Producing Bulbs and Perennials; Sustainable Control of Diseases, Pests and Weeds

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Abstract

In the Netherlands every year flower bulbs and perennials are produced representing a value of 500 m€ (flower bulbs) and of 65 m€ (perennials, 2004). The growers are faced with several threatening pests and diseases during the production. They usually deal with these problems by using pesticides. In 2004 the Ministry of Agriculture and the stakeholders in Agribusiness made an agreement on reducing the environmental impact of pesticides by developing and implementing knowledge on Integrated Crop Protection. As a result growers were expected to control pest and disease problems using effective and sustainable solutions. Sustainable control methods have been developed to control the plural problems the growers encounter during the production and postharvest phase of flower bulbs and perennials. These methods include using clean plant material, decision support systems, pesticides with a low environmental risk, biocontrol agents, natural enemies, pesticide emission reducing techniques, methods for manipulating soil health, etc. These methods were tested not only under experimental conditions at the Applied Plant Research Centre (PPO) Lisse but also under practical conditions at farmers. In this way methods were evaluated for their robustness under different situations (location, farm size, climate conditions). Several examples of the development of preventive and control methods and how they can be applied in integrated crop protection strategies and should be implemented in practice are discussed.

INTRODUCTION

In the Netherlands every year flower bulbs and perennials are produced representing a value of 500 m€ (flower bulbs) and of 65 m€ (perennials, 2004). The growers are faced with several threatening pests, diseases and weeds during the production. Most growers deal with these problems by using measures like crop-rotation, fertilization, etc. but these measures are usually not sufficient enough to cope with these problems. Therefore, most growers also use plant protection products (PPPs) when necessary and when available. This widespread use of these products has led to recovery of PPPs in the surface- and groundwater in the Netherlands. Therefore in 2004 the Ministry of Agriculture, the growers, the PPP producers and the PPP suppliers, the waterboards and the water supplying companies signed an agreement on reducing the impact of PPPs on the environment in general and on surface water and groundwater especially. The ultimate goal was to reduce the impact on the environment by 95% in 2010 as compared to the situation in 1998 (Agreement Sustainable Crop Protection, 2003). This goal should be reached by banning pesticides with a high ecotox profile or restrict their application through legislation and development and implementation of integrated crop protection leading to a sustainable crop production with minimal input of PPPs and minimal hazardous effects of PPPs on the environment.

To be able to offer strategies for integrated crop protection several sustainable methods have been or are being developed by the Applied Plant Research Flower bulbs and Nurserystock (PPO Lisse). Strategies were focused on a combination of preventive measures and control measures, such as using clean plant material, healthy soil, decision support systems, pesticides with a low environmental risk, biocontrol agents, natural enemies, pesticide emission reducing techniques, methods for manipulating soil health, etc. The control measures include chemical and non-chemical (biological, pesticides of natural origin) PPPs. The chemical PPPs must be applied in such a way that their use results in a low environmental impact. This concept is based on the IOBC Guidelines for Integrated Production: Principles and Technical Guidelines (Boller et al., 2004, www.iobc-wprs.org). These measures were tested not only under experimental conditions at the Applied Plant Research Centre (PPO) Lisse but also under practical conditions at farmers. In this way methods were evaluated for their robustness under different situations (location, farm size, climate conditions).

In this article the common pests and diseases in the Dutch horticulture and the concepts of prevention and control are briefly discussed. Furthermore examples of the development and testing of preventive measures and control measures are presented. Finally, integrating these measures into an integrated crop protection and implementation in practice will be discussed briefly.

PESTS AND DISEASES IN DUTCH HORTICULTURE

Producers of flower bulbs and perennials are faced with several diseases including different fungi and oomycetes, viruses, bacteria, nematodes and insects.

Fungi and Oomycetes

Most damage caused by fungi results in poor plant quality and quantity. The most important fungi and oomycetes that cause problems in the soil are *Pythium* spp. causing root rot, *Phytophthora* spp. causing foot- and root-rot, *Fusarium* spp. causing bulb rot and wilting diseases and *Rhizoctonia* spp. causing bulb-, foot- and root-rot.

