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DOMINO – combining herbaceous species with perennial crops to make organic fruit production systems more resilient

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European organic production systems are often concerned by a "conventionalization" of their management methods, with a strong dependence on external inputs.

Introducing or promoting a selected plant biodiversity in perennial crops could be an effective lever for moving towards a low-input agriculture, especially on fertilization and crop protection aspects.
The six institutes involved in the DOMINO project worked on this research hypothesis from 2018 to 2021, in several organic apple and apricot orchards and vineyards.

With experiments performed on nine locations, covering a wide range of climatic conditions (oceanic, Mediterranean and continental climatic areas) and various topographic situations (plain, low and high hills), this work focused on the use of perennial or temporary herbaceous cover crops, settled along the tree-rows or on the interrows, and used as components of a global production system, for the complementary services they can provide: substitution to the standard weed management practices, internal source of nitrogen supply, or additional income for the farmer by the use of secondary cash crops.
44 herbaceous species were tested to be used on the planted rows, with the primary goal to provide a sustainable alternative to the practice of row weeding by tillage. To limit or compensate their potential negative impact on the main crop's yield, some species were chosen for their low-growing habit, or their potential as nitrogen internal source. Officinal or edible crops were also tested, with a marketing perspective, to compensate competition with the perennial crop by adding value.
To assess the performance of these plant species when implanted on the rows, their covering percentage was measured over the three years, and compared with those of weeds and the rate of bare soil. To evaluate their ecoservices for the perennial crop, their impact on some indicators of the physical, chemical, and micro- or macro-biological properties of the soil was also observed, while beneficial mites' populations were monitored on the crop's foliage. Trunk cross section areas, leaves nutrient contents, and commercial yields were also measured on the main crop to evaluate competition effects.

Results showed that none of the herbaceous species that were tested can be proposed as a "turnkey solution" to the farmer, due to a great variability of adaptation to the ecosystem of the planted row. The use of species taken from local biodiversity provides significant advantages in terms of plant resilience and soil cover. *Mentha x piperita* or *M. spicata* seem to be rather ubiquitous plants, while strawberry species (wild or selected clones) and some clover cultivars appeared very dependent from rain (or irrigated) conditions. Overall, without additional weed control measures during the first two years of establishment, most of these species have great difficulty to compete on their own with weeds (especially summer weeds), even if they were chosen for expected allelopathic properties. In suitable local situations, strawberry plants, officinal plants and vegetable crops, such as pumpkin, resulted in interesting options as species able to provide an additional income, as they can give a significant production each year, while controlling weeds, and helping regulating aphids, mites, or nematodes. However, their use as cash crops is compromised in case of pesticide sprays to the main crop, even with PPPs authorized for organic systems.
14 legume species (sown alone or as mixtures with *Poaceae*) were tested to be used as green fertilizers, either as crops on the interrows, or as combined strategies on the rows and the interrows.

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Their value was assessed through mineral nitrogen quantification (N-NO3 and N-NH4), performed several times per year on soil samples, and using the normalized laboratory method.

Several grain leguminous species proved to have intrinsic abilities to establish in a very satisfying way, in terms of soil covering, weed control, biomass production, and nitrogen release, when sowed in the autumn using seeding rates as recommended for forage crops. In contrast, the legume species whose seeding period is in late spring, are subjected to the risk of being invaded by summer grasses. Using perennial legume species mixtures could be an interesting option, but their long-term sustainability is not assured. One promising avenue is given with the use of winter peas on the rows (with a sowing period at autumn or at the end of winter), that can provide significant nitrogen amounts after cutting, just in time to cover a part of the needs of the trees. The development of efficient seeding equipment, specifically adapted to the orchard or vineyard, was identified as one of the ways to simplify green manure use in perennial crops and guarantee a successful establishment of the legume crop in this peculiar environment.

Alchemilla vulgaris and *Mentha x piperita* were also used as study models in this work, to evaluate the belowground interactions that take place in a combined system with fruit trees and herbaceous species directly grown on the tree rows. These two species were established in an apple orchard, and the root architecture of both the trees and the living mulch was analyzed and compared to that of an orchard system weeded by shallow tillage. Root weight and root density, root length, root diameter, root surface area, root volume, tips number, were measured using the WinRhizo software, on soil samples taken three times in one season, at the layers 0 to - 20 cm and - 20 to - 40 cm. Apple trees had respectively, 30% or 42% higher root dry weight densities when Alchemilla or Mentha were grown on the rows. Moreover, even if *Alchemilla* and *Mentha* produced both 42% more biomass than the control, no difference was observed on the N, P, K contents of the apple leaves. With a dense root system in the upper layer, *Mentha x spicata* pushed the tree roots to explore the soil at a deeper level. In contrast, the roots of *Alchemilla* and apple trees were found to co-habit in the upper layer, without negative impact on the uptake of nutrients by the trees. In this case, some root exudates released by Alchemilla, resulting in microbiome changes, could be involved to increase the availability of nutrients.

However, in the cases where ground cover species were poorly established and overgrown by weeds, significant yield losses were observed on orchard's production, as well as rodent and deer damage. Furthermore, establishing selected herbaceous species on the rows of a vineyard or orchard can be very expensive. It is thus recommended to start testing the use of living mulches in small areas, to verify their adaptation to very local conditions (which include climate, soil properties, water availability or excess, and weed seed stock), before considering extending the practice to larger superficies.