# Diversity in organic agriculture

By Vivian Vilich

One of the the Principles of Ecology in Organic Agriculture (IFOAM) states that *«Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water»*.

All organic regulations state in one way or another that organic farms should establish and maintain within-farm sustainability. Factors such as nutrient recycling, habitat protection and formation are important. The need for incorporation of some form of livestock into the production of plant based food materials is also part of many regulations. Historically, humans utilized more than 7,000 plant species to meet their basic food needs. Today, due to the limitations of modern large-scale, mechanized farming, only approximately 150 plant species are under cultivation, and the majority of humans live on less than 20 species. Together with other measures such as the Svalbard Global Seed Vault[i], organic agriculture in general is seen as one of the most important aspects of preserving crop diversity. Unfortunately, this is not always the case for modern days organic farms. The focus on market competition and global integration encourages organic farmers to reduce overhead costs (through monocropping) and increase the scale of production. “Green Revolution” technologies in the organic food sector have been observed where organic businesses are increasingly utilizing monoculture to reduce costs and maximize profits. While the traditional organic philosophy rejects the usage of synthetic inputs and GMOs, the integration of organic agriculture into a system that is based upon monoculture is somewhat problematic for adhering to the organic principle of sustainability.

It is well known that certified organic farms can operate with absolutely no animal. Livestock operations can have no fields other than some marginal pasture (e.g. laying hen operations), and there are crop producers who lack both; fields in rotation and livestock (e.g. blueberry producers). On the other hand, livestock farmers don't know where to put their manure, berry producers are short of crop nutrients, and contract growers have no say in crops rotations, variety selection or cover-crop use.

## Implementing crop and farm diversity

On-farm diversity can be developed on various levels involving crops and livestock:

- ***Plant genetic diversity:*** Utilization of different varieties displaying different characteristics; conservation of heritage varieties and wild forms
- ***Spatial species diversity:*** All types of growing different plant species at the same time on one field (area).
- ***Species diversity over a period of time*:** All types of crop rotations; one or more species can be grown in one year
- ***Combination of crop and livestock production:*** Keeping livestock with the production of cash crops and/or feed crops. Farm sustainability is normally more balanced in livestock – feed crop operations.
- ***Indirect diversity:*** Sustainable agricultural techniques can help to protect natural ecosystems by preventing them from being transformed into cultivated land. Increasing land productivity by means of diversity can help to protect natural habitat because there is no need to convert it into production area.

If there are obstacles to combine livestock and crop production on a given farm, there are still ways to increase diversity on the crop level only. It is well known that the origins of today's prevailing monoculture are buried in our agriculture's past. The constant breeding of crop plants for convenience of planting and harvesting is a lucrative global business. But farmers know about the ongoing race between the development of new crop varieties and the catching up of those addressed in breeding strategies, namely pests, diseases and weeds. It is documented that monoculture encourages the development, multiplication and spread of newly adapted pest, pathogens and weeds in uniform crop stands. So what is the conclusion? Backing off from monoculture by adapting other cropping systems which will result in more on-farm diversity.

A variety of terms are described which are commonly used when increasing crop diversity. Cropping schemes (Vandermeer[ii] ,1989) can be developed to explain the sequence of crops over a period of time. They basically describe the relationship of crops to each other over time on a given area or field.