Fungi that cause above ground problems are several species of *Botrytis* and *Phoma* resulting in leaf blight (*Botrytis* spp. in flower bulbs), leaf and stem spots, members of the *Erysiphaceae* causing mildew, members of the *Peronosporaceae* causing downy mildew and fungi causing rust such as *Coleosporium*, *Puccinia* and *Uromyces*.

Viruses

Infection with a virus causes poor plant quality. But more important several viruses are quarantine-organisms in export countries. Plant material with these viruses can not be used for the export resulting in severe economic damage.

The most important viruses of flower bulbs or perennials are *Tulip Breaking Virus* (TBV), *Lily Symptomless Virus* (LSV) and *Cucumber Mosaic Virus* (CMV). The vectors for these three viruses are aphids. The transmission is non-persistent.

There are a few viruses transmitted by other vectors like *Tobacco Rattle Virus* (TRV) transmitted by the nematode *Trichodorus similus*, *Tobacco Necrosis Virus* (TNV) transmitted by zoospores of the soil fungus *Olpidium brassicea* and *Tulip Virus X* (TVX) probably transmitted by tulip mites and mechanically.

Bacteria

A few bacteria species have very detrimental effects on especially bulb quality. Several *Dickeya* spp. and *Pectobacterium* spp. (formerly known as different *Erwinia* spp.) can cause serious soft rot in different bulbous crops. *Xanthomonas* spp. infection leads to poor bulb quality and infection by different *Rhodococcus* species leads to soft rot and growth distortion of the roots.

Nematodes

Most nematodes causing problems in the bulb and perennial production cause root problems. *Pratylenchus* spp. cause root rot in several bulbs and perennials, whereas *Meloidogyne* spp. cause serious root knot problems in mostly perennial crops. Infection by both nematode species leads to serious reduction in plant yield and plant quality. Several *Aphalenchoides* spp. can cause leaf spots and growth distortion. More problematic is infection with the bud and stem nematode *Ditylenchus dipsaci*. *D. dipsaci* consists of different biological races and the tulip race is a quarantine organism in the Netherlands. Infection with the tulip race leads to very stringent measures for the growers like destruction of the infected plant material and the prohibition on flowerbulb production on infected fields for at least 10 years.

Insects

A lot of different insect species cause damage during production and storage of flower bulbs and perennials. Most important insects in this respect are aphids and white flies especially for the virus transmission, sap sucking insects like cushion scales and thrips, different mite species, cicades, caterpillars and may-beetle larvae feeding on the roots of plants.

PREVENTION

Preventive measures can be applied to the following stages during the production chain; healthy plant material and resistant plant material, good and clean storage of the plant material and healthy soil and crop rotation.

Healthy Plant Material and Sensible Handling and Storage

Starting with clean and healthy plant material is one of the pillars of sustainable production. Growers can take several cultural measures resulting in clean and healthy plant material. One of these measures is sorting out the plant material such that diseased or poor quality material is separated from the good plant material. Although this demands time and costs in the end this investment will be beneficiary. Another important choice growers have is to choose plant cultivars or plant races that are less sensitive for or resistant to diseases and pests.

After bulbs and perennials are harvested they are usually processed. For example tulips are usually rinsed after harvesting. During the processing of the bulbs or plants several risk moments can occur where diseases or pests can spread from diseased material to healthy material or where infection can take place. For different diseases these moments are known and growers are advised to prevent the circumstances during which spread and/or infection can take place. For example, favorable conditions for *Fusarium* infection of tulip bulbs like temperatures above 20°C and high humidity must be avoided during processing of the tulips as much as possible.

During storage risk moments for infection and disease development can also occur. Risky conditions are known for several diseases and these should be avoided during storage. Due to technological developments it has become easier for growers and traders to control conditions during storage very precisely.

Healthy Soil and Crop Rotation

Growing the plant material in healthy soil should be a prerequisite for sustainable production of flower bulbs and perennials.

