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Short contribution

Main Research Needs in Organic Pome Fruit Growing: Results from Participatory Research Survey

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Abstract

BIOFRUITNET project partners evaluated the main obstacles to the organic fruit growing systems across Europe. Pest and disease control were identified the most limiting production factors. Further research for organic pome fruits should focus on the enhancement of the cropping system resilience. This involves the minimisation of the use of copper compounds but also of other plant protection products (PPPs), the enhancement of functional biodiversity, breeding and introduction of new varieties and rootstocks with high fruit quality, tolerant to diseases, pests and abiotic stresses, not requiring labour intensive cultivation practices (e.g. intensive thinning) and new variety concepts for their marketing including the whole production chain. An important research gap related to sustainable strategies to deal with invasive, newly emerging and locally important pests and diseases, which usually occour first in organic orchards.

The development of new selective PPPs suitable for organic fruit growing and the continuous availability of the traditional products emerged as a crucial strategy to support a growing organic fruit production sector. The challenge would thus be to also find new pathways for the registration of PPPs based on naturally occurring substances.

Keywords: research need - pest control – disease control – biodiversity - varieties

Introduction

BIOFRUITNET is an EU-funded project, gathering 16 partners that aims to collect the existing knowledge about cropping practices in organic pome, stone and citrus fruits production in Europe. In this context, the main knowledge gaps wereidentified to be able proposing research activities. The results of the analysis related to the topics “varieties and rootstocks”, “pest and disease control” and “enhancement of functional biodiversity” considered most relevant by farmers are presented for pome fruits in this paper.

Material and Methods

A questionaire was prepared and a survey was conducted among professionals involved in organic fruit production in all 16 EU countries involved in the project as described by Parveaud et al. (2022). The analysis of the answers was also discussed during a panel meeting with BIOFRUITNET partners and other experts on the 27.07.2021.

Results and Discussion

Strategies for pest control

Codling moth (*Cydia pomonella*) is the most common pest in apple and pear in Europe. The main strategy in all countries is based on the combination of Cydia pomonella Granulovirus

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(CpGV) applications and mating disruption. Nematode application against the diapausing larvae is an additional tool to reduce high populations. The main challenge in this strategy is the virulence management of CpGV and the management of small orchards with infestation pressure from the neighbourhood. Storage boxes set near the orchards are a source of the pest, increasing its risk of damage. An adequate long-term strategy for the virulence management of CpGV is needed. This includes an accurate monitoring of the occurrence of codling moth resistances in the field, the improvement of the knowledge about the resistance mechanisms and a better understanding of the host-virus relationship, the study of molecular mechanisms of infection of different virus isolates and the search for new isolates which should be tested with different pest populations in the field and in the laboratory.
Different methods are available for mating disruption, but a comparison between them is necessary considering the regional conditions. In case of high number of generations, as in Italy and France, Spinosad is used additionally to this strategy, but this causes damage to the orchard functional biodiversity.
For small organic orchards surrounded by extensive orchards in the neighbourhood, the strategy combining CpGV and mating disruption is not effective enough, due to the continuous infestation pressure from outside. In this case, the potential of physical barriers on the borders of the orchard should be tested. Physical barriers are already used in Southern Europe. However they are expensive and often arise problems with other insects (e.g. woolly apple aphid, leaf miners).

Several alternative methods have emerged as potential additive tools for the control of codling moth, but require extensive research. Disinfection of storage boxes, killing the diapausing larvae that hide in them, is a method that deserves development.
A great interest was expressed in better understanding the effect of improved use of biodiversity measures (e.g. flower strips) or of mixed orchards with different fruit species on codling moth control. The potential of mass trapping should be explored further, eventhough the use of fructose in field conditions was considered not very reliable by the experts.
In case of pear, from the expert panel it emerged that pear fruits are not always susceptible to codling moth infestation. To reduce the number of applications of CpGV, it should be investigated if there is a period of limited susceptibility/attractiveness, defining a method to define it as clearly as possible. Considering depency on the variety, studies should first focus on the variety Conference and then to other common varieties in organic pear growing.

