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# Predatory mites Neoseiulus californicus and Phytoseiulus persimilis chose plants with domatia

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**Abstract**

Plants added to an IPM cropping system can potentially enhance establishment of beneficial organisms and thus improve the efficiency of biological pest control in IPM greenhouses. However, despite the clear function of their presence, there is a lack of scientific knowledge about the way the additional plants function precisely. In the present study, we analyse one aspect, the importance of the presence of domatia for the presence of the phytophagous mite *Tetranychus urticae* and the predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis*. We employed eight potential banker plant species differing in plant architecture, the presence of pubescence, domatia or waxes, leaf texture, etc. The purpose was to identify which plant functional types enhance the reproduction of predatory mites, which banker plant species the predator and pest prefer, the characteristics of these plants and the factors responsible for this choice. We observed the distribution of all pest and predatory mite species on each plant species infested artificially, including roses as ornamental crops, after 12 weeks. The results showed that spider mites (*T. urticae*) and predatory mites (*N. californicus, P. persimilis*), plant growth and the development of both pest and predator mites were clearly affected by the presence of banker plants. No banker plant species was infested by *T. urticae*, contrary to bt the ornamental rose crop. Two plant species were responsible for best predator installation and rose growth, both of which had acarodomatia on their leaves which favoured the installation of predatory mites. Leaf number and height increments showed no significant differences in infested and non-infested plants of the eight plant species. In this experiment, we identified two plant species as efficient banker plants, *Viburnum tinus* and *Vitis riparia*, which hosted predators and not pests. Both are well adapted to the local Mediterranean climate and can easily be grown in open fields and greenhouses in the region. Their high tolerance to temperature extremes and drought is advantageous in the light of climatic changes to be expected. With this knowledge, practical solutions for biological pest control as an alternative to chemical control can be optimized with the aid of additional plants in the system.

## Introduction

Biocontrol plants, such as banker plants, may provide shelter or food for beneficial organisms (Frank 2010, Huang et al. 2011, Parolin et al. 2012). The addition of such plants to crop systems can have positive effects on the productivity of crop plants and enhance the effectiveness of biological pest control (Frank 2010, Huang et al. 2011). However, there is a lack of scientific knowledge of why plant species act as banker plants, and which plant morphologies and structures enhance the desired proliferation of the beneficial organisms (Cortesero 2000, Parolin et al. 2014, Bresch et al. in press). Consequently, only few species of banker plants are in use, many of which are not natural in the region of employment. We postulate that the potential of banker plants is underestimated. If we know more about the morphologies which bear positive implications for the crop system, we can choose additional local plant species instead of potentially invasive ones. We then can increase the efficiency and optimization of banker plants in biological pest control.

The use of additional plants with special functional types in an IPM cropping system may favour the installation of beneficials which protect crop plants from pest organisms and thus induce positive effects on the productivity of crop plants. Additional plants may provide shelter and/or food for beneficial organisms which influence the interactions between phytophagous arthropods, beneficial organisms and culture plants.

The two-spotted spider mite *T. urticae* Koch (Acari: Tetranychidae) is a phytophagous mite known as one of the main pests on rose crops (Reid, 2008). The use of biological control agents such as the predatory mites *P. persimilis* Athias-Henriot (Acari: Phytoseiidae) and *N. californicus* (McGregor) (Parasitiformes: Phytoseiidae) appears as a safe alternative to pesticide use in pest management (Skirvin et al. 2002, Blümel & Walzer 2002).

The aim of our experiment was to determine the plant preference of arthropods and mite pests and predatory mites *P. persimilis* and *N. californicus* between eight different potential banker plants. This study aimed at identifying suited biocontrol plants for the target rose crops in a Mediterranean glasshouse. We chose these plant species as they are common plants in the Mediterranean region and thus do not represent potential danger as invasive species, and have been indicated as potential banker plants in earlier studies.

