CORE organic DOMINO

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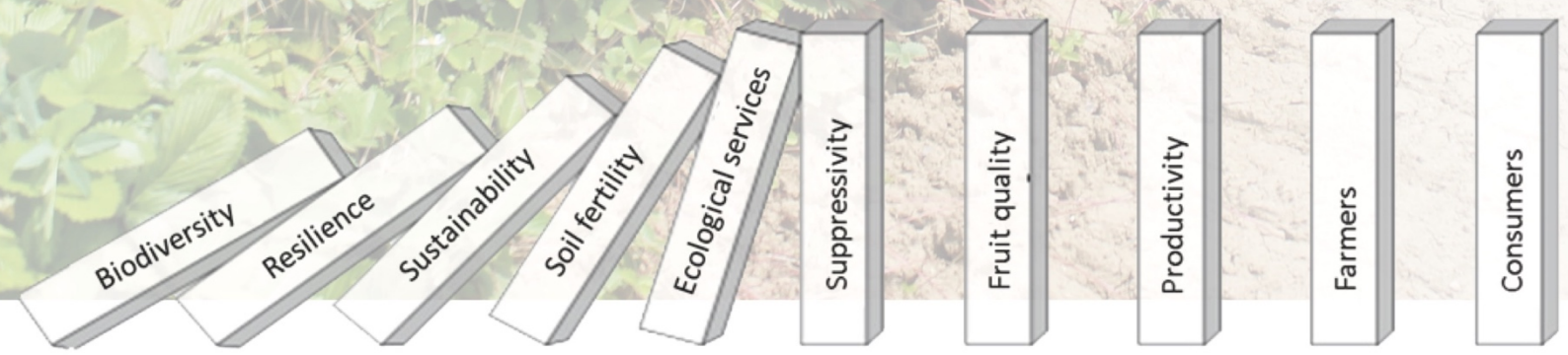
DYNAMIC SOD MULCHING AND USE OF RECYCLED AMENDMENTS TO INCREASE BIODIVERSITY, RESILIENCE AND SUSTAINABILITY OF INTENSIVE ORGANIC FRUIT ORCHARDS AND VINEYARDS

Effective Options on Integrated Soil Management



AIAB Bioland BIOSÜDTIROL Ctifl FiBL LAIMBURG VAL VENOSTA föko InHort

TEAM/CREDITS:

Università Politecnica delle Marche
P.zza Roma 22, 60121 Ancona, Italy

Fruit Growing Institute
Ostromila12 str. 4004, Plovdiv, Bulgaria

Laimburg Research Centre
Laimburg 6 I-39051 Vadena (BZ), Italy

Research Institute of Horticulture
(Instytut Ogrodnictwa)
Al. 3 Maja 2/3 96-100 Skierniewice, Poland

CTIFL French technical Interprofessional Centre for Fruits and Vegetable
22 rue Bergère, 75009 Paris, France

FiBL - Research Institute of Organic Agriculture
Ackerstrasse 113, 5070 Frick, Switzerland

University Hohenheim
Schloss Hohenheim 1, 70599 Stuttgart, Germany

What was the DOMINO project about?

The project DOMINO[1] was established to demonstrate that innovative orchard management can enhance soil fertility, biodiversity and economic sustainability of intensive organic fruit orchards.

Intensive organic fruit production systems are characterized by a 'conventionalization' of the management methods that are frequently reducing biodiversity and depend largely on external inputs to maintain soil fertility and assure plant protection. There is thus the need to introduce new strategies using multifunctional cover crops, which can improve also the economic return of orchards.

The research performed within DOMINO aimed at improving the long-term sustainability and the ecological foot print of intensive organic fruit production. It focused on the interaction of fruit trees with different wild species, organic residues and the microbiome, and intended to break the paradigm of monoculture in organic fruit growing, enhancing the ecosystem services.

In the following, three of the tested innovations within DOMINO to improve soil fertility, biodiversity and economic sustainability of intensive organic fruit orchards are presented:

1) The use of ground cover species in the tree row for weed control which also provides additional ecosystem services
2) The use of legume species in the inter-row and tree row to improve soil fertility
3) The use of alternative fertilisers using regionally available recycling fertilisers and leguminous intercrops to improve nutrient balances and ecosystem services

The activities were carried out in five European Union states (Italy, Germany, Poland, France and Bulgaria) and in Switzerland, in different major fruit production regions.