The **rosy apple aphid (*Dysaphis plantaginea*)** is the aphid species causing the main damage in apples. Because in an early phenological phase even few aphids can produce severe damage, this species is difficult to control only by enhancement of functional biodiversity. However, measures to increase biodiversity are, nonetheless, an important tool for a combined strategy needed for an efficient control. This holds true particularly considering that the current control strategy is based on the direct control with only one active substance, i.e. the extract of *Azadirachta indica.* In a context with increasing land area of organic apple production, this situation could result in a risk of resistance building. Alternatives to the use of Neem extracts should thus be developed. Nevertheless, for Denmark and partly also The Netherlands, the current lack of authorization of Neem extract as PPP is an important obstacle to a successful strategy, thus requiring a solution. Moreover, there are still many knowledge gaps regarding the best use of the biodiversity measures to enhance the predation of the rosy apple aphid during the season, because of the different aims sought along it. In early spring, before damage occurs, it is effective if the climatic conditions are favourable for the predators; in late spring and early summer biodiversity shall reduce the population that survive the direct control measures; in autumn, when the aphids return on the apple tree from the herbaceous summer host, the need is to reduce the

infestation pressure for the following year. Since physical barriers are known to enhance the infestation by the rosy apple aphid, specific control strategies should be developed.

The **apple sawfly** (*Hoplocampa testudinea*) is an economically very important pest especially in Germany, Denmark, Austria and France. The pear fruit sawfly (*Hoplocampa brevis*) occurs also in Italy and France. The current strategy is the direct control with Quassia extract. However, Quassia extract has still to be listed as basic substance to allow a continuous availability for the farmers. The withdrawal of the authorization of Quassia in the new organic regulation is considered a major threat to the economic performance of organic pome fruits orchards in the regions concerned by sawfly damage. Therefore, the current work of a Task Force of IFOAM Organics Europe supported by private and public funding from several member states is a major effort to improve the control strategy. Nevertheless, the toolbox of possible measures should be enlarged with other solutions. Among them can be listed entomopathogenic funghi, which potential should be explored but seems not so promising until now, or mass trapping, that can be useful depending on the interaction of the hatching of the adults and the full blossom of the trees. Indeed, only if there is time enough to reduce the adults before they can lay their eggs in the open blossom (sawflies hatch with mature eggs and can start egglaying one day after hatching) these measures have some potential. Thus, these measures are not fully reliable. In any case, alternatives to plastic plates as mass traps should be tested (for example plastic ropes but possibly also alternatives that cause no microplastic pollution). The evaluation of the efficacy in using Spinosad in a correct way, at the definitive end of blossom, requires further research, as well as the search of other tools for direct and indirect control. The use of repellent compounds was explored, but no compound was significantly effective under field condition. The absence of apple sawfly rearing makes difficult the screening of strategies because trials in controlled conditions are limited by field sampling during the season.

The occurrence and damage by the **woolly apple aphid** (*Eriosoma lanigerum*) is increasing especially In Northern Italy, where intensive infestations can cause a loss of fruit quality and of yield up to 90%. Physical barriers to reduce disease pressure enhance very much this aphid species. The efficacy of direct measures as oil applications are limited and can have considerable side effects on beneficials. For these reasons, research should focus on breeding and selection of less susceptible varieties and rootstocks (for example G 11) and to strategies that enhance natural enemies, as *Aphelinus mali* or ladybirds, or prevent negative effects on them from direct control strategies of other pests. A complementary control measure to be evaluated is the application of sticky belts to reduce the aphid migration to the tree canopy in spring.

A major challenge in organic pome fruits production is the increasing occurrence of **invasive insect species.** The current most important of them is the marmorated stinky bug (*Halyomorpha halys)*. The control strategy at orchard level is based mainly on physical barriers since measures for direct control are missing. This is very expensive and has several negative side effects (e.g. the enhancement of woolly apple aphid and other pests infestations). The release of natural enemies at regional level could be a solution to reduce the massive infestation pressure (Haye and Weber 2017). However, concerns regarding nature protection and the effects on the native species are still subject of discussion and it is difficult for authorities to find a correct way to deal with the situation. Because of climate change and trade globalization, the invasion of not native species is currently rather frequent and requires high professional skills for the release of their natural enemies. Therefore, research is needed to better understand the meccanisms and the consequences of such releases. Nevertheless, pilot projects of beneficials release should be allowed by national authorities also to learn how to deal best with this new situation.

Native minor pests or even neutral insect species have become problematic due to climatic change. Stink bugs such as the red legged stinkbug (*Pentatoma rufipes*) since several years have caused high economic damage in pear orchards, but recently also in apples. The development of control strategies for such emerging pests is also a very important research topic for the coming years, to develop direct control measures and to understand the causes of this shift, including the interrelation with antagonists.

