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THE IMPORTANCE OF BIODIVERSITY IN NATURAL ENVIRONMENT AND IN FRUIT PLANTATIONS

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A B S T R A C T

Biodiversity is a popular way of describing the diversity of life on earth. It includes all life forms and the ecosystems in which they live (Menini 1998). Biodiversity plays fundamental role in organic and sustainable food production. Biodiversity ensures countless kinds of foods as well as raw materials for clothing, shelter, fertilizers, and medicines. In agriculture, genetic diversity enables crops and animals to adapt to different environmental conditions. Biological resources are sustainable if they are not excessively exploited. We should be alarmed by the destruction of plant communities caused by cutting, burning, weeding, cleaning, over-fertilizing, over-watering, and pollution. Scientists estimate that there are about 1.4 millions species on earth, including 750,000 insects, 41,000 vertebrates, and 360,000 plants. 80,000 plant species are edible, but only 150 of them are currently grown on a large scale. Only thirty plant species contribute to the “industrial food” supplied to supermarkets. The flora of Europe is gradually growing poorer. In the last thirty years, about 35,000 plant species have disappeared (Lugo, 1980, cited by Menini, 1998). Plant breeders contribute to the erosion of biodiversity when they select only the most productive strains, ignoring thousands of local heritage cultivars. At the beginning of this century, there were about 10,000 apple cultivars in Europe. Only a few are still commercially grown. In some countries, gene banks have been established to protect valuable genetic resources, but they are threatened by frost and disease.

Biodiversity in vascular plants depends on geographical latitude, abundance, and habitat heterogeneity. Tropical plant communities consist of 1500-3000 plant species. The flora of central Europe consists of only 1000-1500 plant species. The richest plant communities are autogenic and semi-natural plant communities created by natural forces under favorable conditions. When they are destroyed by human activity, the resulting anthropogenic communities are dominated by a very limited set of species.

Ecology examines questions such as: what kind of interactions there are within a plant community and between different plant communities; how biodiversity develops; whether it is stabile; whether it recovers after being disturbed; and whether the patterns of plant communities are similar to those in place before the disturbance occurred. There are several theories to explain these interactions. The most widely accepted is niche theory, according to which changes in environment create new ecological niches, which bring about changes in the make-up of the plant community. According to equilibrium theory, the members of a plant community exist in relationship with each other in terms of space allocation. While individual species have the potential to spread and monopolize the environment, this is balanced by the existence of commensal and symbiotic interactions among the members of the plant community. If one member of the community should grow beyond certain limits, its spread would be inhibited by its need for the other species in the community, and the spread of the other species would increase to compensate.

Key words: biodiversity, plant succession, natural contact in plant communities, fruit plantation

The importance of biodiversity in natural environments and in fruit plantations

Sustainable fruit production is not possible without biodiversity. Sustainable fruit production should be practiced in harmony with the ecosystem, in which a large variety of plants, pollinating insects, predators, birds and other small animals maintain a proper balance between cultivated plants and pests.

Biodiversity in the world

Biodiversity means the variety of life forms on earth (Mc Allister, 1991). Ecologists are exploring the causes of biodiversity and the role biodiversity plays in biological equilibrium. The definition of biodiversity emerged because of the need to describe the wealth of life forms on earth, and how they differ over time and from place to place (Falińska, 1997a).

Table 1. Biodiversity of vascular plants in the northern hemisphere (Kornaś and Medwecka-Kornaś, 1986)

Plant community	Number of plant species represented in a local plant community
Arctic	30-90
Sub-arctic	150-350
Boreal	400-750
Central European	1000-1100
Mediterranean	1000-1500
Desert	250-450
Tropical	1500-3000

Scientists estimate that there are about 1.4 millions species on earth, including 750,000 insects, 41,000 vertebrates, and 360,000 plants, including microorganisms. (Willson, 1988).

There are some geographical and environmental patterns to biodiversity. For example, biodiversity decreases towards the poles. It increases with the trophic abundance and heterogeneity of the ecosystem (Pianka, 1970, cited by Falińska, 1997a). This can be seen in the table presented below:

Biodiversity and food

In the developing world, biodiversity provides food, raw materials for clothing, shelter, fuel, fertilizers, and medicine, and harnessable energy in the form of draft animals (Menini, 1998). The rural poor rely on biological resources for about 90% of their needs. In the industrialized world, access to diverse biological resources is necessary to support a vast array of industrial activities. Biological resources provide raw material for plant and animal breeding.

