A Review of Integrated Pest Control In Protected Vegetable Crops In Southern Europe

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1. Introduction

The Mediterranean Basin is especially conducive to the growing of protected crops, as in amply demonstrated by their solid concentration in the area lying between the 35 th and 45 th parallels. Most of the existing tunnel facilities consist of wood or metal structures covered by plastic film and designed for maximum exploitation of the area's many hours of sunlight-over 900 hours yearly in Sicily (14). Since the 1960 s there has been a progressive increase in protected-crop acreage, the current figure being about 72,000 hectares in Europe (20), although to this must be added the number for small tunnels (semi-forced), which currently exceeds 40,000 hectares in Italy, France and Spain alone (16). The marked differences between growing techniques of protected crops in the Mediterranean Basin and northern Europe considerably affect the approaches to plant protection and, hence, to biological control/integrated pest management (IPM) strategies.

2. Northern Europe and the Mediterranean Basin Compared

The differences in protected crop farming between these two areas can be divided into three broad groups: a) greenhouse facilities, b) climate and c) management practices.

2.1 Greenhouse Facilities

The northern European greenhouse is built of glass and metal and often covers an area of 5,000-10,000 m^2 in a single unit. In addition, the heating system, which is part of the computer-controlled overall air conditioning unit, is kept running through much of the year to provide plants with the most favourable climatic conditions. This helps to limit abrupt swings in temperature, i.e. the overnight minimum often does not dip below 16-18° C, as well as influence relative humidity.

The Mediterranean greenhouse, by contrast, is supported by a wood and/or metal framework covered by plastic, is often moveable and rarely exceeds 1,000 m^2 in size. Only ornamentals and cut-flowers are grown in metal-framed heated glasshouses (only 10 % of greenhouses in Italy are heated). And, because most of the protected crops in southern Europe are grown without climate conditioning, daily temperatures can vary widely, ranging from close to 0° C overnight to over 25° C during the day in winter and to 40-45° C in the milder seasons. Climate conditioning is thus limited to manual opening and closing of the greenhouse and to tunnel shade screens or whitewashing.

2.2 Climate

Climatic conditions directly affect pest development as well as influencing greenhouse design and crop choices. The rigid northern European climate, with temperatures often below 0° C for many months, limits pest activity and, for reasons of energy input, dictates that glasshouses be so constructed as to keep to a minimum any contact between inside and outside, creating in effect an isolated agroecosystem. For instance, glasshouse openings are installed on the roof only and opened but briefly solely at certain times of the year. The low winter temperatures also limit the growth of weeds around the glasshouse; and many pests have long periods of winter diapause-eg. *Tetranychus urticae* Koch (Acarina Tetranychidae).

The Mediterranean climate on the other hand is mild most of the year, with winter temperatures that seldom drop below 0° C, and enables pests to develop year-round even outside the greenhouse (eg. whiteflies and spidermites). This results in a sharply higher number of pest generations and, hence, a marked increase in the threat they pose.

Then, too, the mild winter and high summer temperatures compel growers to ventilate crops very often, and the number and deployment of greenhouse openings are designed accordingly. Yet this means continuous contact between the greenhouse and external environment even during winter, resulting in the fact that unlike in northern Europe the protected crops here cannot be considered a closed agroecosystem because insect pests can cross over from field crop to tunnel crop and vice versa, depending on climate trend (1).

Another drawback is the frequent growth of weeds around the greenhouse: they can serve as vehicles for both harmful and beneficial organisms: aided by the ample greenhouse openings, large migrations of insect pests, which adversely affect pest control-eg. the greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.) (Rhynchota Aleyrodidae)- can occur from one tunnel to another at certain times of the year, and especially near infested crops.

2.3 Management Practices

Here again the differences are rather marked. The horticultural crop cycle in northern Europe is far longer. Transplanting takes place in November and cultivation can continue up to September-October of the following year. Most crops are grown in inert medium (eg. rock-wool) so as to prevent problems linked to soil fumigation and post-transplant stress.