[1] http://www.domino-coreorganic.eu/

INNOVATION 1: Comparison of different crops for row management suitable for weed control

Identified problem

Weed management within the tree row, without using herbicides and with reducing soil tillage. Despite an initial positive effect of mechanical weed control through tillage, which is organic soil matter mineralisation, tillage is detrimental for the soil's physical, chemical and biological fertility, and the herbicides, even if they are natural, reduce the biodiversity.

Idea/concept of innovation

An alternative strategy to manage the space between fruit trees, which also increases the biodiversity of the orchards, is a permanent cover with living mulches. The following criteria should be considered when choosing a certain species for living mulching:

- The species is adapted to the local environmental conditions and forms a stable plant cover stock (quality of establishment and durability),
- The species is able to outcompete weeds, i.e., rapid and dense coverage, if possible allopathic properties, but having low competition with the main crop (fruit trees), i.e., species producing little biomass, with low height development, no tap root or maximum 20-25 cm rooting depth, or even carpeting species,
- The management of the species is compatible with the management of the fruit trees,
- The species should provide some agro-ecological services (e.g. soil improvement, phytosanitary properties, pest regulation, nitrogen supply, pollination),
- The species provides an additional income source (i.e., officinal plant, vegetables, berries).

Within the project DOMINO, more than 40 local wild and cultivated species have been tested as living mulches. The species were mostly tested in pure stand to facilitate the evaluation.

From top (left to right): *Hieracium aurantiacum* (orange hawkweed), *Potentilla reptans* (creeping cinquefoil), *Galium album* (white bedstraw), *Alchemilla vulgaris* (lady's mantle), *Tropaeolum majus* (Nasturtium), *Mentha x piperita* (peppermint), and *Cucurbita pepo* (pumpkin).

Practical information on the species for living mulch, grown in the tree row, which yielded positive results

Species	Benefits	Coverage	Recommendations for implementation and maintenance
Achillea millefolium (common yarrow)	Local	+(++)	Insufficient coverage on the first year, but good coverage and weed competition from the second year on.
Alchemilla vulgaris (lady's mantle)	Officinal plant	+ + +	During the first year it was not able to fully cover the tree's understory, therefore either hand weeding or higher planting density should be foreseen. From the second year on, the soil cover was sufficient to compete with weeds and the plants produced flowers and leaves that could be harvested.
Cucurbita pepo (pumpkin)	Food plant and phytoremediation	+	Covers the soil well if planted early in the season. Being annual, it requires some tillage yearly. Well suited to perform as phytoremediation crop for organic pesticides residues (e.g. DDT).
Medicago sativa (dwarf alfalfa)	Nitrogen source	++	Good coverage achieved in spring when sown in autumn.
Fragaria vesca (wild strawberry)	Local, food plant	+(++)	Re-planting from locally available ecotypes/varieties works very well, but also commercial plants/varieties showed a good establishment (6-8 plants per tree). It has low competitiveness against weeds (mainly the first year), therefore weeding is required during the first year. However, from the second year on it covers the soil well and strongly reduces weeds. It prefers fresh and acid soils; not adapted for hot and dry areas.
Galium album (white bedstraw)	Local	+ + +	Very good establishment, after transplantation of locally available varieties/ecotypes. It tolerates brushing before winter.

Species	Benefits	Coverage	Recommendations for implementation and maintenance
Mentha x piperita (peppermint)	Officinal plant	+ +	Good coverage and weed control from the second year on. High biomass production; in late summer and autumn it can be necessary to control the height by cutting/mowing it. It can have a positive effect on beneficial fauna (increase in predatory mites).
Tropaeolum majus (nasturtium)	Pollination, pest control	+	Good competitiveness against weeds from the second year on. It can have a positive effect on beneficial fauna (increase in predatory mites). The flowers are edible.
Potentilla reptans (creeping cinquefoil)	Local	+ + +	Re-planting from locally available ecotypes/varieties works very well. Fast and persistent coverage, with full coverage from May until September and acceptable coverage the rest of the year. Cutting of the plants should be avoided (as it may promote weeds).
Tagetes sp. (marigolds)	Pest control	++	Establishes with some difficulty due to competing weeds, and therefore needs a high plantation density. Can be combined with other species (e.g. *Pulmonaria sp.*), which rapidly cover the soil but have a small biomass development. It is repellent against parasitic nematodes.
Trifolium repens (white clover)	Nitrogen source	++	Requires good water management after sowing, which ensures enough moisture for germination and fosters its establishment. Slugs can be a problem as they feed on the clover. White clover is not competitive enough during the establishment phase when sown alone; it needs to be sown with a cover crop to avoid the emergence of weeds. This species improves soil structure. Micro-clover is a good alternative. Micro-clover is a white clover that produces very small leaves and forms a carpet-like coverage on the soil, which strongly limits weeds' occurrence.