The hypothesis tested in the present study was that if predatory mites (*N. californicus* and *P. persimilis*) had the choice between plants with and without domatia, they would choose those with domatia. By finding out which among the chosen species was the best suited banker plant for *N. californicus* and *P. persimilis*, its employment for local IPM programs might become more common. The implementation of biological control with the aid of biocontrol plants is still very rudimentary despite its high potential.

## Materials and methods

We worked with the predatory mites *N. californicus* and *P. persimilis* and the pest spider mite *T. urticae* and gave them the choice among eight plant species standing closely and connected together. Two of the plant species bear domatia on their leaves. The question was which plant species the predatory mites prefer if they have the choice. We also added pest mites to test for their presence and proliferation on the plant species as a biocontrol plant is not efficient if it also enhances the pest populations. We performed a long-term experi-

Table 1: Plants employed for the experiment and their characteristics.

| Species | Common name | Family | woody / weedy | annual / perennial | growth habit | wax urface | glandular trichomes | non-glandular trichomes | domatia |
|---|---|---|---|---|---|---|---|---|---|
| *Capsicum annuum L.* | Sweet Pepper | Solanaceae | weedy | A/P | subshrub forb/ herb | ++ | - | - | - |
| *Crepis nicaeensis Balb* | French Hawk's-beard | Asteraceae | weedy | A | forb/herb | + | - | + | - |
| *Eleusine coracana (L.) Gaertn.* | Finger millet | Poaceae | weedy | A | graminoid | - | - | + | - |
| *Rosa var. Sonia* | Rose | Rosaceae | woody | P | subshrub | + | - | - | - |
| *Solanum lycopersicum var. Saint Pierre* | Tomato | Solanaceae | weedy | A/P | forb/herb | + | + | + | - |
| *Sonchus oleraceus L.* | Common sowthistle | Asteraceae | weedy | A | forb/herb | + | - | - | - |
| *Viburnum tinus L.* | Laurustinus | Caprifoliaceae | woody | P | shrub | +++ | + | + | + |
| *Vitis vinifera var. riparia gloire clone 1030* | Grapevine | Vitaceae | woody | P | vine | ++ | - | + | + |

ment lasting 12 weeks, i.e. over several generations of arthropods. We employed eight plant species with differing characteristics, i.e. presence or absence of domatia, but also architecture, presence of pubescence, waxes, leaf texture (Table 1) by offering the mites the full complexity of whole living plants, we wanted to test the practical applicability in the greenhouse under realistic conditions like the local producers are facing.

We chose eight BP based on their origin or traditional employment as crop plants in the Mediterranean area or on the knowledge about their efficient employment as banker plants. The choice of these species was also based on their different morphological structures or their usual use as BP in IPM or their promising characteristics e.g. hairy leaves and stems, or waxy surfaces or domatia on the lower side of their leaves. Different growth forms ranging from a herb (*Eleusine*, *Lycopersicon*) over little structured physiognomy with few free standing leaves (e.g. *Capsicum*, *Sonchus*) to very dense canopies with many leaves and many stem bifurcations (e.g. *Viburnum*) were used.

Four replicates of all treatments of 8 different species of potential banker plants, including crop plants of similar size and age in 3 l. plastic pots were placed in a greenhouse of INRA Sophia-Antipolis (Table 1; Figure 1).

We employed entire plants in order to preserve the complexity effect of the tritrophic interactions system (Finke & Denno 2006). All plant species were grown from sown seeds except rose (in vitro culture), *Vitis* (cutting) and *Viburnum* (originated from a nursery). The experiment was carried out without restriction of food and moving. Pollen from *Pinus halepensis* P. Mill. was collected on trees outside the greenhouse and added to the plants at regular intervals.

We carried on the experiment in a greenhouse with conditions comparable to those used by local farmers. The climatic conditions in the greenhouse were only slightly regulated through open windows. Temperature and humidity were recorded at hourly intervals by Aria Soft® with an Aria hygrometer (ref. SDE-HYGRO-4) and Aria thermometer (ref. SDTEOA45, SDTS 0/60).