Several pests as the spotted leaf miner (*Leucoptera scitella* L**)** or the pear gall midge (*Contarinia pyrivora*) resulted to be only **of local or regional importance.** Currently, there is no strategy for an efficient control in organic fruit orchards for the pear gall midge. This is a major limiting factor for the increase of the organic pear area in some regions (for example Germany, Austria, The Netherlands, Belgium, France). BIOFRUITNET partners and experts recommended further research on effectiveness of pheromones, possibilities for mass-trapping, sanitary measures (pick infested fruit) and improvement of the application technique for the existing PPPs characterized by low efficacy. The sinuate pear tree borer (*Agrilus sinuatus*) is another example of these pests which leads more and more frequently to the uprooting of organic pear orchards in France.

Strategies for disease control

The most important disease in pome fruit is **scab** (*Venturia inequalis*), which damages leafs and fruits and can lead to total economic loss. The minimization of the use of copper compounds and the general reduction of the applications for disease control are a major topic for research in pome fruits. However, minor diseases such as sooty blotch (*Marssonina coronaria)* or storage diseases have become more important from the moment when the application of fungicides containing copper, sulphur and lime sulphur was reduced. Thus, developing the strategy of scab control should consider the whole spectrum of fungal diseases, especially if copper reduction is implemented.

A valuable tool in the strategy of disease control is the variety choice. However, varieties with multiple resistance, which would be highly useful, are limited or lacking and the scab resistance is already broken in the “resistant” apple varieties currently available. These varieties can be a solution to reduce the input of fungicides at medium term, but for a sustainable long term strategy other varieties will be needed. A lower susceptibility or higher rusticity to several diseases could be a promising strategy to adopt. The breeding of varieties with good market quality and shelf life that are tolerant to the main diseases is one of the most important challenges for organic fruit growing. However, the funding and the activities in this sector do not reflect this importance at all, requiring urgent actions.

The strategy aiming to minimise the use of copper can foresee preventive methods such as the reduction of the infestation potential by targeting the leaves in autumn or – for pear scab – the reduction of the scab spores overwintering on the shoots. The further improvement of the application technique and the development of new fungicides suitable for organic fruit growing are also necessary to increase the efficacy of the scab control strategy. However, the new fungicides will probabely be not as unsusceptible to resistance building as copper. Thus, it is important not only to rely on product replacement, but to enhance the resilience of the whole strategy as a combination of different tools, which assures the long-term stability of the production system. In this context, the control of the tree vigour is also an important tool to take into consideration.

Whenever alternative products will become available to practice, the authorization process as PPP is a crucial step. The products currently under evaluation to reduce the application of copper are all of botanical origin, but the EU registration process is still designed to mainly assess synthetic substances. An adaption of the process by the regulators is crucial for the availability of alternative products to copper.

Promising tools for disease control could be also antagonistic microorganisms and *Bacillus subtilis*. Even if *B. subtilis* has proved to be not effective in sooty blotch control in Italy, the potential of such antagonists should be studied not only for scab control but also for the control of sooty blotch. For sooty blotch it was shown in Italy that the infestation is enhanced by organic foliar fertilizers (e.g. algae), but also by calcium chloride. A mixture of these products with antagonistic microorganisms to mitigate the stimulating effect for sooty blotch should be tested. For the strategy of sooty blotch control, an important question is also the reduction of the overwintering forms on the trees.
For the control of storage disease (Gloeosporium sp.) the equipment for hot water treatments is not available in all regions and farms. Especially small farmers cannot afford this investment. Thus, the availability of acid clay (e.g. Myco-sin) is very important for copper minimisation. Currently, the use is compromised in most countries since there is no authorisation as plant protection product at European level. Also laminarin, an effective compound, should be made available in all member states.
Physical barriers are currently tested to reduce the problems with fungal diseases. They show promising effects but they induce also new problems in insect control. There is the need for more research aiming not only to the effects on pest and disease control but includes also the overall impact of physical barriers, i.e. through life cicle assessment.

