A complex monitoring of biodiversity of organic apple orchards could uncover the impactof agro-management strategies

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Abstract

This complex study investigates causal relationships between biodiversity of insect indicator-insects in soil, on land surface and on trees, and agro-management practices in organic apple orchard in the region of Plovdiv, Bulgaria. In 2013-2015, indicator-insects density and biodiversity were higher in organic than in conventional orchard which was attributed to practices facilitating improved activity of beneficial insects in keeping pest population below threshold levels. Regression analysis showed a positive but mild correlation (at polynomial model) between agricultural intensification (AI)index and biodiversity indices (of Shannon and Simpson) of soil insects and land-surface insects, and a strong correlation (at linear model) between the indices on the organic trees. The AI index should however reflect other important factors impacting biodiversity, i.e. climate and soil conditions or agro-management (e.g. time of mowing, irrigation regime or time of pesticide applications).

Introduction

The modern organic fruit production in Europe strives to establish ecologically-balanced and productive agro-ecosystems. In the last decade, the concept of "ecofunctional intensification", based on efficient use of renewable resources, recycling of organic matter and use of enhanced biodiversity, is taking increasing importance (Niggli, 2010). The central place of functional biodiversity in the concept is determined by important ecosystem services it provides at farm level, e.g. integrated pest management, recycled soil organic matter and better water-holding capacity, etc. However, at the level of EU-28, there are no unified standards for monitoring and assessment of biodiversity of organic agro-ecosystems or the level of their eco-functionality. Therefore, the study investigated applicability of a complex monitoring of biodiversity of organic apple orchard and causal relationships between complex organic agro-management strategies and biodiversity in a local agro-ecological conditions context.

Material and methods

The three-year study was performed in 2013 to 2015 in an organic and a conventional apple orchards of approximately 0,5 ha each. The organic orchard is maintained at premises of the organic demonstration farm of the Agro-ecological Centre of Agricultural University of Plovdiv, and the conventional near the village of Kalekovetz situated at few kilometers from the town of Plovdiv. Climatic data (i.e. average rainfall, humidity and temperature) were taken from the local meteorological station of Plovdiv. Two apple varieties i.e. Florina and Melodie relatively tolerant to major apple diseases powder mildew and apple-scab were monitored. The intra-rows of organic orchard were maintained with a grass-clover mixture since April 2010, while the intra-rows of

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conventional orchard were partly grassed after spring of 2014. Major soil parameters of alluavial soils, typical for the studied region, i.e. digestible forms of nitrogen ($N\text{-}NH_4$ and $N\text{-}NO_3$, mg/100 g), phosphorus (P_2O_5 mg/100 g), potassium (K_2O mg/100 g), pH in water extract 1:5, humus content (%) were analysed by soil sampling from two layers, i.e. 0-20-cm and 20-50-cm, from eight experimental plots randomly placed in the intra-rows of the two apple varieties in the beginning of each vegetation season. Monitoring of biodiversity considered major factors in the apple growing (i.e. Scheme 1 below).

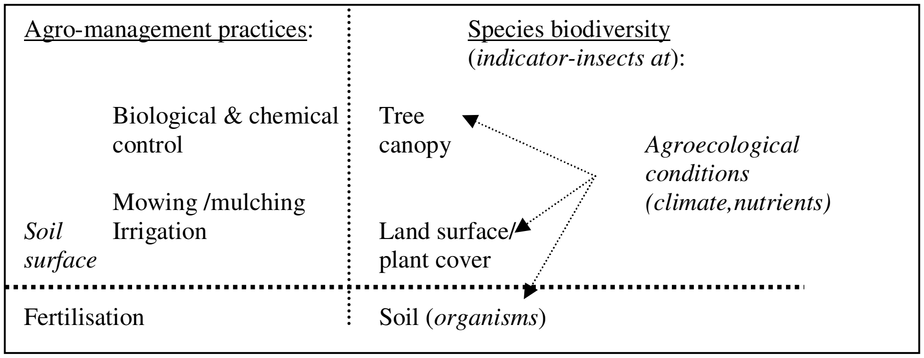

Figure 1. Factors impacting apple growing dynamics.