Galium odoratum (sweetscented bedstraw), *Hierochloë australis*, *Melissa officinalis* (lemon balm), *Taraxacum officinale* (dandelion), *Tropaeolum majus*, *Veronica officinalis* could not establish. *Hieracium aurantiacum* (orange hawkweed), *Hieracium lactucella* (European hawkweed), *Hieracium pilosella* (mouse-ear hawkweed) produce flowers that are visited by pollinators. Planting of seedlings (6 per tree) showed to be more successful than sowing. Very fast and good coverage during winter and until end of June, but then overgrown by weeds. Best coverage on second year, but the *Hieracium* species disappear the third year (not persistent). *Mentha spicata* (mint): No satisfactory coverage. *Trifolium resupinatum* (reversed clover): It was supposed to produce fertile seeds to generate new seedlings, but became senescent and completely disappeared from the orchard on second year. *Viola odorata* (sweet violet): Very good coverage and weed control on first year, probably due to allopathic activity, but it was overgrown by weeds during the second year.

Conclusion / Lessons learned

- Flowers of living mulch species can provide additional nectar sources for pollinators and improve the aesthetic aspect of orchards. In addition, some living mulches provide habitats for antagonists of pests.
- Certain species can also represent an additional source of income, for example when they are utilised as food crops as well. However, plant protection measures on the main crop (fruit trees) must be adapted in order to avoid pesticide residues on the living mulch.
- Despite the presence of living mulches, no symptoms of water stress were observed on the fruits trees under the different tested conditions.
- Root density of the apple fruits trees was higher when using certain living mulch species like mint or *Alchemilla vulgaris* (lady's mantle).
- No significant differences, neither on fruit yield nor on macro- and micronutrients contents of tree leaves, were found between treatments with or without living mulch.
- The process of soil coverage in the tree-row is slower and more heterogeneous than in open field, because the environment is more shaded (especially in older orchards), (often) irrigated and very rich in nutrients.
- Results achieved by the project DOMINO emphasise the potential of living mulches in a wide range of growing conditions. But the performance of the living mulch species is always site-specific. Therefore, the challenge is to identify the species that is vigorous enough to compete against weeds in a specific agro-environment which comprises soil, climate, weed pressure and type of orchard management.

Recommendations for the fruit growers:

- Test in situ (= in the original place, i.e. the orchard) the suitability of the chosen species, first in small areas.
- The living mulch plants grown in the tree rows can later serve as a source of plantlets for additional areas of the orchards.
- Establishment in fall rather than in spring is recommended to prevent invasion by summer grasses (e.g. Echinochloa crus-galli, Setaria sp, Digitaria).
- The use of complementary weed control measures during the establishment phase of the living mulches can greatly help them to compete with weeds and thus to develop sufficient biomass. Such weed control measures can be manual weeding or the use of intercepts blades to cut the tap root of weeds.
- Local species (e.g. ecotypes) provide significant advantages in terms of plant adaptation, resilience and soil coverage. Nevertheless, in case of plants that are purchased from nurseries, the natural occurrence of this species in the region is not a sufficient condition for this species to establish satisfactorily under a specific environment (pedo-climatic conditions) and even less within the tree row of orchards.
- Special caution is required in areas of high rodent pressure, since the living mulches can serve as hiding place.
- The ground cover can pose some constraints to the application of fertilisers for the trees. However, a careful management of the living mulch can allow the application of organic fertilisers. Furthermore, the nutrient requirements of the living mulch should be taken into consideration when fertilising.
- An initial labour investment for the establishment of the living mulch is needed to cover the cost of seeds/plants, manual selective weeding, etc.

INNOVATION 2: Row and inter row management with legume intercrops

Idea/concept of innovation

The goal of this innovation was to use legume intercrops that besides increasing the orchard biodiversity will function as an internal source of N and as a tool to increase soil fertility.

Within the project, different leguminous crops have been tested in the inter-row and in the row of fruit tree orchards, in several European countries.
The following aspects were evaluated: a) Impact on biodiversity as related to soil protection; b) Effect of biodiversity on entomofauna; 3) Impact on nutrient balances.