Factors determining soil quality are soil structure, soil life or soil biodiversity and soil fertility. The level of Organic Matter (OM) in the soil influences these factors. A big part of the flower bulbs and perennials is produced in the western part of the Netherlands on calcareous coarse sandy soils with a naturally low OM content. It is difficult to increase and maintain a higher OM level in these soils. At PPO a long term project , Top Soil+ was initiated to develop farming systems with an optimal soil quality for intensive open field ornamental production (van Reuler et al., 2008). Two interventions were tested: broadening the crop rotation and increasing the OM content. Using different bioassays with soil from the fields with different OM content it was determined that increasing the OM content to 2.4% starting from 0.7% by a peat-manure mixture (5%) resulted in more soil suppressiveness against the nematodes *Meloidogyne hapla*, *Pratylenchus penetrans* and *Pythium* spp. (van Os et al., 2009). In the field the same effect against *M. hapla* was found (Fig. 1). Soil suppressiveness also plays an important role in natural suppression of *P. penetrans* in lilies (de Boer et al., 2005).

Furthermore a broad and sensible crop rotation and removal of crop residues after harvest is important in maintaining a healthy soil. Concerning crop rotation the most sensible choice can be based upon host plant information for nematodes since a lot of information is known for this disease causing soil organisms and its host plants. Therefore PPO Lisse wrote a brochure for growers of perennials and summerflowers that compiles all information concerning hygiene, plant material and crop rotation with emphasis on nematodes (van der Helm, 2009).

CONTROL

In the control of pest and diseases several measures play a crucial role; detection of diseases and pests in plant material or in soil, cleaning plant material, cleaning the soil and the use of plant protection products; chemical, biological or of natural origin.

Detection

To be able to apply the correct measures to control a certain disease problem it is important to know which organism(s) can be the cause of the problem. For nematodes in soil and in plant material good tests are available at commercial labs. For more specific problems in bulbs and perennials specific detection methods are being developed such as the causal agent of soft rot by *Dickeya* spp. and *Erwinia carotovora* subsp. *carotovora* (van Doorn et al., 2011). Furthermore tests for different *formae speciales* of *Fusarium oxysporum* causing bulb rot in, among others, tulip and narcissus are developed. These tests based upon molecular techniques (PCR) that can be used by professional testing laboratories like the Flowerbulb inspection service.

Another kind of tests are the ones that can be carried out on farm by the grower himself. These last tests are mainly developed to give growers and traders insight in the number of infections of a certain disease in the plant material.

After identifying the organism(s) that cause(s) the problem(s) it should be established whether the numbers of this organism are above the threshold level for damage. This threshold level is not always known for all pest-plant combinations. But this is a prerequisite for good advices to control the organism.

Cleaning Plant Material

A very efficient and environmentally friendly way of controlling nematodes in plant material is by using the hot water treatment. This treatment is developed for specific combinations of bulb species and nematode species (Leaflet Aaltjesbeheersing in de bloembollenteelt, 2006). Van Leeuwen and Trompert (2011) developed a hot water treatment to control *Aphalenchoides subtenuis* in *Allium* and *Crocus*.

Another example is the hot water treatment for the control of the nematodes *Pratylenchus penetrans*, *Aphalenchoides fragariae* and the bulbmite *Rhizoglyphus robini* in lilies optimized by Kok and Aanholt (2008, 2009). It was demonstrated that the temperature of the hot water treatment could be safely raised to 41°C and applied for 2.5 h when (if) the lilybulbs were pretreated with one day at 20°C followed by one day at 20°C after the hot water treatment. With this treatment the nematodes and the mites were completely eradicated.

An environmentally friendly method to clean the surface of the bulb is the use of easy degradable compounds. The control effect of these compounds, including chloride containing compounds, is mostly based upon oxidation of spores or cells of organisms. Several of these compounds are effective against bacteria and/or fungal spores when tested on contaminated plant material. A problem in the practical application is that these compounds react with all organic matter and directly lose their effect after such a reaction. An extra complicating factor is the difficulty to measure the concentration of the effective compound for example during the dipping of the bulbs (Van der Lans et al., 2004).

Cleaning the Soil

Several alternative methods for chemical soil disinfestation to control soil borne pathogens have been developed and tested the past years. Methods like the use of biofumigation crops and the use of specific precrops were discussed by de Boer et al. (2005). Biofumigation, the incorporation of Brassicaceous green manure crops resulting in the release of vegetative biocidal compounds like isothiocyanates, is still being tested in field experiments. The effects of this method are promising but also variable. Therefore a broad application is still not practicable.