Mites

Two-spotted spider mites, *T. urticae*, were reared on rose and bean plants in our laboratory. The predatory *N. californicus* and *P. persimilis* were respectively purchased from the commercial strains Spical® and Spidex® at Koppert Biological Systems (Berkel en Rodenrijs, the Netherlands).

The rose plants were inoculated with 50 pest mites *T. urticae* and kept away from the 8 banker plants. A week later, the infested rose plants were put in contact with the 8 BP at as many points as possible in order to promote the migration of mites between the rose and the different BP. Artificial "bridges" of wooden sticks were installed in order to improve connectivity between the plants and the dispersal of predators (Skirvin & Roberts 2007).

Extreme temperatures in the greenhouse on the week-end of the 06 and 07/03/2010, (0.1°C during the night and 49°C at daytime) induced a substantial decrease of the phytophagous mite and led to a second inoculation on the 18/03/2010. On the 21/04/2010, 10 individuals of *P. persimilis* and of *N. californicus* were added on each of the 8 BP. On the 27/05/2010, we observed the distribution and counted the number of pest and predatory mites on all plants which were 20 cm tall at the beginning of the experiment.

## Results

There were no significant differences of height increments or leaf number in infested and non-infested

Figure 1: Experimental setting with one individual of each species placed in direct contact with the other species in a plastic tray.

plants of the 8 species, after the 12 weeks of experiment (Figure 2 and 3).

Both predators were found in highest numbers on *Rosa*, *Viburnum* and *Vitis*. Lowest numbers of individuals of *N. californicus* occurred on *Eleusine*, *Lycopersicon* and *Capscicum* and no predatory mite at all was found on *Crepis* and *Sonchus* species (Figure 4).

Six genera of pests were observed on the BP in addition to *T. urticae*. *Lycopersicon* and *Rosa* appeared attractive to most of the pests with a high level of *T. urticae* on *Rosa*. *Sonchus* and *Crepis* attracted a high population of *Aphis gossipii*. On the opposite, no pest was observed on *Viburnum* and *Vitis* (Figure 5).