In agriculture, genetic diversity enables crops and animals to adapt to different environments and growing conditions. Without biodiversity, plants and animals would lose their ability to adapt to changing needs and conditions. Diversity in individual plants and animals, species, and ecosystems also enable human communities to adapt to changing conditions. Without biodiversity, humans would have a restricted range of responses to environmental challenges (Menini, 1998).

Of the 360,000 plant species on earth, about 80,000 have been found to be edible, of which about 7000 have been used by man as food. Over the ages, Mankind has utilized about 7,000 of these plants for food, though 150 plant species them are currently grown on a large scale. Thirty plant species supply 95% of food. However, 75% of food consumption comes from only twelve plants and five animals. Half of this food comes from four plants species (rice, maize, wheat, potato) and three animal species (cattle, swine, and poultry) (Menini, 1998). The wide variety of products produced by the fruit and vegetable industry allows consumers to have a varied diet.

World population is currently 6.5 billion, and is expected to grow to 8 billion by 2030. To feed the whole population, food production must increase by 25-30%.

Biodiversity and human activity

Biodiversity stabilizes the ecological equilibrium in plant communities. Plant communities can be classified as in the following table (Faliński, 1969, modified by the author).

T a b l e 2 . Classification of plant communities

AUTOGENIC COMMUNITIES	Created by natural factors
Primary communities	Local species not changed by human activity
Natural communities	Local species with slight changes by human activity and environmental factors
ANTROPOGENIC COMMUNITIES	Created by human factors
Semi-natural communities	Local species reorganized by repeated human activity on fields
Synanthropic communities	Local and extraneous species
Segetal communities	Weeds friendly to human activity
Ruderal communities	Nitrophilic plants friendly to human settlements
Xenospontaneous communities	New communities organized on transformed sites

Plant communities in fruit plantations can be classified as anthropogenic communities.

Biological resources are renewable as long as they are not exploited beyond their sustainable yield. Destruction caused by human activity is the greatest threat to plant communities and biodiversity. Forests are being cut and burned, grasslands are being overgrazed, natural plant communities are being cleared for agriculture purposes, crops are being over-watered, water is being polluted, and fertilizers, herbicides and pesticides are being applied in excessive doses. Urbanization and the water and air pollution which accompanies it threaten biological diversity (Menini, 1998).

Human activity promotes the spread of monotonous synanthropic plant communities at the expense of diverse natural plant communities.

Genetic erosion also reduces biodiversity. In the 1700s and 1800s, farmers developed thousands of local varieties which were well adapted to local conditions, and resistant to harsh weather, pests and disease. Scientist and breeders then began to develop improved varieties with a primary focus on productivity and fruit quality. Most of the old varieties were abandoned, forgotten, and lost. Individual genes and gene complexes which allowed the plants to adapt to local environments were also lost (Menini, 1998).

An estimated 35,000 to 40,000 plant species disappeared from 1970 to 2000 (Lugo 1980, cited by Menini, 1998). The natural flora of Europe is gradually becoming more impoverished (Falińska, 1997a). 40-50% of the vascular plants in Western Europe and 30% of the vascular plants in Poland are threatened with extinction because some species have been selective eradicated, habitats have been destroyed, and the environment has been permanently changed.

At one time about 10 000 apple cultivars were grown in Europe. In some countries, only a few cultivars are still cultivated. Only a small percentage of the former botanical wealth has been preserved in apple gene banks. Other fruit species have suffered a similar fate.

Plant succession

In most European orchards, mechanical soil management is performed for one, two or three years after planting. After that period, either mechanical soil cultivation is continued, or herbicides are sprayed along tree rows and alleyways are mowed. In many orchards, grassy turf establishes itself as soon as mechanical soil cultivation is discontinued. The question arises of how many plant species occur naturally, which species dominate, whether biodiversity is broad enough for sustainable fruit production, and whether the new plant community is stabile.

These questions can be answered by theory of plant succession, proposed by Clements in 1916 (cited by Jensen and Salisbury, 1972). According to this theory, the first stage coincides with the appearance of plants on uncultivated land as a result of the germination of seeds present in the soil and of seeds which have migrated to the site. The second stage coincides with a reduction in the number of species as the plants compete with each other for light, water, and nutrients. An ecological niche is created for new species, such as grasses. The third stage coincides with the development of a stabile plant ecosystem which is adapted to local soil, water, and light conditions. According to Clements, the plants which appear in the earlier stages create conditions which promote the growth of the plants which appear in the later stages. There are also numerous other theories which attempt to explain plant succession.