Agro-management practices

In organic orchard these included between 3 and 8 irrigations per month, 3-7 grass mowings per season, maintaining soil fertility with composted manure (13.33 t ha^{-1} in 2014) and Hemozim Bio-5 and use of pheromone (mating disruption) dispensers, Trifolio S Forte, Pirethrum, Madex, Nimazal. In conventional these included ~21-24 irrigations per month, ~3 mowings plus Roundup per season, and use of 4-5 applications of mineral fertilisers and 18-25 applications of chemical pesticides (i.e. Fungoran, Quore Christal, Chorus, Thiram, Karate, Score, Calipso, Vuksal macro-mix, Flint Max, Vucsal Bor, Delan, Decis, Dursban, Punch, Reldan, etc.).

Biodiversity monitoring

Biodiversity of soil organisms in soil depth was monitored by single sampling (using methodology of Guilyarov (1987)) at spring, summer and autumn in both orchards. Two plots of 0,50 m^3 each were placed in four apple orchards' intra-row. Soil was sampled in depth of 40 cm in each plot and then normalised per 1 m^3. Density and diversity of harmful and beneficial insects was calculated. Using a pitfall-trap method (Greenslade 1964), indicator-insects living on land-surface was counted once every month. For determining biodiversity of indicator-insects on apple trees, a 'shaking branches' method was used in both contrasting orchards, i.e. shaking at about 100 branches from the 4 sides of a tree, taking at least 10 trees per unit of land. Individuals caught in a hand-sack, were then collected, counted and their density was normalised per 100 tree-branches. It was done from March to November in each of the study years, three times a month aimed to consider the impact of climate and soil conditions. Species diversity and abundance were determined down to taxa (family) (Fauna Europea 2013), by employing following ecological parameters:

a) Density: total number of individuals of a taxa relative to 1 m^3 of soil (Magurran 1988) or on 1 m^2 land surface.
b) Shannon index (entropy): A diversity index, considering the number of individuals and number of taxa. Varies from 0 for communities with only a single taxa to high values for communities with many taxa, each with few individuals.
   $$Hi = - \sum (ni / n) \ln (ni / n)$$
c) Simpson index 1-D: The value ranges between 0 and 1. The greater the value, the greater the sample diversity. The index represents the probability that two individuals randomly selected

from a sample will belong to different species.

Simpson's Diversity Index = 1 - D = ∑ (n / N)2

The two indices of biodiversity are calculated by softwear PAST (Hammer et al. 2001) and data processed by STATISTICA 9.0 (StatSoft, Inc. 2004). The AI index (Herzog et al. 2006; Flohre et al. 2011) for both contrasting orchards was calculated on the basis of agro-practices aplied on the contrasting orchards, i.e. pesticides (number of treatments/season), applied fertilisers (kg N/year/da) and number of mechanical tillage (number of operations/season including mowing):

$$\mathrm{AI} = \frac{\sum_{i=1}^{n}(y_i - y_{i\min})/(y_{i\max} - y_{i\min})}{n} \times 100$$

where AI is the agricultural intensification index, y_i is theobserved value (number of pesticide applications,amount of applied fertiliser and number of tillageoperations), y_{min} is the minimum observed value in allregions, y_{max} is the maximum observed value in allregions, n is the number of individual indicators, and i isthe identifier for the three indicators. Using regression analysis, the study investigated possible correlations between AI index and biodiversity at three levels, i.e. in soil, on land surface and on apple trees in both orchards.