Another difference is that usually each northern grower produces a single crop, a fact that enables him to attain a higher degree of specialization and expertise and in turn to manage his operations very efficiently. This same efficiency also holds for such other options as, for example, the most suitable cultivars and proper fertilization (the latter aided also by more sophisticated systems designed to provide a more effective management of nutrient inputs).

The Mediterranean farmer on the other hand grows several horticultural species in brief cycles not exceeding 4-6 months, eg. a spring (Jaunary-June/July) and a summer-autumn one (July/August up to the first frost or January, depending on latitude). Transplanting occurs in summer (July-September), at the time of pests outbreaks, making it very difficult to start at low infestation levels (as for the greenhouse whitefly).

This overlapping of seasons and diverse crops tends to favour a stable presence of certain pests in a given farm. Very often in fact little attention, is paid to farm hygiene: the greenhouse is neglected at season's end for the sole reason that it is not thought important to root up the plants, the result being that other operations are given higher priority. This gives rise to dangerous outbreaks of infestations, a good case in point being zucchini which is susceptible to a great many pest (greenhouse whitefly, cotton aphid, red spidermite, leafminers).

Specialization in one or two crops is pursued only in the ornamentals sector, whereas a limited importance is attributed to phytosanitary problems that may derive from improper rotation and the resulting negative effects for the entire farm's plant protection management. Also to be taken into overall account is the fact that crops are grown in soil and its disinfection is costly both economically and ecologically.

3. Main Arthropod Pests

The list of pests that pose a threat to protected crops in the Mediterranean Basin is more or less made up of the same key pests found in northern Europe (13). The most significant difference in the warmer climates, aside from infestation intensity, is the greater number of certain «minor» pest species, a fact that is especially evident when chemical control is relaxed. These can attack crops and cause severe problems in carrving out IPM strategies.

The importance that key pests can have depends a great deal on the crop, local situation and pesticide resistance development or their import from other continents, the latter making it all but impossible to draw up a list rating their potential danger. The Aleyrodidae, or whiteflies, are definitely among the most harmful: of these *T. vaporariorum* is the most common and, when conducive temperature is added to its polyphagy, can register very high population levels in many crops. More recent is the spread of another whitefly species, *Bemisia tabaci* (Genn.), which not only is becoming rapidly resistant to pesticides but can also transmit in tomato the dangerous virus TYLCV (4). Jordan valley is now spreading dangerously to certain areas of Sicily and Sardinia (8). Thus sharply reducing the possibility of employing biological control/IPM strategies.

Two species of the Diptera Agromyzidae are also worthy of note: the native *Liriomyza bryoniae* (Kalt.), which sometimes can be harmful to tomato, and the American *Liriomyza trifolii* (Burgess), which instead has brought severe damage since its accidental introduction in the late 1970 s to both horticultural and ornamental crops despite consistent efforts of chemical control. The South American leafminer *Liriomyza **huidobrensis*** (Blanchard) has been recently reported in Italy (18).

Thrips (Thysanoptera, Thripidae) were not considerd very threatening until a few years ago when to them was added the imported species *Frankliniella **occidentalis*** (Perg.), the western flower thrips (WFT), which has disrupted many IPM programs in a number of crops. For, while the other species-*Thrips tabaci* Lind. and *Helothrips **haemorrhoidalis*** Bouchè - caused but sporadic harm to horticultural crops, *F. occidentalis* has severely damaged pepper, eggplant, cucumber and bean in Sicily, thereby hindering the expansion of newly launched IPM programs. In northern Italy's Po valley WFT has been confined to flower crops and ornamentals, although its control is proving very difficult because of the ineffectiveness of almost all the insecticides.

The most serious problems posed by aphids (Rhynchota Aphididae) come from *Aphis* gossypii Glover. It is especially harmful to cucurbits, eggplant and pepper because it has developed resistance to almost all aphidicides, and particularly to pirimicarb an active ingredient employed in IPM programs for its selectivity. As with WFT, it will be necessary to develop a control system that enables the efforts so abruptly interrupted here to be resumed. The other most common aphids are *Macrosiphum **euphorbiae*** (Thom.) and *Myzus **persicae*** (Sulz.), which attack tomato, pepper and eggplant; *M. euphorbiae* and *Chaetosiphon fragaefolii* (Cock.) in strawberry, and *Aphis fabae* Scop., which is often found in bean and eggplant.