Other methods like biological soil disinfestation, the incorporation of compost or chitin and intercropping with *Tagetes patula* are currently under investigation (Korthals et al., 2009). In a field experiment for several years these and other methods and a combination of different methods are tested for their effects against *P. penetrans*, *Verticillium dahliae* and several other soil borne pathogens. First results are promising and show long-term effects of the combination of different measures on reducing the numbers of *P. penetrans* and enhancing the yield of lilies grown 2 years after application of the different methods.

Flooding of the soil for at least six to eight weeks can also be a good alternative. This method can only by used on the calcareous coarse sandy soils in the western part of the Netherlands where bulbs are grown. The last years there is an increase in fields that are flooded. Bulb growers apply this method more frequently since it is a good alternative for chemical disinfestation with metam-sodium for most soil borne problems like nematodes, fungi and weeds (Leaflet Inundatie in de bloembollenteelt, 2009).

Plant Protection Products

To develop integrated control strategies it is also necessary to have plant protection products (PPPs). Most PPPs are chemicals but at PPO Lisse we have also tested biologicals and PPPs of natural origin like essential oils or waste products of the agricultural industry. The application of natural enemies is discussed at the end of this section.

1. Biological PPPs. By biological PPPs we mean antagonistic microorganisms or microbial pesticides like *Pseudomonas* spp. or antagonistic fungi. At PPO Lisse we have tested several of these microbials the past years against several soil-borne diseases. *Pseudomonas fluorescens* strain R1SS101 is able to suppress *Pythium* root rot of hyacinths in field applications (de Boer et al., 2006). The mycoparasite *Verticillium biguttatum* was able to suppress *Rhizoctonia solani* AG2-2IIIB in lily in large scale field experiments (de Boer et al., 2006). Unfortunately these microbials have not been registered yet. An obstacle for official authorization of these microorganisms as biological control agents may be the limited sales potential for a relatively small market (de Boer et al., 2006).

2. PPPs of Natural Origin. Several groups of compounds like essential oils that attract or repel insects or waste products of the food chain that have microbial growth inhibiting capacities have been tested against several pests and diseases in flower bulbs and perennials. Evaporation of an essential oil from plants in the storage cell proved to be very effective in controlling *Thrips simplex* on corms of gladiolus (Conijn and de Kogel, 2008). A waste product of the citrus industry proved to be effective against *Botrytis* leaf blight in lily causes by *Botrytis elliptica* (Fig. 2). Although it is not always as effective as the fungicide application it is a promising new product with no environmental impact (de Boer, 2009).

3. Chemical PPPs. Chemically produced PPPs, pesticides, are still essential for an effective and good control of several pests and diseases in large scale flowerbulb and perennial production. In line with the IOBC/WPRS guidelines for integrated production PPO Lisse is developing different methods to apply pesticides in such a way that the application results in the lowest risk possible for humans and environment. Disease forecasting systems that assist the grower to apply the pesticide only on the most effective moment based upon weather forecasting have been developed for the control of mildew in outside grown summerflowers and *Botrytis* leaf blight in flower bulbs (van den Ende et al., 1999). Depending on the weather conditions the use of these systems can reduce the number of sprayings by more than 50%.

Another method to reduce the amount of pesticides used is by using precision disease control. Van der Zande et al. (2010) have investigated whether matching spray volume to crop canopy sizes and shapes can reduce the use of PPPs, thus reducing operational costs and environmental pollution. In flower bulbs (lily) it was shown that in *Botrytis* leaf blight control on average spray volume of a fungicide could be reduced by 45% by using a new application; the canopy density sprayer (CDS). This sprayer consists of a sensor to quantify crop canopy combined with spray techniques to apply variable dose rates (van der Zande et al., 2010). At PPO we simulated this method in a weekly spraying scheme by starting with a low dosage of the fungicide (12.5%) when the lilies were about 10 cm above the ground and raising this dosage every week by small steps reaching the 100% dosage around flowering of the lilies. With this simple method a good *Botrytis* leaf blight control was reached with at least 21% less fungicide (Fig. 2) (de Boer, 2009).