We will now present the first stage of plant succession in an experimental apple orchard.

In the spring of 2002, 'Gala' apple trees on M.9 dwarfing rootstocks were planted 3.5 x 1.6 m apart in Skierniewice, in central Poland. After planting, alleyways were clean cultivated, and row strips were either weeded by hand or mulched with an organic mulch. The plant species that appeared on the experimental plots were counted twice a year. For each soil treatment, counting was performed in three randomly chosen one-square-meter areas. Over the two years of the study, twenty-five plant species were observed which could be classified as either segetal or synathropic species. On composted soil, ground coverage was 100%. On clean-cultivated, irrigated soil, ground coverage was 50%. On clean-cultivated, non-irrigated soil, ground coverage was only 25%.

Table 3. First stage of plant succession in an apple orchard with three different methods of soil management

Plant species	Soil treatment		
	compost	clean cut with irrigation	clean cut without irrigation
Rumex acetosella	x		
Polygonum tomentosum	xx		
Polygonum persicaria	xxxxxx		x
Polygonum hydropiper	xxxxxxxxxxxx	xxxx	xxx
Chenopodium polyspermum	xxxxxxxxxxxx	x	x
Atriplex patulum	xxxxxxxxxxxx		
Amaranthus retroflectus	xxxxxxxxxxx		x
Ranunculus repens	x		
Erysimum cheirantoides		x	
Sinapsis arvensis	x	x	x
Thlaspi arvense	x	xx	
Vicia hirsute	x		
Taraxacum officinale	xx	xxx	xxxx
Erigeron Canadensis	xx		
Trifolium repens	x	x	x
Lamium amplexicaule	x	x	x
Galinsoga parviflora	xx		
Cirsium arvense	x		
Sonchus asper	x	x	
Sonchus arvensis	x		
Setaria glauca	xxxxxxxxx	xx	
Malva neglecta	x		
Anthemis arvensis	xxxxxxx	xxxx	xxxx
Poa annua	xxx	xxxxx	xxxx
Agropyron repens		x	xx
Mean ground coverage	100%	50%	25%
Total number of species	23	13	11

In integrative and organic fruit production, biodiversity ensures that predators and pollinators have shelter and an ample supply of nectar and pollen. Our experiment on plant succession shows that a very limited number of plant species are present in the first stage of plant succession. Drip irrigation only slightly increased the number of species present. It appears that the amount and variety of dormant seeds in the soil was very limited. The mulch we used was composted fruit waste which had been aged for two years in the open. Mulching doubled the number of species observed. To increase biodiversity in integrative and organic orchards, some plant species should be sown in alleyways.

Biodiversity in plant communities

When we admire nature in all its glory, we seldom ask: Why are these plant species here? How did they come to be here? How many species are growing together? What are the mutual relationships between them? Is this plant community stabile, or is it changing over time? Does this plant community recover when disturbed? Ecology tries to answer these questions.

There are two kinds of biodiversity: biodiversity within a plant community, and biodiversity between plant communities (Whittaker, 1975).

The topography of a plant community depends on soil properties, soil moisture, variety of terrain, protection from wind and sun, and many other factors. Plant communities are usually organized either in belts or mosaics. Plant communities along rivers or the sea are organized in belt-like zones in which conditions change rapidly the further one gets from the shoreline, but change very little if one moves parallel to the shoreline. Plant communities in forests and fields are organized in mosaics reflecting the irregular distribution of soil conditions (Jensen and Salisbury, 1972).

Mutual contact in plant communities

If different environments support specific plant communities, then what happens when two different plant communities come in contact with each other? The answer is that there is a transitional zone between them in which the members of both communities can be found (Faliński, 1961). This transitional zone is usually only a few meters wide, but can sometimes be as wide as one hundred meters, especially in forests and meadows (Falińska, 1991).

How do plants organize themselves, how do they co-exist, and what abiotic factors affect how they interact? There are several theories which attempt to explain why a particular plant community exists in a particular place in terms of evolution, history and ecology. We will examine three of them.