An especially dangerous group in the Mediterranean area is the Lepidoptera, above all those belonging to the Noctuid family. This group includes a number of the most harmful and common species: *Spodoptera littoralis* (Boisd.), *Chrysodeixis chalcites* (Esp.), *Mamestra brassicae* L. and *Heliothis armigera* F., all of which are characterized by a marked polyphagy enabling them to attack many different horticultural crops. Another harmful moth is the European corn borer *Ostrinia nubilalis* (Hb.) (Pyralidae), which attacks pepper.

The most dangerous of the mites is the two-spotted spidermite *T. urticae,* whose accentuated polyphagy and marked tendency to develop resistant populations have caused, and cause still, severe problems in chemical control.

Also the tomato russet mite *Aculops lycopersici* (Massee) (Acarina Eriophyidae) is harmful, albeit its attack is confined to tomato (19); more dangerous is the broad mite *Polyphagotarsonemus latus* (Banks) (Acarina Tarsonemidae), which strikes pepper and certain ornamentals like gerbera (13).

In addition to the pests of the above-ground plant system, very dangerous to the root system are nematodes. They force growers to disinfect the soil with fumigants having a high impact on the environment.

4. IPM Strategies

The experience gained in northern Europe in the 1960 s formed the basis upon which the first IPM strategies were launched in the Mediterranean Basin, although the time lag from the former to the latter was at least fifteen years. The initial trials in Italy were conducted in Sicily around 1980 (15), though they were preceded by those in France in 1975 (17). Greece's and Spain's initial tests date respectively to 1979 (2) and 1985(16).Jordan valley early 1980s, Portugal's to 1987. Algeria's (9) and Tunisia's (7) are very recent.

The application of IPM strategies encounters, as we have mentioned above, problems ascribable to differences in local conditions, the major one in the Mediterranean being the frequent appearance of «minor» pests whenever chemical control pressure is relaxed. Noctuids, myrid bugs and tarsonemid mites are among some of the more familiar examples. Very beneficial on the other hand is the action that numerous natural enemies can perform in protected crops whenever low-impact approaches are employed. The advantage that can be gained is definitely greater than what can be achieved in northern Europe, for the Mediterranean's more favourable climate extends the beneficials' period of activity and enables them to reach higher population densities. A good example of this is the Coccinellidae or the Syrphidae: these aphid predators, which are not yet commercially produced, can often keep pest population levels below the damage threshold.

Two other important factors to bear in mind are the extreme diversity among protected crops themselves and the varying of the climatic conditions from one local area to another. They help to explain why, for example, a strategy developed in northern Italy's Po valley proves a failure in Sicily, incidentally underscoring the fact that work in applied research must focus more effort and adapt its methods to peculiar local conditions (greenhouse design, more dangerous pests, mild climate). The contrast with northern Europe, where glasshouse environments are more uniform (being as we have mentioned closed ecosystems) and often what succeeds in one area can more easily be extrapolated to another, thus promoting the spread of IPM techniques, is evident.

France, Italy and Spain are the Mediterranean countries that have already developed IPM strategies, employing the same beneficial species successfully used in northern Europe for such crops as tomato, cucumber, eggplant, pepper. One of these beneficials is the predatory mite *Phytoseiulus persimilis* Athias-Henriot (Acarina, Phytoseiidae), which has proved highly effective in controlling *T. urticae* in a number of crops, both in greenhouse and open field (11). Indeed, given that the Mediterranean Basin is in all likelihood its area of origin, research is now under way to determine whether it is more effective to release native strains in the peculiar conditions of protected crops in southern Europe, ie. low relative humidity and high temperature.