4. Natural Enemies. A specific way of controlling pests is by using natural enemies. Application of natural enemies of pests is quite widespread in the production of vegetables and flowers in the greenhouse. But for crops produced outside the application of natural enemies it is more problematic due amongst others to variable conditions outside. Despite these problems one predator mite *Amblyseius andersoni* was rather succesful in controlling spidermites in *Verbascum*. Another example of the use of natural enemies is the use of *Amblyseius cucumeris* against the bulbmites *Rhizoglyphus robini* or *R. echinopus* during the storage of hyacinth bulbs. A big advantage is that for the control of the bulbmites insectides are no longer necessary. But a new problem arose during storage; thrips started to cause damage and this is not controlled by *Amblyseius* (P. Vreeburg, pers. commun.).

GENERAL DISCUSSION INTEGRATED CROP PROTECTION STRATEGIES

In the above paragraphs different preventive and control measures that have been developed or are developed for flowerbulb and/or perennial growers are discussed. Depending on the different crop protection problems a flowerbulb or a perennial grower is confronted with, the above presented measures should be the base for an integrated crop protection strategy to be able to control the pests and diseases in a sustainable way.

One example of the development of an integrated sustainable control strategy we are working on is the integrated control of *Pythium* root rot. The application of the biocontrol agent *Pseudomonas fluorescens* R1SS101 (de Boer et al., 2006) is integrated in a complete management strategy that includes crop rotation, different types of fertilization, incorporation of green of dead manure crops and fungicides. The compatibility of *P. fluorescens* R1SS101 with these other measures was determined by following the root colonization of R1SS101 on hyacinth in the field during the growing season. The effect of this strategy is tested in a long-term field experiment on two different experimental fields and together with growers where the different measures are incorporated into their own production strategy. With this long-term integrated strategy we expect that the general and specific suppression against *Pythium* root rot will be enhanced. Using the combination of different control measures also enhances the chance that this strategy will be effective in different soils under different conditions. Finally, using different ways of controlling a disease like *Pythium* root rot reduces the risk of development of resistance.

In general we advice growers to choose healthy soil, clean plant material, resistant plant material, a broad crop rotation and preferably non-chemical PPPs. When using chemical PPPs a grower should use different methods that are available to reduce the environmental impact of these pesticides. Disease forecasting systems can be used, techniques that reduce emission and reduce spray volume and other methods that result in effective disease control with less fungicides like starting with a lower dosage.

So, the growers are confronted with a lot of new methods and a rather new way of thinking in integrated crop protection strategies instead of just using a few pesticides that are effective against several disease problems. To assist the growers with the implementation of new methods into an integrated crop protection strategy projects like Farming with a future (Telen met toekomst) are carried out. In this project a network approach is used to bring growers and several stakeholders together concerning the testing of a Best Practice. Best Practices are measures that contribute to a sustainable crop protection as discussed in the earlier paragraphs. The Best Practices that have proven to be effective and feasible are ready for implementation on many farms (Brinks and de Kool, 2006).

PPO Lisse is working on the development of sustainable control methods that are integrated into crop protection strategies and that are implemented in practice together with growers and stakeholders.

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Figures

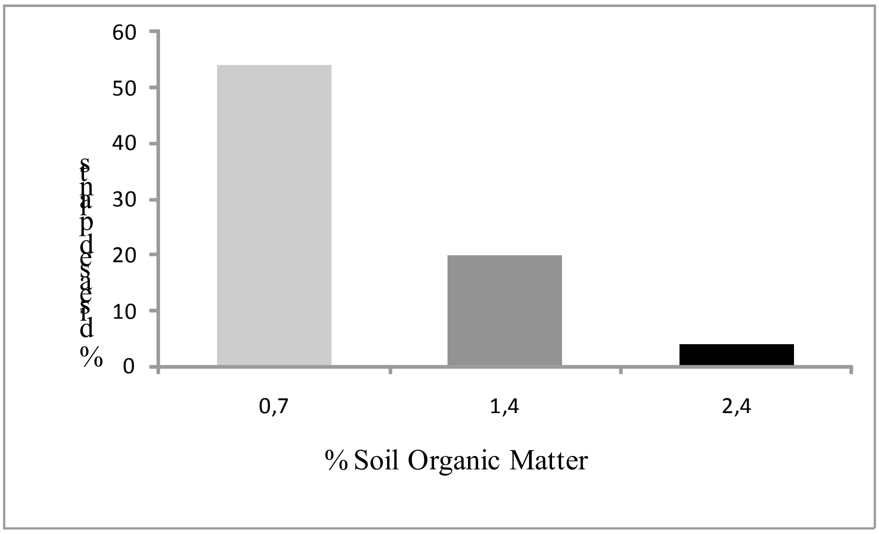

Fig. 1. Percentage of plants of *Aconitum napellus* with root knots in a field. Slightly *Meloidogyne hapla* infected plants were planted in soil with different OM contents. After one growth season the number of plants with root knots was determined.