Evaluation of legumes in the inter-row and in the tree row

Species	Information
Trifolium repens (white clover)	Seed quantity: 2 g/m² Establishment: It needs irrigation and full light during the germination phase. Slow initial development, but resistant to soil pounding by machines. Best technique is to sow it with other cover crops to avoid competition by weeds during the establishment phase (e.g. *Festuca ovina*). Micro-clover: White clover with very small leaves, less biomass than regular white clover, but also less competition for water and nutrients, due to its small size. Nutrients in the biomass (with three cuts from May to July): 63 kg N, 11 kg P and 83 kg K per ha orchard for white clover, and 54 N, 9 kg P, 73 kg K per ha orchard for micro-clover.
"MULTIFLORE LD" mix (Micro white clover + *Medicago lupulina* + *Lotus corniculatus* + *Trifolium incarnatum)*	Seed quantity: 2 g/m² Provided 5 kg N/ha The mixture composition evolves to an almost monospecific composition with *Trifolium repens,* after 2 years
Festuca ovina (sheep's fescue) + *Trifolium repens* (white clover)	It is a good solution for the orchard, as it developed well. The grass develops first, followed by the legume, as it normally occurs in meadows. A cut in mid-June can provide organic mulch and some nutrients for the trees.

Trifolium ambiguum (Kura clover) and *Galega orientalis* (goat's rue) resulted not well adapted to dry conditions and did not properly develop in the orchard, even when sown as a mixture with *Festuca ovina* (sheep's fescue).

Recommendations for the fruit growers:

- The efficiency of the leguminous species used in the inter-row and row for providing green manure is strongly bound to appropriate seeding and proper seed germination. Key factors are: a) Correct sowing time, b) adapted seeding machine, c) minimising soil disturbance after seeding until the cover crop is fully established, d) sufficient water and light availability for seed germination, e) sow leguminous species with a high seed density or as a mixture with fast establishing cover crops to avoid an invasion by weeds.
- In the inter-row, a perennial legume crop is a better option than an annual one, thus reducing the workload and the risk of problems in crop establishment. Alternatively, the legume can be sown in the tree row, therefore minimising disturbance by machinery.
- When enough biomass is produced, the legume must be incorporated into the soil, at the latest in July (depending on the specific site), otherwise the nitrogen is mineralised too late for the needs of the trees.

Preparation of the seedbed (left), high weed pressure in the inter-row after sowing white clover sown pure (middle), successful weed control and dense, uniform soil cover by micro-clover sown as a mixture with *Festuca ovina* (sheep's fescue) (right).

INNOVATION 3: New fertilisation strategies

Identified problem

Fertilisation of organic fruit orchards is typically strongly based on external commercial fertilisers, permitted in organic farming. In Central Europe, these fertilisers are mainly derived from conventional animal husbandry (e.g. horn grit or dried and pelleted cattle or poultry manure) or from conventional food residues (e.g. stillage from sugar or yeast production). Such fertilizers are currently considered to be contentious inputs in organic agriculture as they generate nutrient flows from conventional into organic farming systems. In addition, animal-based fertilisers are in discussion in general as vegan organic farming systems gain in importance.

Idea/concept of innovation

The objective was to test different alternative fertilisers (recycled nutrients, clover grass based materials, other non-contentious inputs, leguminous intercrops) in the tree row for their applicability in organic fruit production. The fertilisers were tested in trials in the lab, in pot trials and in apple orchards. The trials were also set to determine the mineralisation dynamics of alternative fertilisers and their effect on apple tree growth and leaf nutrient content, as generally the nutrients (mainly N) availability of organic fertilisers does not completely match the temporal requirements of the tree.


Fertilisation with silage (left) and winter peas (right) before mulching in April


Peas sown in the tree row (pictures taken in May). Peas were sown end of March and incorporated into the soil in July, around ten weeks after sowing.