Another beneficial is the whitefly parasitoid *Encarsia formosa* Gahan (Hymenoptera, Aphelinidae), which instead has encountered some problems in controlling whitefly in unheated greenhouses during winter and spring (when nocturnal temperatures can drop below 12-14° C) and during the summer (when temperature can peak above 40 ° C, thereby causing high adult death rates). It is often found, however, that when IPM is combined with *E. formosa* releases, certain whitefly-predators species (Rhynchota, Myridae) can enter the greenhouse and control the pest even in climatic conditions adverse to *E. formosa*. The most important species are *Macrolophus caliginosus* Wagn., *Nesidiocoris tenuis* (Reut.) and *Dicyphus errans* (Wolf) (3), the former appearing to be a very promising candidate for mass rearing and subsequent use in seasonal inoculative releases in greenhouse.

The control of leafminers *(L. trifolii* and *L. bryoniae)* again points up the difference: inoculative releases of *Diglyphus isaea* (Walk.) (Hymenoptera, Eulophidae) are used in southern and *Dacnusa sibirica* Telenga (Hymenoptera, Branconidae) in northern Europe, especially with low temperatures. The latter is the key factor in attributing the success or failure of one beneficial over onother. It must be added, however, that the biological control of leafminers is the only case for which this distinction holds: beneficial for southern and beneficial for colder areas. It implies that continued research will likely be necessary to assess the performances of several promising biocontrol candidates that are found in the Mediterranean environment and that might be added to *D. isaea*. Other studies should address the biology of both pests and beneficials at temperatures that are not constant yet have thermoperiods of marked minimum-maximum swing to simulate greenhouse conditions. The initial investigations carried out on the common lacewing *Chrysoperla carnea* (Steph.) (Neuroptera, chrysopidae) may be cited as an example (12).

While the release techniques employed for beneficials in the Mediterranean Basin are the same as those used successfully in northern Europe, the release rates need to be considerably revised to deal with the higher southern infestation levels. In the control of whitefly, for instance, at least 35-40 *E. formosa* black pupae per m^2 need to be released for a 4-6 month crop cycle, whereas only half that number is sufficient in the north for a much longer cycle. It should also be added that the infestation threshold tolerated by the Mediterranean grower is undoubtedly higher than his northern counterpart. Another drawback, which is perhaps easily inferred from what we have mentioned, is the unit cost of biological control. Releasing more beneficials per square meter quite often means that IPM is not competitive with chemical control, **especially when residues are not checked**. IPM in Mediterranean countries currently extends to 1,375 ha, or only about 2 % of total acreage (including all of France as a Mediterranean country). If we add to this that there are only four biofactories rearing and retailing beneficials (two in France, one in Italy and one in Jordan valley), and compare this area to northern Europe's, we can clearly see that it does not amount to very much. And, while research has shown the viability in certain cases of their application, IPM strategies are still far from being widespread in use. Accordingly, a brief look at the main reasons for this faillure to «catch on» is in order.

The most prominent reason is the poor or even total lack of effective extension services in the Mediterranean, the result being that growers have been left entirely to the vested-interest «advice» of the chemical companies. It bears stressing here that it is very difficult, especially initially, to apply biocontrol methods without proper information and technical assistance. Then, too, the weak background in training of many growers often prevents them realizing the risks to human health they may run in abusing or improperly using pesticides. As mentioned, investigations in both basic and above all in applied research should be strengthened. And, accurate checks of pesticide residue levels would be a deterrent to incorrect use of chemical control and at the same time stimulate the application of such alternative strategies as IPM.

Mention should be made in this connetion of the efforts made undertaken by several northern Italian cooperatives to promote the sale of certain horticultural produce (eg. strawberry) grown under biocontrol/IPM regimes: their label assures consumers that there are no chemical residues or that their level is well below the legal limit. The advantages of such a program include higher market prices for crops and new retail outlets. Yet there is also the fact that the consumer''s concept of quality is changing: not only appearance but also the absence of residues is important. Thus, an increase in demand for this type produce is foreseeable, and whoever is best equipped to meet it will undoubtedly reap the economic benefits.

الملخص

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يستعرض المؤلفون الفروقات بين بنية الدفيئات وطبيعة المناخ والمعاملات الزراعية في دول أوروبا الشمالية وأوروبا الجنوبية وتأثيراتها في المكافحة المتكاملة لآفات الخضر تحت ظروف الزراعة المحمية في دول أوروبا الجنوبية.

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