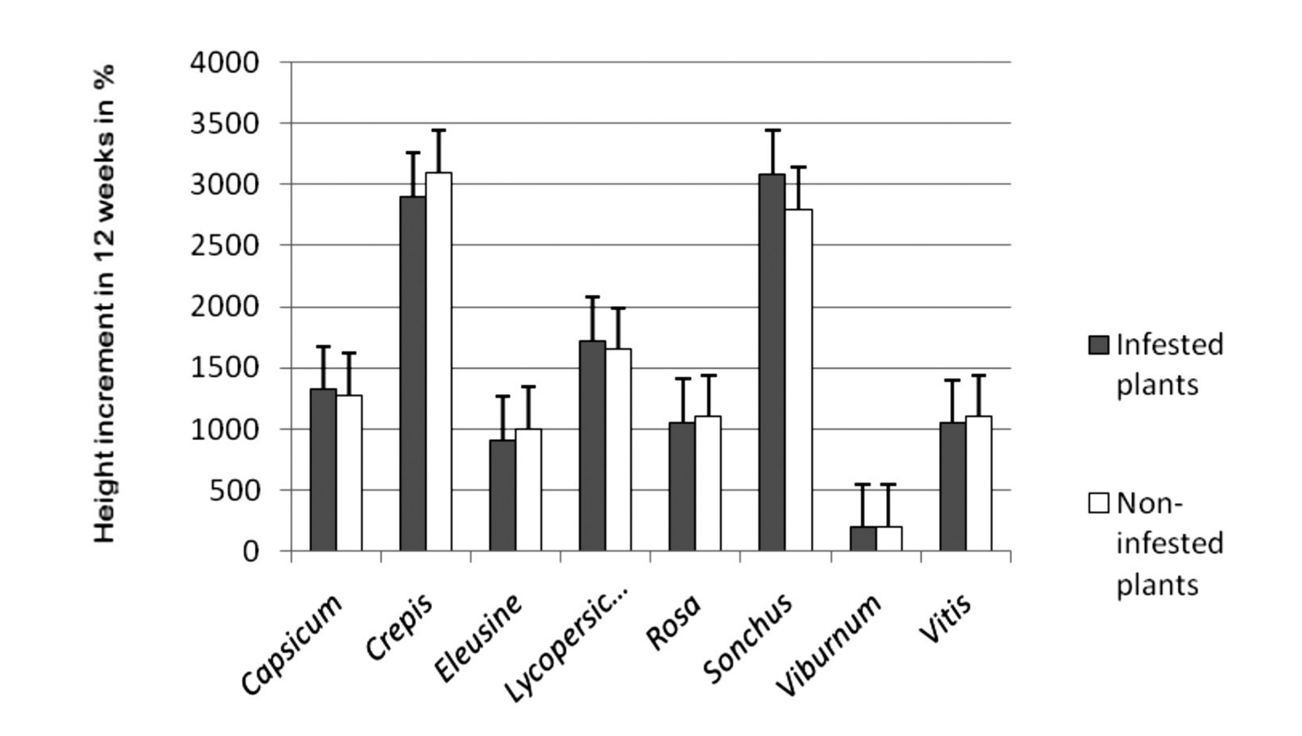


Figure 2: Height increments of the 8 species of plants in 12 weeks of experiment, with or without presence of pest and predatory mites.

