BioGreenhouse

Guidelines for Experimental Practice in Organic Greenhouse Horticulture

Edited by Martin Koller, Francis Rayns, Stella Cubison and Ulrich Schmutz

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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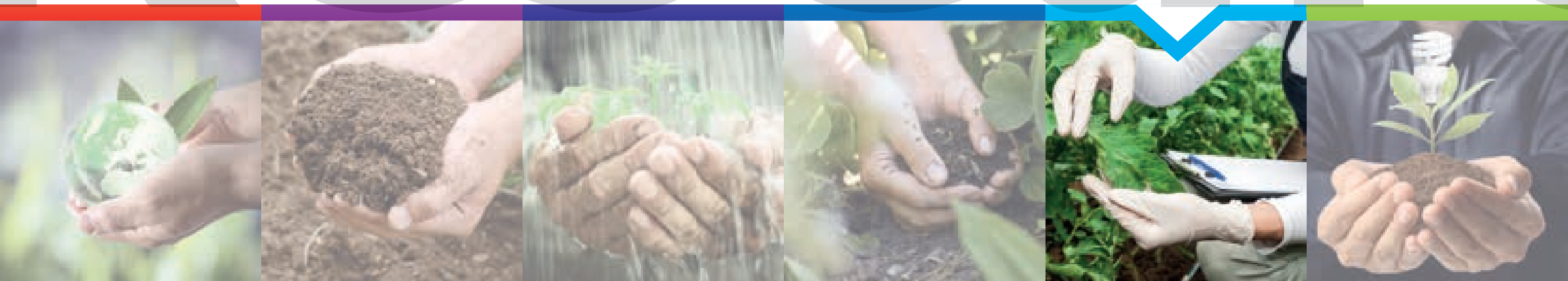
Research



The Editorial Board *This picture was taken at the final meeting to discuss these guidelines, held in Tori, Estonia in September 2015. A commercial organic greenhouse with a tomato crop is shown in the background. Left to Right: Pedro Gomez, Stella Cubison, Wolfgang Palme, Justine Dewitte, Martin Koller, Yüksel Tüzel, Francis Rayns, Ingrid Bender and Ulrich Schmutz.*

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The guidelines were initially based on the following publication with many new chapters contributed by European and international authors:
Lindner, Ulrike and Billmann, Bettina (Eds.) 2006. Planung, Anlage und Auswertung von Versuchen im Ökologischen Gemüsebau. Handbuch für die Versuchsanstellung ["Planning, Setup and Evaluation of Trials on Organic Vegetable Cultivation. An Experimental Design Manual"]. Forschungsinstitut für biologischen Landbau (FiBL), Frick, Schweiz und Frankfurt, Deutschland, ISBN 978-3-906081-97-7, http://orgprints.org/9863.

Pictures
All pictures are by members of the Biogreenhouse COST Action FA1105. Contributors to the pictures (in alphabetical order) are: Ingrid Bender, Stella Cubison, Justine Dewitte, Pedro Gomez, Martin Koller, Carolyn Mitchell, Jérôme Lambion, Wolfgang Palme, Virginia Pinillos, Ulrich Schmutz, Yüksel Tüzel and Anja Vieweger.

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A wide range of material can be used as mulch material; these may be organic (e.g. straw) or synthetic (usually a plastic film). Once an organic mulching material has been incorporated into the soil and has decomposed it will improve soil structure, especially in the case of "heavy" soils such as clays, clay loams, and silty soils. This improves drainage, and thus aeration of the root zone. The water-holding ability of more well drained soil will also be improved by increased organic matter. Synthetic mulches may also be biodegradable.

Available nitrogen in the soil can be reduced when incorporating organic materials from mulches into the soil. This 'nitrogen robbery' can occur because the bacteria and fungi involved in the decomposition process will utilize large amounts of nitrogen as they multiply rapidly during the break-down of the organic matter. One of the most important reasons for organic mulches is weed control by placing them directly on top of small weeds; a layer of 10cm of organic mulch will block light and the photosynthesis will be prevented.

Experimental layouts
Experiments with mulches can help to quantify the benefits and costs of using them. Measurements can be made of crop yield (including its earliness and quality), effects on soil water and interactions with irrigation requirements, effects on the soil (mineralisation patterns under the mulch and the supply of nutrients as an organic mulch breaks down) and the costs of using them (in terms of labour hours and materials).

If commercial scale machines are used to lay down the mulches then the plots will need to be quite large which may limit the number of replicates and treatments. Although organic mulches can be simply applied to small scale plots by hand it may be difficult to simulate commercial use of synthetic mulches on a plot scale. A strip of about 50 to 80cm is required between rows covered by mulches, regardless of type, to prevent cross movements of soil between adjacent plots.

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3.4 Plant protection experiments

3.4.1 Evaluation of fungicides and insecticides in organic cropping

By Martin Koller and Ellen Richter (based on Martin Hommes, 2006)

Preconditions and site selection
Before plant protection experiments are carried out it is advisable to understand the biology of the pest or the pathogen concerned and to collect information regarding its incidence in the experimental region. Appreciating the route of infection of a pathogen, for example, is crucial for determining the experimental procedure. For soil-borne pathogens, such as the clubroot disease of Brassica species, a uniform contamination of the experimental side is of great importance. For exclusively seed borne pathogens, it is important that each seed batch is uniformly treated and the origin of the seed is recorded.