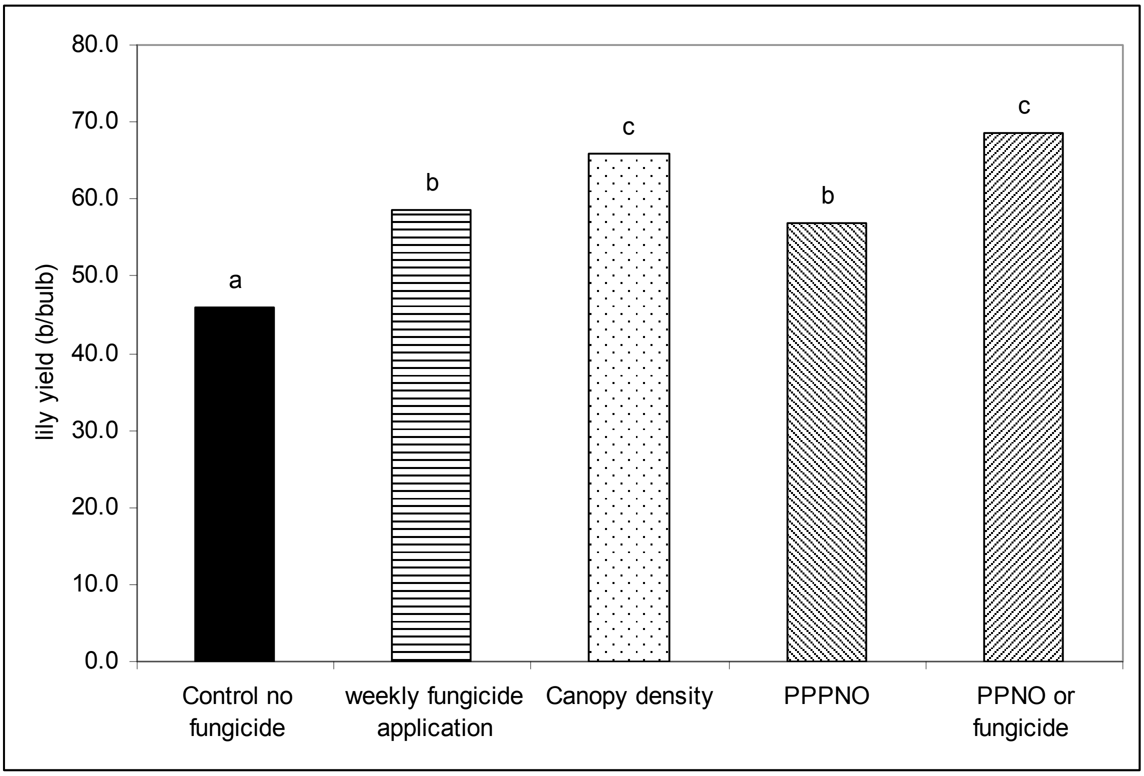

Fig. 2. Yield of lilybulbs 'Menorca' (g/bulb) of different treatments against *Botrytis elliptica* in a fieldexperiment. Several treatments resulting in a reduction of the number of fungicide applications and/or the total amount of fungicide applied for *Botrytis* control were tested in a field experiment on an experimental field in Drenthe, an important lily production area. The size of one replicate of a treatment was 3 m^2, 4 replicates per treatment. The canopy density treatment started with a weekly application of a low dosage (12.5% of the full dosage that was applied in the weekly fungicide application treatment) that was raised in small steps to 100% around flowering of the lilies. PPNO is a Plant Protection Product of Natural Origin derived from the citrus industry. The PPNO was applied according to a *Botrytis* warning system. In the treatment where either a PPPNO or a fungicide was applied, the PPPNO was applied when the risk level was between 25 and 50% (according to a *Botrytis* warning system), the fungicide was applied when the risk level was above 50%.