Enhancement of functional biodiversity

The enhancement of functional biodiversity is a key element of organic fruit growing. However, a lot of potential in this tool is not exploited due to a lack in understanding the interrelations between measures enhancing biodiversity and the antagonists of the key pests. These relations depend very much on the climatic conditions, the landscape surrounding the orchard, the genetics of the fruit crop and of the “beneficial” plant species, which require that studies are conducted at local or regional level. More technical information about the implementation is still required in many regions. Crop covers could contribute to nitrogen fertilization and enhance beneficials or living mulches should reduce weed pressure and maybe increase soil fertility or host beneficials or repell pests. In this context, more research is needed to identify the best locally adapted plant species and the methods for their integration into the cropping system and agronmical practices, including direct plant protection programs, to avoid the risk of negative side effects from PPPs on beneficials. The combination of enhanced functional biodiversity with measures for nature conservation could be a strategy to enhance the ecosystem services provided by the orchard that deserves more studies and attention.
Organic farming systems depend much more than IPM systems on the effects of antagonists on the different pests.The impact of climate change on the interrelations between key pests and their antagonists is another aspect that requires further studies and extensive monitoring, to support the adoption of biodiversity measures. This would also contribute to assess and develop control strategies against invasive or alien pests that can be modulated at regional level.

The increase in functional biodiversity could also include the use of different **varieties** to reduce the infestation pressure of pests and diseases. Assessing the impact of orchards composed of local varieties or with a number of genetically different varieties should be a topic of research interest. To bring these approaches to practice, special marketing concepts are needed and shall be developed by involving the whole production chain.
Soil biodiversity, often a neglected topic, has in the recent past received more attention, also due to the renewed effort world-wide and the recognition of its central role in soil fertility and health. Nevertheless, more research should be carried out to improve the knowledge

about soil biodiversity management and the impact that different soil and orchard management practices have on it.

Varieties and rootstocks

Breeding varieties suitable to organic farming is of crucial importance to enhance the resilience of the organic production system. It should be oriented more toward tolerance/ robustness than toward resistance and consider also easy growing characteristics, taste and shelf life of fruits. More mutual information and a better collaboration between participative concepts for breeding would be useful. In apple production, cooperations of organic fruit growers have allowed to introduce several scab “resistant” varieties to the market. Topaz, Santana, Natyra, Story, and Dalinette are success stories of this approach. However, the introduction of more robust varieties (i.e. more tolerant/resistant to pests/diseases) is considered a turning point within a copper minimisation strategy, but can affect also the provision of stable yields. Nevertheless, the whole production chain must be involved in the change of varieties, to develop specific marketing concepts avoiding commercial failures. The change of variety would be even more difficult for pear, due to longer lifetime of orchards, thus requiring a stronger research effort.

A high number of varieties with a high genetic diversity could be considered a best practice from an ecological point of view to be promoted among growers. However, in some regions (e.g. Italy) this is not considered realistic from a commercial point of view. A marketing concept which would transpose this diversity into a quality feature together with general biodiversity and pesticide reduction could be a solution to be tested, as it has been discussed in The Netherlands and Germany where the regional markets are the main points of sale. Research is needed to recommend an intelligent concept for a variety mixture which reduces the infestation pressure of pests and diseases.

Anyway, beside the urgent need for breeding of varieties suitable for organic farming, new marketing concepts to introduce potential new varieties in the market are also needed. The conventional club concept resulted not suitable for organic fruit production, while innovative cooperative approaches or a variety concept with a social background are worthy of exploring being them more adapted to the organic farming philosophy.

Research needs in rootstocks derive from the observation that M9 is the main rootstock used in organic apple orchards all over Europe. It does not tolerate vegetation in the tree row, is very susceptible to vole attacks and to woolly apple aphid. Therefore, growers have high interest in new rootstock varieties showing some more vigour and with a lower susceptibility to woolly apple aphid. Testing of other rootstocks, including the promising Geneva 11, under different pedo-climatic and cropping conditions would be thus necessary to fill the gap in this regard. New interesting pear rootstocks (e.g. Kwee Farold, Farold 40 and Provence-Quince) and self-rooted plants could be worthy to test under organic growing conditions.

Conclusions

The survey and experts’ discussions carried out have pointed several aspects that will need to be addressed with specific reference to organic pome fruits productions. These should concern variety breeding and testing, agronomical practices, functional biodiversity management and management strategies for pests and diseases. Nevertheless, for each innovation related to PPP, the authorization process is a crucial step for the application in practice. Currently, the fact that the EU registration process is still designed to mainly assess synthetic substances, is a great obstacle for innovations adoption, especially in the case of copper minimization but also for the continuous availability of essential products traditionally used in organic farming such as Quassia or acid clay. An approach to adapt the process to

naturally occurring substances would be thus highly welcomed, particularly in view of the goals set in the Green Deal and Farm to Fork strategies.

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