolla V., M. García. 1984) was as good as standard fumigation with Methyl bromide. The combination technique by using Methyl Bromide (Busto, A del, 1989,1990) (Cebolla V, et al 1995,1996) and Metham Na (Jimenez Diaz, RM, et al.1991) allows to shorten the period for solarization with high diseases control guarantee.

Solarization combined with herbicides pendimethalin (Cabello S, Verdu AMC. 1995) trifluralin, oxyfluorfen (Busto, A del, et al. 1990)are good to control weeds. Also combination with glyphosate helps to control *C. rotundus*.

Irrigation before plastic covering is the normal use for standard solarization. Due to the kind of soils present in most of the Spanish land, which are heavy, loamy, more or less reach on silt and clay, soil moisture remains long time in soil, when the upper layer is dry, in depth the soil is still wet. In solarization combined with Metham Na the fumigant is added to the irrigation water, and the field is flooded or drip irrigated under the sheet. When combined with Methyl bromide the fumigant is applied in proper soil conditions, and three days later is irrigated under the plastic. In both cases the sheet is open at the end to permit the exit of the air, and avoid air bags that difficult the irrigation..

4.Problems for Extension of solarization

The problems found from th epoint of view of technology transfer are summarized al follows:

- Longtime exposure required to be effective.(1 or 2 months).
- Difficult to adapt for a normal crop rotation.
- Needs to be done in summer, not in other time.
- Sheets are torn with storms, wind, dogs...
- Lacks of security due to abnormal summer.
- Growers needs to be enthusiast at the beginning.

5. Action to the diffusion of the technique

The main action from the point of view of Technology Transfer, made by a governmental institution in Spain was conducted by the Generalitat Valenciana (GV), as a result of a demonstration of the impressive effects on a carrot crop. The Agricultural Department offered the plastic sheet free to those farmers belonging to Cooperatives specialized in horticultural products, for applying Soil solarization. The combination with small doses of fumigants was recommended for those farmers that required security in their results or shorten the exposure time. Also the courses sponsored by the GV for qualified farmers in horticulture, biological growers, and Integrated Production for Agronomists, uses to include a lesson about Soil Solarization.

As a result of this campaign, most farmers began to use Solarization combined with fumigants and after several trials some of them come back to soil solarization without fumigants for certain crops. Young farmers, specially those concerned by environment, became enthusiasts on the use of soil solarization without any institutional help.

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