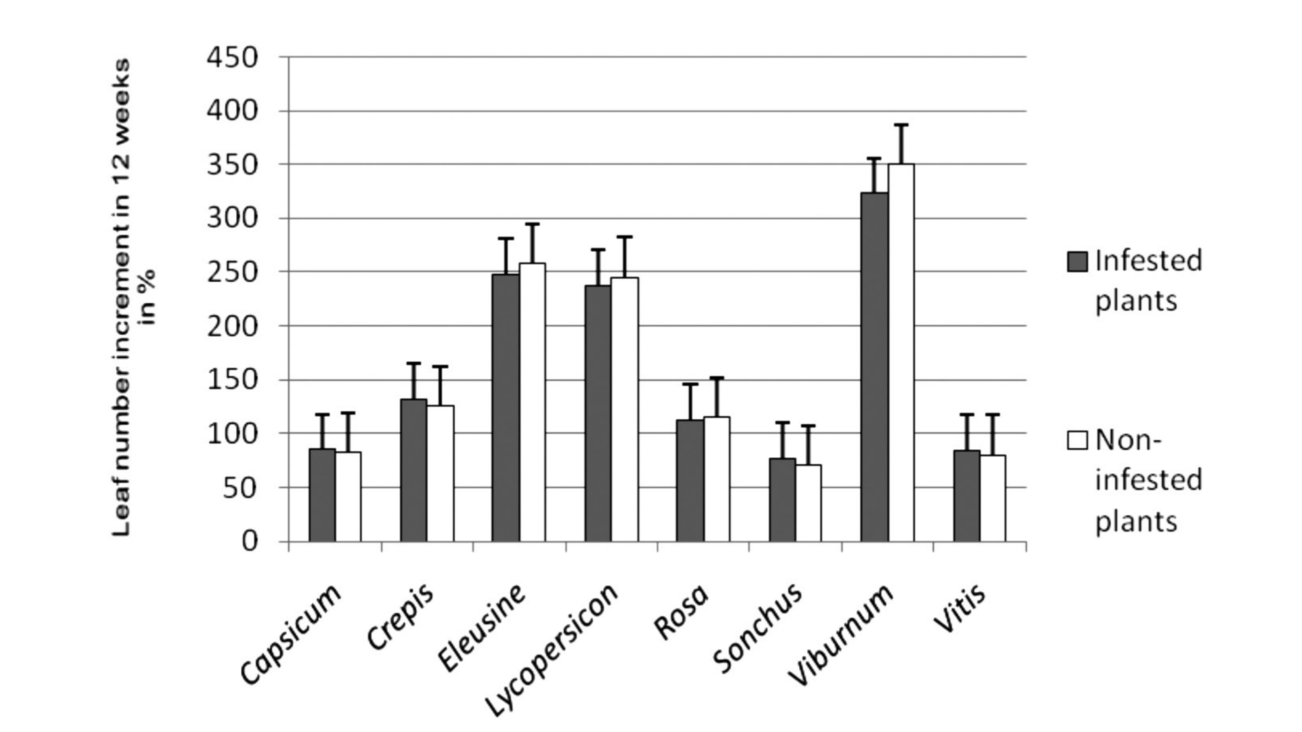


Figure 3: Leaf number of the 8 species of plants in 12 weeks of experiment, with or without presence of pest and predatory mites.

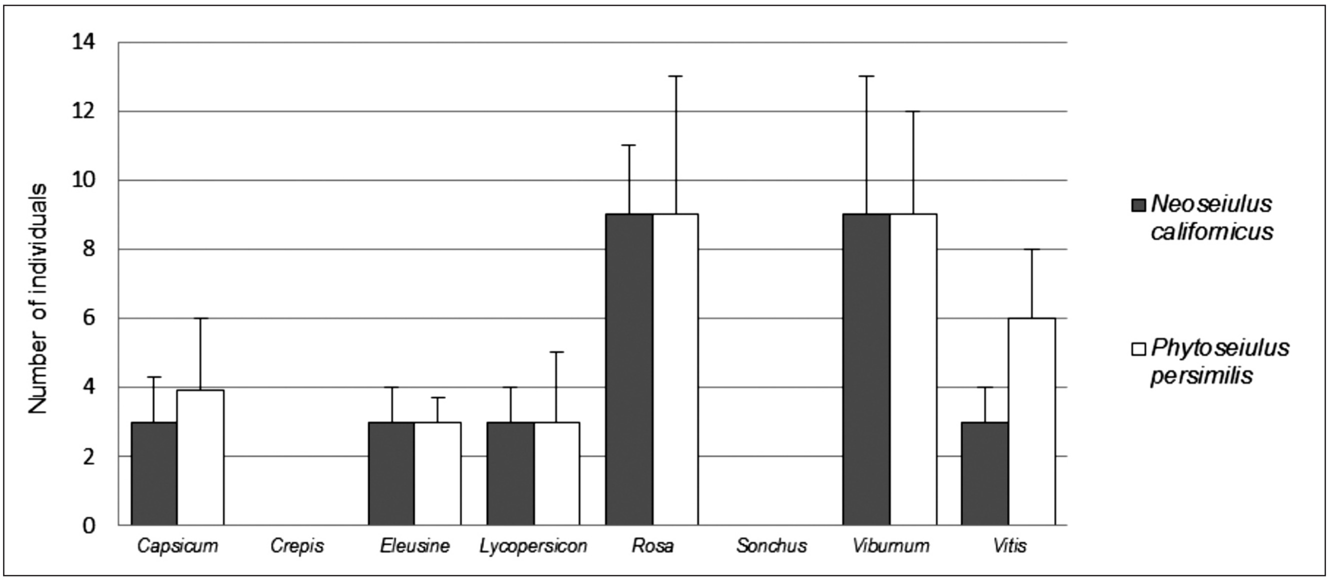


Figure 4: Number of individuals of the predatory mites Neoseiulus californicus and Phytoseiulus persimilis after 12 weeks on the eight species of potential banker plants.