Results

The low level of N and P in the soil of organic apple orchard was compensated by addition of composted animal manure and liquid fertlisers. Selection of species and group of insects, indicators of changes of biodiversity in response to changes in agro-ecological and management conditions, was crucial. Above the norm average rainfall and temperatures in 2014 and 2015, added by application of organic fertilisers, lead to higher density of soil indicator-insects, i.e. taxa *Lumbricidae* and *Porcelioidae*in organic orchard compared to conventional thus confirm Popov et al. (2014). The higher biodiversity indices (i.e. of Shannon and Simpson) for soil indicator-insects in conventional orchard indicated uniformiity of representativeness of species in soil, i.e. not only from taxa *Lumbricidae*, but also taxa *Geophilidae* and *Limacidae,* attributed to more frequent irrigation in intra-rows and grassing.ANOVA showed a significant impact (P<0.05) of interaction of main factors landuse, season andinsect taxa on the indicator-insects living on the land-surface in the two contrastingorchards. In the organic, the

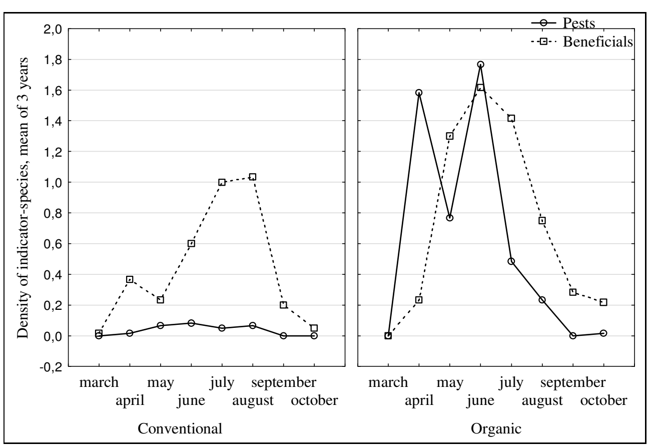

Figure 1. Impact of interaction of factors i.e. landuse and month (climate) (F(14, 1822)=17,796, P<0.05) on population dynamics of beneficial and pest insects on trees of organic and conventional orchard, mean of 2013, 2014 and 2015

impact was more profound in summer as shown by dynamics ofpest indicator-insects i.e. taxa *Grylidae* and the *Carabidae*, while in the conventional in autumn as shown by the taxa

Carabidae.The higher density of pest-insects on organic land-surface might be attrributed to organic fertilisation, maintenance of turf-mulching system and avoidance of herbicides. The impact was also significant (ANOVA, P<0.05) on the density of beneficial indicator-insects (i.e. *Coccinelidae, Chrysopidae* and *Cantharidae)* on organic trees (Fig. 1), where it was higher than conventional as well as the indices of biodiversity of Shannon and Simpson. Population dynamics of beneficial insects followed the dynamics of pest insects (because of food availability), but higher biodiversity reported on organic trees does not necessarily provided for a sustainable control of pest population density of *Tortricidae* (apple codling moth) and *Chrysomelidae* (leaf beetle). The polynomial and linear regression models and the mild to strong correlation (i.e between 0,632 and 0,801) between the AI index and the biodiversity indices (i.e. of Shannon and Simpson) of indicator-insects on organic soil, land-surface and trees indicated that ecological intensification lead to a higher biodiversity. However, only between 39% and 64% of the changes in the response variable biodiversity can be explained with changes in the factorial variable AI index. Almost 2/3 to 1/2 of these changes may be attributed to e.g. agroecological (e.g. climate and soil conditions) or agro-management (e.g. time of mowing, irrigation regime or time of pesticide applications) factors and the AI index should reflect these.

Discussion

The study contributes to global attempts to find a balance between ecological intensification of organic orchards and achieving sustainable production. Only a complex research of complex agroecological and agro-management relationships in various organic orchards may uncover the keys to achieve such balance. The study suggested that medium-term strategy for organic apple productionmust continue to employ biodiversity-friendly practices (e.g. turf-mulching, organic fertilisation)combined with pheromone mating disruption dispensers and bio-pesticides such as Madex and Nimazal to support beneficial insects in keeping pests below the damage threshold level. As shown by regression analysis, ecological intensification lead to a higher biodiversity, but it also signified that important agroecological (e.g. climate and soil conditions) or agro-management (e.g. time of mowing, irrigation regime or time of pesticide applications) factors must be considered when design organic pest-management strategies.

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