Niche theory proposes that differences in environmental conditions from place to place favor different combinations of species (Tilman, 1986 after Falińska, 1979a; Tilman, 1988).

Equilibrium theory proposes that environmental conditions change over time. These changes favor less dominant species, giving them a chance to spread (Pickett,1980b after Falińska, 1979a).

Competition theory proposes that competition between plants depends on the abundance of the plant community (Grime, 1979 after Falińska, 1979a).

When plants exist in the same place, they interact with each other. How many species can co-exist in a given habitat? Why does one species displace its neighbors? Individual species in a plant community compete with each other for light, nutrients, water and space. Individual species usually spread at the cost of other members of the plant community. However, individual species also often have a beneficial effect on the other members of the plant community. In many cases, when we examine a plant community, what we see is not so much species competing with each other as much as species interfering with each other. The most blatant form of competition is when one species literally grows over and shadows another (Falińska, 1997b).

In stabile plant communities, there is a dynamic equilibrium between members of the community. In unstable plant communities, the community can lose some species while taking on new species. In suppressive plant communities, some species spread at the expense of others.

Plants compete among each other for space more than for anything else. Competition dictates the size, height and shape of plants. Some plants have developed strategies to avoid competition. For example, some perennials develop rapidly in the spring before leaf growth on trees and shrubs limits their supply of light and space. Other plants avoid competition thanks to long stratification periods and late germination dates.

T a b l e 4 . An example of plant succession in natural grass turf between rows of bushes (xxx) in 12-year-old blackcurrant plantation on light sandy soil near Skierniewice. The initial flora consisting of *Hieracium pilosella* (H), *Trifolium repens* (T) and *Festuca rubra* (F) is gradually being displace by the more robust grass *Calamagrostis epigejos* (C). The figure shows a 3.5 m long strip between rows 1.5 meters apart.

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Direction of *Calamagrostis* succession

A – *Achillea millefolium*
C – *Calamagrostis epigejos*
E – *Erodium cicutarium*
F – *Festuca rubra*
H – *Hieracium pilosella*
L – *Lolium perenne*
M – *Malva sylvestris*
R – *Rumex acetosella*
T – *Trifolium repens*
V – *Vicia villosa*
X – *Taraxacum officinale*

In plant succession in the naturally grassy alleyways in fruit orchards, competition means that some species suppress and displace others. On light soils, the species encountered in the first stage of plant succession are tender grasses such as *Holcus lanatus*, *Poa pratensis*, and *Festuca pratensis*, and broad-leaf plants such as *Trifolium repens*, *Hieracium pilosella*, and *Taraxacum officinale*. These species are gradually replaced by grasses with strong rhizomes, such as *Calamagrostis epigejos*, and *Agropyron repens*, which can even compete with the fruit crop. Below is an example of how *Calamagrostis epigejos* suppresses *Hieracium pilosella* in a blackcurant plantation.

A niche is a defined area which provides all of the conditions necessary for the development of a particular species (Hutchinson, 1957, cited by Falińska, 1997). An ideal niche means that all conditions are optimal, and the growth and development of the plant is not restricted by competition. In reality, in every niche there are some factors which restrict growth and development. Niches can be totally isolated from each other, or totally blend in with each other. Niches expand and contract over time in response to changes in environmental conditions. In each niche, not only is the number of species important, but also their characteristics, especially their adaptability to unfavorable growing conditions like frost or drought.

The seedling, rosette, and adult stages of the same plant can be distributed in different patterns. For example, upright adult forms are usually distributed in a mosaic pattern, whereas seedling forms are distributed in a carpet pattern. These carpets of small seedlings are ubiquitous and develop because of the heterogeneous assortment of seeds in the soil. These carpet patterns can persist for many months or seasons, and readily recover if they are disturbed. In orchards, these carpet patterns can be very stable because the trees are in place for a long time.

Biodiversity in old orchards

In the Carpathian region of Poland, rainfall is abundant (600-800 mm). In old orchards, branches are high off the ground so that sheep and cows can graze under the fruit trees. The orchard floor is left to grow as a meadow, which prevents soil erosion, conserves water, promotes the build-up of bioelements, and fosters the formation of a diverse, esthetically pleasing local biosystem. This ensures a diverse and reliable supply of food for the local fauna and for the domesticated animals which supply milk, meat, wool, and leather.

There are 88 million hectares of grassy ecosystems in Europe, which produce 316 million tonnes of dry matter and have a potential of producing four times as much (Prończuk, 1982).