For pests or diseases which invade the experimental plots actively there is often a clear gradation of infestation from an edge towards the field centre. The Latin square is a suitable experimental design to deal with these border effects. If they are transported by the wind and infestation is regularly distributed within the field, other designs such as a randomised block design are as most suitable.

Experiments with plant protection products, plant 'strengtheners', or 'tonics' suitable for organic production require particularly stringent design and implementation. The effects of these products may not be very strong and therefore sample size and number of replicates should be increased in order to demonstrate statistically significant differences between the treatments. If products have only a preventive but no curative effect they must be applied before infection and on a regular schedule as long as disease pressure persists. It has to be taken into account that most plant diseases have an incubation period between infection and outbreak of symptoms.

Moreover, it is important to know the mode of action and the physical and chemical characteristics of a product under test. For example, the bacterium *Bacillus thuringiensis* has to be taken up actively before it becomes effective in the gut of caterpillars. In addition, temperature affects larval feeding activity and bacterial growth, older instars show reduced susceptibility and the microorganism is inactivated very quickly by UV radiation or washed off by rainfall.

Application technology and water requirement

The application technique can have a considerable impact on the efficacy of a product. Therefore, it is important to record the exact application parameters, such as spraying equipment, nozzle type, application technique, amount of water, application rate, additives etc. In order to check the application technique, water sensitive paper can be attached to different parts of the canopy to record the degree of wetting. Additionally, the weather conditions should be noted during and after application.

The amount of water needed for water based applications of fungicides and insecticides depends on the crop development and the mode of action. In Germany, for example, the following amounts of water are generally recommended for typical vertical greenhouse crops such as tomato or cucumber:

Plant height < 0.5 m = 6 litres/100 m^2.
Plant height 0.5-1.25 m = 9 litres/100 m^2.
Plant height > 1.25 m = 12 litres/100 m^2.

If a thorough wetting of all plant parts is recommended (as it is for products with contact effect only such as insecticidal soaps or rape seed oil) the amount of water amount may be somewhat higher but excessive use of water will just drip off the plants and thereby reduce efficacy. More accurate methods to estimate the amount of water needed are currently under development (e.g. Rueegg *et al.* 2012).

Assessments and artificial inoculation

Counting, estimating and measurements of disease and pest infestation levels are better suited for an appropriate statistical evaluation than using scales. However, a scale from 1 to 9 may be appropriate if no statistical evaluation is planned.

At low infestation levels (< 10) pest numbers can easily be counted and with some experience high numbers may be estimated. The incidence and expression of disease and pest symptoms can be expressed in percentages (e.g. as disease incidence and disease severity). If assessments are conducted by several people, it is best to harmonize the estimation of pest numbers or disease severity beforehand and to make sure that each person evaluates all treatments in one replicate. This ensures that personal effects will not distort the results of the treatments. Inexpensive and accurate methods are also available today for measuring the leaf area damage through digital image analysis (e.g. Bock *et al.* 2010).

If pest infestation is very heterogeneous within the plots then it may be useful to mark certain plants and to follow pest development on these plants. In this case it is particularly important that the assessments do not compromise the development of the pest.

If the natural pest or pathogen incidence is very low artificial inoculation can be considered. Sometimes it may be sufficient to place artificially inoculated plants into to the different plots. However, it is important to distribute these plants equally to all replicates and treatments.

Efficacy evaluation

Four main formulas are available to calculate the corrected efficacy in pesticide trials. The selection of the appropriate formula will depend on the trial conditions which means considering infestation or population stability and homogeneity as well as on the data available. When dealing with infestation levels or live individuals in uniform pest or disease populations the formula according to Abbott (1925) is convenient. For non-uniform populations, the Henderson and Tilton (1955) formula is suited which allows us to judge differences in the population development. In this formula the mortality ratio is corrected on the control mortality. If mortality is assessed as such, the formulas after Sun-Shepard or Schneider-Orelli should be used (Püntener 1981).

a) Efficacy formula according to Abbott (1925)

b) Efficacy formula according to Henderson and Tilton (1955)

References and further information

General information on trials for efficacy evaluation of plant protection products can be found in two general EPPO guidelines: PP1/152(4) Design and analysis of efficacy evaluation trials and PP1/181(4) Conduct and reporting of efficacy evaluation trials, including Good Experimental Practice. Many general (for phytotoxicity assessment, minimum effective dose, etc.) and specific EPPO standards are available at http://pp1.eppo.int/

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3.4.2 Evaluation of bio control agents and natural enemies

By Gerben Messelink

Introduction

Biological control of greenhouse pests with natural enemies has been applied successfully in greenhouse crops for decades (Pilkington *et al.* 2010). However, there are still serious problems as some pest species are difficult to control with currently available natural enemies (Messelink 2014). The efficacy of natural enemies may strongly depend on the type of crop; existing species therefore need to be evaluated in different cropping systems. In this chapter, some practical advice is provided for evaluation experiments with natural enemies in greenhouse crops.