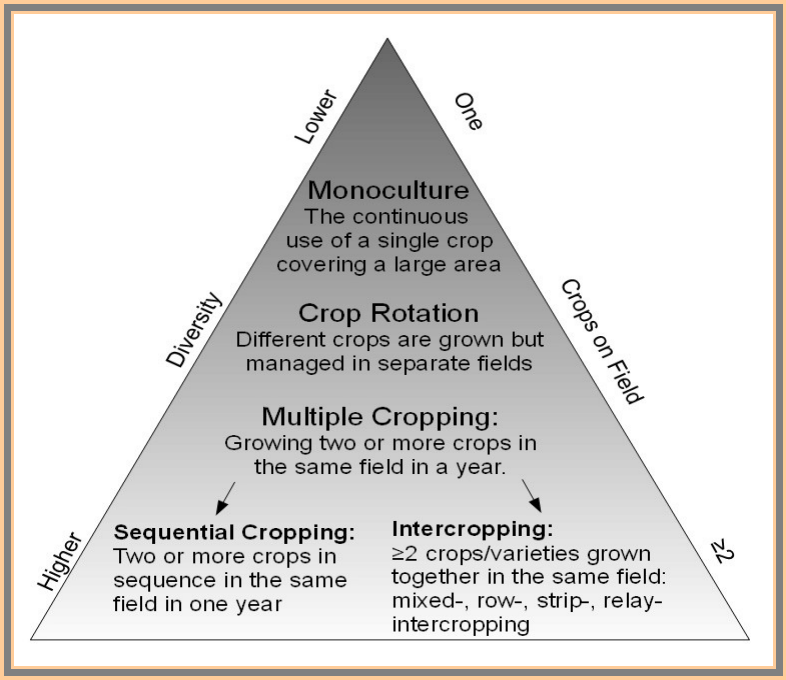


Fig 1: Crop diversity and cropping schemes

## Monoculture

In monoculture cropping systems the same crop is grown in the same field on a continuous basis. It is globally the single most common system in large-scale or industrial farming. The pros and cons are well documented and very much reflect the differences between organic and non-organic farming. Monoculture allows for specialization reducing the cost of farm machinery. It enables large scale co-ops sharing expensive equipment. It simplifies many aspects of growing crops such as seeding, planting, fertilizing, weeding, and harvesting by narrowing the time window for the task. It also serves the commercial demand for large quantities of agricultural commodities of a certain market dictated quality. Disadvantages of monoculture are obvious: the overall loss of farm diversity makes farms prone to market fluctuations (prices, demands). The use of commercially adapted varieties limits the spectrum of varieties in use to a dangerous number. Hyper-mechanization disconnects the needs of productivity from soil protection leading to soil erosion and degradation. Monoculture executes an immense selection pressure on flora and fauna resulting in more pests, diseases and weeds, and therefore increasing the need for plant protection.

## Crop rotation

Historically, crop rotations were almost mandatory. Humans needed nutrients, fibres, building materials and feed for livestock. Also, frost, drought, insect and disease calamities forced farmers to spread the risk over several crops planted each year. Even though crop rotations have been subject to countless research projects, there are still new and interesting facts emerging from research. Farmers who use computers in their operation might find electronic tools helpful to theorize about rotations suitable for their farm. The University of Illinois publishes FAST Tools, a selection of downloadable programs to calculate corn, soybean and wheat rotations. The Food and Agricultural Policy Research Institute (FAPRI) provides a crop/forage budget generator. FAO's Ecocrop database[iii] is a very useful online-tool where growers can identify a suitable crop for a specified environment, a crop with a specific habit of growth, a crop for a defined use, or look up the environmental requirements and uses of a crop. The Sustainable Agriculture Research and Education program (SARE, www.sare.org) provides downloadable documents on many farming topics including rotations, cover crops and soil building.

## Multiple cropping

Growing two or more crops in the same field in a year resembles a further step in diversity as interactions among plants are increased. There is intensification of cropping in time and space dimensions.

- ***Sequential cropping (factor time):*** two or more crops grown in sequence in the same field per year. The succeeding crop is planted after the the preceding crops has been harvested. Farmers manage only one crop at a time and there is no intercrop competition of crops. It can be discussed whether green manure or under-seeded crops fall into this category as crops can overlap and can be carried over into the next season.

- ***Intercropping (factors time and space):*** two or more crops or varieties of one crop are grown simultaneously on the same field. Farmers manage more than one crop/variety at a time in the field. There is intercrop competition during all or part of crop growth. Related to intercropping is the term Land Equivalent Ration (LER). It is the sum of the yield fractions of the intecrops relative to their pure crop yields. If intercrop yield exceeds the yields of its pure stand counterparts, beneficial interactions between plants occurred. If it is less, competition and antagonism is involved.

**Mixed intercropping:**
Two or more crops are interspersed with a maximum in interaction. Sometimes two or more different varieties of one species (i.e. two wheat varieties). This is also known as an 'intraspecific' mixture.

When using two or more different species (i.e. barley and oats), often referred to as 'interspecific' mixture. Popular turf grass or pasture grass mixtures are used to spread the risk of plant failure on more than one plant species. The 'Three Sisters' (corn, beans, and squash) have been planted by traditional Native American growers for thousands of years in many different regions of North America. This tradition of intercropping in the same mounds is a sophisticated, sustainable system that provided long-term soil fertility and a healthy diet to generations.

**Row intercropping:** two or more crop species/varieties are grown in alternating rows simplifying management. Recent studies in Germany on seed quality of organic spring wheat intercropped with false flax (*Camelina sativa*) or flax showed positive effects on kernel quality, protein and gluten content, whereas intercrops of rye or barley with canola showed decreased kernel quality, highlighting the need for further tests. In berry crops and vineyards row intercropping appears to be very promising as rows are already established and soil cover crops can add to farm income and soil quality. Grape growers in the Okanagan Valley worked with hairy vetch, black medic (*Medicago lupulina*) and even ginseng. Oilseed radish, alfalfa, rye-grass, and strawberries were tested in Ontario vineyards.

**Strip intercropping:** The multiple crops are grown in narrow, adjacent strips, that allow interaction between the different species, but also allow management with modern equipment. Iowa State University research on strip intercropping corn and soybean with strip widths greater than 6 rows revealed benefits on total production and net returns. The inclusion of small grain strips as a third component has the added advantage of slowing surface water run-off/erosion.