In Poland, extensive meadows can harbor up to four hundred plant species. In a grassy ecosystem, the number and variety of species depend mainly on soil quality and moisture. There are more species on fertile, moist soils than there are on poor, dry soils. The predominant species are grasses (eighty species), sedges (eighty species), and papilionaceous plants (forty species). On one square meter of meadow, there are about one hundred plants representing usually less than fifty species. The number of actively growing shoots ranges from 960 to 2000, giving a leaf area index of almost 12 (Prończuk, 1982). The turf is about seven centimeters thick and can be easily separated from the soil without damaging the roots and rhizomes. The turf is so firm that a 700-kilogram animal cannot damage it. Grassy ecosystems also have a very rich small fauna.

Grasslands, both in meadows and on orchard floors, have a high biological value. In a modern orchard, the leaf area index is only about 2, and light interception is reduced only by 60%. The vast amount of solar energy reaching the orchard floor through the canopies can be assimilated by the grassy ecosystem. In an organic orchard, farm animals can safely graze on the grass underneath the trees because no chemicals are used. In an integrative orchard, grass can be used for mulching trees, or left in place to build up organic matter in soil.

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ROLA RÓŻNORODNOŚCI BIOLOGICZNEJ W NATURZE I NA PLANTACJI ROŚLIN SADOWNICZYCH

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STRESZCZENIE

Określenie „różnorodność biologiczna" oznacza bogactwo form życia na ziemi, we wszelkich jego postaciach. Różnorodność biologiczna odgrywa fundamentalną rolę w produkcji integrowanej i ekologicznej. Dzięki różnorodności biologicznej człowiek ma zapewnioną żywność, surowce na odzienie, schronienie, leczenie itp. Różnorodność genetyczna w świecie roślinnym i zwierzęcym umożliwia dostosowanie się organizmów do trudnych warunków przyrodniczych i ich przetrwanie. Biologiczne zasoby ziemi są odnawialne pod warunkiem, że człowiek nie będzie ich eksploatował w sposób nadmierny lub rabunkowy. Niestety współczesne społeczeństwo jest alarmowane, że następuje destrukcja ekosystemów przez działalność człowieka obejmującą nadmierne wycinanie, wypalanie, niszczenie, odchwaszczanie, nawożenie, nawadnianie, zanieczyszczanie świata roślin i zwierząt. Naukowcy oceniają, że istnieje na ziemi 1,4 miliona form życia, w tym 750 000 gatunków owadów, 41 000 kręgowców, 360 000 gatunków roślin. 80 000 gatunków roślin nadaje się do spożycia, ale tylko 150 gatunków jest spożywana na większa skalę. Tak zwana „żywność przemysłowa" sprzedawana w supermarketach pochodzi od 30 gatunków roślin.

75% naszej żywności to zaledwie 12 gatunków roślin. Człowiek przestał korzystać z bogactwa różnorodności biologicznej, które zapewnia nie tylko kalorie, lecz także zdrowie. Różnorodność biologiczna jest zagrożona. Szacuje się, że w najbliższych latach może zginą około 30 000 gatunków, jeśli nie podejmie się środków zapobiegawczych. Na początku XX wieku było w sadach Europy około 10 000 odmian jabłoni. Obecnie uprawia się na dużą skalę tylko kilkanaście odmian, poddając zagładzie pozostałe odmiany, które są bardzo wartościowym źródłem genów warunkujących odporność drzew na choroby i niesprzyjające warunki atmosferyczne. Podobny proces odbywa się w innych dziedzinach rolnictwa.

Ekologia stara się wyjaśnić i zrozumieć wzajemne zależności między roślinami w zespołach roślinnych, relacje między zespołami roślinnymi i otaczającym je środowiskiem. Przedmiotem badań ekologii jest między innymi powstawanie różnorodności biologicznej, jej trwałość i zmienność, szczególnie w związku z działalnością człowieka. Nowoczesna produkcja sadownicza prowadzi do zubożenia biologicznego środowiska z powodu opryskiwania, stosowania herbicydów i nawozów. W celu rozwoju produkcji integrowanej i ekologicznej w sadach konieczne jest działanie zwiększające różnorodność biologiczną.

Słowa kluczowe: różnorodność biologiczna, sukcesja roślin, wzajemne kontakty zespołów roślinnych, plantacje owocowe