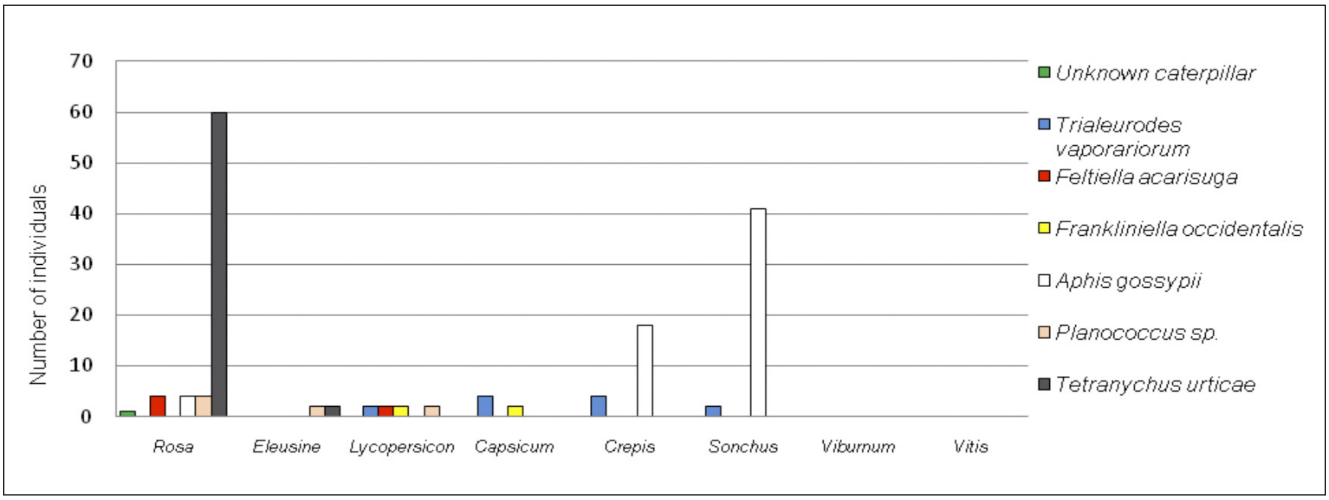


Figure 5: Number of individuals of different pest organisms on the chosen plant species of different pest organisms after 12 weeks.

**Discussion**

Under the given environmental conditions in an open glasshouse, the two predator mite species showed highest population densities on *Rosa*, *Viburnum* and *Vitis*. The heavy infestation of the rose plants with *T. urticae* was responsible for the high number of predator mites found on the ornamental target crops. Prey distribution clearly influenced the foraging behavior of the predatory mites *P. persimilis* (Gontijo et al. 2012). On the other hand, the high number of predators on two of the offered banker plants, *Viburnum* and *Vitis*, cannot be explained by the presence of prey. As these two plant species were the only ones with domatia, we suppose that the reason for increased presence of predatory mites was the shelter offered by the domatia. The acarodomatia on these plants are small structures, simple tufts of hairs located on vein axils at the underside of leaves (Matos et al. 2006). These structures may host several mite species and play a role in mutualistic interactions between plants and mites (Lundström, 1887; Walter & O'Dowd, 1992; Romero & Benson, 2004) (Figure 6). Although further experiments are needed here, we postulate that they may offer shelter from climatic less favourable conditions on the leaf surface, e.g. related to heat and drought protection, and from predators who might feed on the mites and who thus use the domatia as refuge for themselves and their eggs.

**Distribution of pests on the plants.**

The distribution of pest organisms at the end of the experiment was not uniform among the eight plant species. The plants which were least populated by all pests were *Viburnum* and *Vitis*. Perhaps the pests specifically avoid the relatively high number of predatory mites

Figure 6: Domatia formed by non-glandular trichomes on the lower leaf side of Viburnum tinus (left) and Vitis (right).

present on these two plant species (Figure 4) but our data is not sufficient to state this.