**Relay intercropping:** Growing two or more crops simultaneously during part of the life cycle of each. Relay intercropping of wheat and soybeans showed good results in Ohio (Indiana) when winter wheat varieties were used that perform well in wide-row spacing. Wheat was planted in October and interplanted with soybean in May/June. Relay intercropping also allows crops to be planted at an optimal date when soil conditions are good or demands for nutrients can be matched. Increasing the time between maturity of each crop may reduce crop competition. In Sweden, this cropping system successfully reduced weed pressure in winter wheat relay intercropped into oats, peas or field beans in spring. Winter wheat varieties with a strong demand for vernalization before flowering can be sown in spring together with a summer annual – relay cropped - and be harvested the following year. In any instance, information is needed on equipment tailored for planting, maintaining and harvesting relay intercropped fields.

The list of terms used in intercropping shows a lot of variability, but most important is to understand that there is diversity over time and/or over space (area). If the degree of physical interaction between crops increases, a multitude of interactions involving all kinds of organisms follows: microorganism above and below ground, insects, nematodes and even animals act differently in more diverse habitats than in monoculture.

## Benefits of intercropping

Distinctive botanical characteristics in varieties and species can act as a buffer against adverse conditions when crops are grown together. Important agronomic factors can be improved in diversified crop stands:

- winter hardiness
- pest & disease resistance
- growth patterns
- drought resistance
- efficiency in nutrient uptake
- weed competition etc.

In most instances, diversity benefits the total by helping the individual. An often underestimated phenomenon is the ability of crops, varieties and plants in general to act very different when grown in a pure stand (one variety only) versus in a mixed stand (more than one variety or species). Therefore, certain species or varieties will not be mixed by farmers because they seem not to match based on their pure stand characteristics. Only the on-farm experiment will show if this is the case.

One major positive aspect is seen in having less pest and/or disease susceptible plant tissue on a given area. By intercropping hosts and non-hosts (to a certain disease) a “barrier effect” can be established, which will in general lower the disease pressure in a field. Mixtures of different grains (i.e. barley/oats) are a good example because important diseases such as powdery mildew and rusts are host specific organisms. Simply, a barley mildew spore which ends up on an oat leave cannot infect the oat, and vice versa. The spore is lost for any further infection.

Plants extensively communicate with organisms in the environment. Roots secrete an enormous range of compounds into the surrounding soil, an area called rhizoshpere. Root exudates mediate positive and negative interactions in the rhizosphere[iv] including associations with other plants and microorganisms. The microorganisms can be beneficial or cause negative effects such as diseases. The quantity and quality of root exudates are determined by plant species, individual plant factors (variety, age) and external factors from the environment. Furthermore, plants communicate with organisms in their surroundings though volatiles[v] and these volatiles can be induced by feeding insects, also called pests (herbivory). Diverse plants under diverse living conditions can release cocktails of such volatiles. One can easily imagine the multitude of interactions occurring in a field with different crops and therefore different insects feeding on them. Intercropping in general does not qualify for a single factor view. In most instances 'suitability tests' or 'which plant for what mixture' ask for a multiple-factor approach. The system follows a holistic concept – as with almost every ecosystem.

## Challenges in intercropping

Thinking about intercropping is almost like thinking of starting a new farm in an unknown country. In most instances research goes back into history. What did they grow before the advent of technology, monocultures and supermarkets? What species were common and thrived in the climate. What varieties of those crops are available nowadays, how do they perform and how do they differ in performance? When having a selection of suitable crops, the next step is the matching and mixing. Again, history might already have some answers, but in most instances the modern varieties would differ a lot from old ones. This brings up the experimental phase. If research technology for intercrops would be as well developed as it is for monocultures, if machinery and equipment for intercropping would be available, and if specific modern varieties for intercropping would have been developed, things would be easier.

## In-depth farming knowledge

Intercropping requires in-depth farming knowledge. To come up with the best crop combinations, features of each crop and variety have to be known. Obviously, nobody wants to sacrifice mechanization which needs to be considered next. How is the seeding and weeding done with existing techniques? Do maturity dates of crops match when grown in a mixture? Do intercrops adapt to each other as seen in some grain mixtures? Do techniques enable separate harvests if needed as seen in many row-intercrops? Are beneficial organisms deterred or attracted as in onion/carrot intercrops? Is the end product used/sold separately as in most vegetables or is it used in one piece as in mixtures for feed? The list of questions can go on, and most answers cannot be found in books. The only way to find out for sure: on-farm testing. It is a perfect way to do trans-farm trials utilizing different soil types, water tables or even micro-climates. Intercropping should be seen as part of an overall strategy to increase farm diversity. Numerous examples can be utilized to come up with the best version(s) for each farm. Today, the internet provides plenty of information and forums to do the first step. Knowing relevant keywords to start an online search for a particular crop should speed up the process significantly. It is after all very rewarding to see two or more crops growing in perfect harmony.

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