Tested fertiliser	Type	Characteristics and recommendations
Liquid Biogas digestate	liquid	Incubation trial: Rapid mineralisation (high mineral nitrogen – Nmin – release within 7 days and up to 60 days), large amount of Nmin released in a short time Pot trial: Rapid mineralisation and high increase in Nmin in the soil after two weeks Field trial: The mineralisation pattern makes this fertiliser a good fit for the nutrient needs of apple trees when applied early in spring. It showed also a positive impact on soil microbial and nematode communities' diversity **Nutrients**: The nutrient content can vary depending on the source/origin and processing method **Cost**: Low cost, but feasible to be used only within a limited distance from the biogas digestor location due to transport costs **Application**: Easy **Caution**: Potential risks due to the content of contaminants should be ruled out (e.g. heavy metals and pathogens have to be tested if Global GAP or other standards are required by the buyer, even if the biogas digestate is permitted for the use in organic farming)
Clover-grass pellets	solid	Incubation trial: no significant change in Nmin Pot trial: very little N release within eight weeks after application, substantial increase in Nmin after 10 weeks Field trial: Low N availability **Nutrients**: Rich in P, K, some Mg **Cost**: Expensive **Application**: Application technique same as pelleted fertiliser Vegan-compatible
Compost	solid	Incubation trial: little Nmin release Field trial: Low N availability in the year of application **Nutrients**: High input of P, K, Mg, Ca as additional nutrients **Cost**: Low cost, but feasible to be used only within a limited distance from the composting plant due to transport costs **Application**: Easy

Tested fertiliser	Type	Characteristics and recommendations
		Caution: Potential risks due to the content of contaminants should be ruled out (e.g. plastic, heavy metals, weed seeds) Vegan-compatible
Legume seeds/legume biomass	solid	Incubation trial: most Nmin released after 60 days, slightly decreases pH (- 0.2) Pot trial: first release of N after five weeks Field trial: The legume is sown in high density within the tree row and the biomass produced is incorporated in the soil. Sowing density: 250 g/m^2. Timing of seeding (winter or spring) and incorporation by mulching: Winter sowing allows to till the plant earlier (is linked to the age/development of the legume) and to have a longer period of mineralization of the biomass. **Nutrients**: ca. 20 kg N/ha can be provided, rich in P **Cost**: Rather expensive **Caution**: Strong dependency on local weather conditions (timing of sowing, survival during winter, incorporation into the soil): Risk of failure. Sourcing of seeds (in particular for winter varieties difficult) Vegan-compatible
Silage (clover grass)	solid	Incubation trial: Immobilised N and released only a small amount of it after more than one month, slightly increases pH (+ 0.2) Field trial: Strong delay of N availability → autumn rather than spring application recommended **Nutrients:** similar to pellets, rich in K, P, some Mg **Cost**: Low cost. Silage can be produced on-farm if machinery is available or sourced in cooperation with other farms. **Application**: Difficult, machinery often not available on fruit farms Vegan-compatible
Stillage	liquid	Incubation trial: Rapid mineralisation (but slower than biodigestate, gradual increase in Nmin with maximum at 60 days), slightly decreases pH (- 0.2) Pot trial: Rapid mineralisation and high increase in Nmin after two weeks

Tested fertiliser	Type	Characteristics and recommendations
		Field trial: The mineralisation pattern makes this fertiliser a good fit for the nutrient needs of apple trees when applied in early spring. Positive impact on microbial and nematode diversity. **Nutrients**: Rich in K, Na **Cost**: Low cost. **Application**: Easy Vegan-compatible

Incubation trial: addition of fertiliser to small containers with soil and incubation for 60 days
Pot trial: pot trial with 1-year old apple trees, fertilisation 3 weeks prior to bloom (2/3) and just after bloom (1/3).
Field trial: field trial with established apple trees.

Recommendations for the fruit growers:

- Regular soil analyses together with nutrient budget calculations are the key tools to developing a fertilisation strategy that is sustainable in mitigating nutrient imbalances in the long-term.
- For a full assessment of the compatibility of a fertilisation strategy with basic organic principles, an extended sustainability assessment is needed, e.g. through Life Cycle Analysis; SMART (Sustainability Monitoring and Assessment RouTine) or RISE (Response-Inducing Sustainability Evaluation) analysis.
- The alternative fertilisers should be alternated on a same field on an annual basis or over one or more vegetation periods.
- Biogas digestate (unseparated and preferably from plant materials) as well as clover-based fertilisers, like silage and clover pellets, show the best fit in the N:K ratios with fruit trees. These fertilizers help to reduce K deficits at comparatively low P supply, minimising the risk of P accumulation. In case of a high level of available P in the soil, living mulches based on dense seeding of grain legumes, as well as compost and farmyard manure, are less suitable due to their high P inputs when fertilisation rate is calculated on the N demand of the apple trees.
- Keratin-based fertilisers, like horn grit, remain the only N fertilisers providing small inputs of accessory P and K.

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