Since all the organisms could migrate to all plants freely in this experiment, this may indicate that the presence of predatory mites was not the determining factor for pest distribution on the plants. It was probably more related to the different characteristics of the available eight plant species. Spider mites preferred the roses among all other plants, and so did *Feltiella*, *Planococcus* and *Aphis*. Like the roses, *Solanum* was attacked by 4 species of pests, whereas *Capsicum*, *Eleusine*, *Crepis* and *Sonchus* were attacked by two different pest organisms. *Crepis* and *Sonchus* were preferred by *Aphis* which occurred in rather high numbers on these plant species.

One important point for the application of banker plants is that they should not serve to enhance the pest populations. A banker plant must be able to host and enhance sustainably only the reproduction of the beneficial arthropods. The purpose is to provide long-term pest suppression (Frank 2010; Huang et al. 2011) without the need for pesticides. This way, as the pests are controlled by the predators and predation is indirectly decreased, crop productivity and yield are also indirectly increased by the presence of predators (Ripper 1944). In our experiment, this was given for the organisms involved.

**Potential to serve as banker plants for predators.** *Viburnum* and *Vitis* appeared to have a high potential to act as efficient banker plants for biological control against the pest *T. urticae*. These two species were not attractive for any of the pests, and they both hosted a high quantity of predatory mites.

*Viburnum tinus* is a Mediterranean native evergreen shrub (Bailey & Bailey 1978). A few studies already analysed its potential to host predatory mites in its acarodomatia (Grostal & O'Dowd, 1994 ; Rowles & O'Dowd, 2009) (Figure 6). Our results confirm these findings also for greenhouses in Mediterranean climate.

*Vitis riparia*, the riverbank grape, is a common species of grape originating in Eastern and central North America (Moore, 1991) and frequently used as a source of genetic material by grape breeders (Reisch & Pratt, 1996). Its role as banker plant has not been analysed to date, but since it is a common species in the Mediterranean which tolerates the climate very well and bears domatia, it can be suited for the purpose.

## Conclusions

We identified two plant species as efficient banker plants, *Viburnum tinus* and *Vitis riparia*, which hosted predators and not pests. These species are outstanding

Figure 7: Lower leaf side of a rose leaf, highly infested with spider mites Tetranychus urticae and eggs (not from the current experiment where the infestation was not as strong).

in contrast to the other plant species present and which did not show the same potential to enhance biological pest control in rose crop raising. The two plant species are well adapted to the local Mediterranean climate and can easily be grown in open fields and greenhouses in the region. Their capacity to tolerate high and extreme temperatures as well as drought is advantageous in the light of climatic changes to be expected.

From the results of our experiments, and from literature reviews, we can deduce the following criteria for the selection of efficient species of BP which have to be case-specifically analysed in experiments preceding the application:

- Non-affinity of most problematic common pest species
- Affinity of the natural enemies chosen to decrease pest populations
- Growth form suitable for crop production. Vines such as *Vitis* can be positive in that they form long stems winding through the crops and thus provide bridges which guarantee connectivity for mites, which is known to enhance their efficiency (Skirvin & Roberts 2007). On the other hand, vines can grow very large and uncontrolled and thus may hinder a clean and clear cultivation of crops. Their control and maintenance may be time consuming since they need to be cut regularly.
- Resistance to climatic factors which are optimal for the needs of the crop (and not of the BP, e.g. when regulated in greenhouses). A wide range of ecological tolerance of the BP is recommendable, even more so in the light of climatic changes which in the Mediterranean region will bring about the necessity to tolerate low light in winter, heat and drought extremes (Nicotra et al. 2010).
- Special attention should be paid to the employment of native plants. They can increase predator abundance as much as widely recommended non-natives (Fiedler et al. 2007). By employing local species, farmers can contribute to restoration in the open field and limit the risks of introducing potentially invasive plant species (Chrobock et al. 2011).

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