Organic Farming in Germany: Concepts, Methods, and Practices

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Introduction

In this report, organic farming as it is practiced in Germany is described with regard to the work at the Institute of Organic Agriculture. The Chair for Organic Agriculture in Bonn was founded in 1987. During the past 5 years, the department has been characterized by a steady increase in personnel and labor. An intensive program of lectures was held outside the university in addition to the research work and normal student lectures. Furthermore, close contact with practical farmers and the extension service was maintained.

Aims and Principles

"Organic agriculture" is a type of agriculture that is also known as "biological" or "ecological" agriculture. The main approach of organic agriculture is the conduct of a mixed farm practice as far as possible within a closed system cycle.

The production system, while adhering to certain organic standards and regulations (IFOAM, 1989), demands implementation within its own local, ecological, socioeconomic and cultural setting. Since site-conditions are individual properties by definition, a "farm organism" can be conceived as an individual.

Organic agriculture gives up all claims to maximum yields by rejecting the use of chemo-synthetic, resource-extravagant and energy-demanding mineral N fertilizers and pesticides, which can be used to manipulate strategies. In the light of the European Community's (EC) surplus production, organic agriculture poses an efficient and environmentally-sound option for the common agricultural policy of the EC.

The production system can be characterized by the following principles:

- nearly closed cycles of nutrients and organic matter within the farm;
- predominantly farm-produced manures and composts;
- slowly soluble minerals for fertilizing if needed;
- self-produced seeds if possible;
- weed control by crop rotation, cultivation, thermal methods, and competition;
- pest control based on homeostasis and inoffensive substances, as well as the use of predators and their promotion by structures like hedges, flowering plants and others.

Animal welfare has to be ensured by appropriate housing systems, which allow the expression of essential behavior patterns, and by suitable feeding with on-farm grown crops (up to 10 to 15 percent of the daily dry matter ration may be imported). Lasting fertility is ensured by efficient reproduction of soil organic matter. Stability is achieved by a balanced diversification, i.e., a balanced combination of plants and animals which permits self-sufficiency regarding feed and manures. Since chemo-synthetic N fertilizers and pesticides are not used, organic agriculture seeks to maintain and improve the productivity of land and animals as far as possible by encouraging and enhancing biological processes (for example, N_2-fixation by leguminous crops).

Special efforts are made to assess the consequences of farming in order to minimize the negative impacts on producers, livestock, consumers, produce and environment. On the other hand, maximum conservation and protection of soil, water, air and nature are set up as goals.

These aims and principles ensure a diverse, sustainable and stable kind of production. Since socioeconomic implications and ethic values are taken into consideration as well, the basis of organic agriculture is that of a system-oriented concept contrary to conventional fanning with its product-oriented goals. Organic agriculture realizes, therefore, a holistic approach.

Organic Farming in Germany

In 1970, about 200 organic farmers cultivated an area of 4,000 hectares in the western states of Germany. Since then, a steady increase has occurred which now involves some 3,500 farms covering 85,000 hectares (Figure 1).

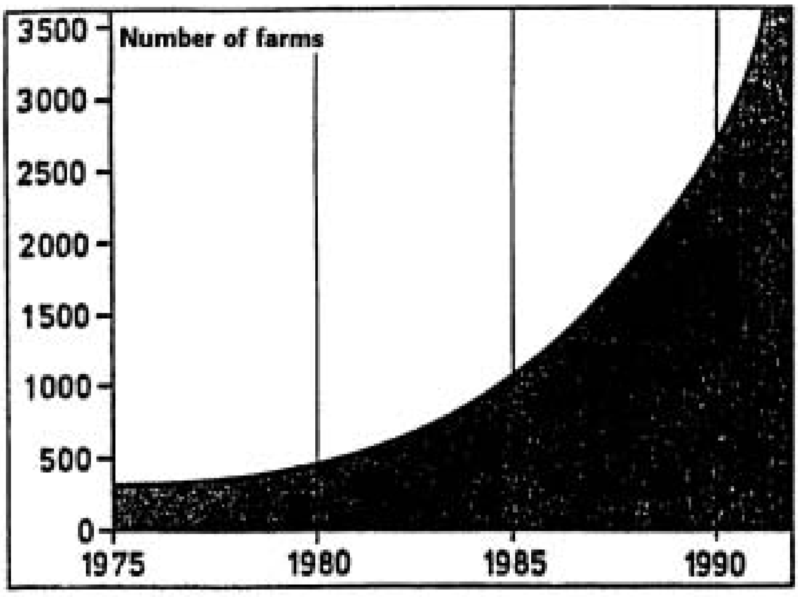


Figure 1. Organic Farming in Germany: Number of Farms as Members of Six Official IFOAM Organizations.

The increasing problems of surplus production within the European Common Market and environmental pollution linked with intensive agricultural practices has required a search for new concepts. We observed a dramatic increase in the number and area of farms cultivated organically in 1990 because of an EC program financing the transition of conventional farms to organic agriculture as a strategy to reduce surplus production. As a result of a disproportionately increased demand for organic products, more than 50 percent of the German demand for organically-grown produce is now being imported. Some authors have predicted that organic farmers will increase the area of production to about 5 to 10 percent of the total land cultivated by the year 2000.

Producers receive higher prices for cereals and potatoes than their conventional colleagues. On average the reduction in yield is considered to be about 30 percent. A product price, which is two or three-fold higher than prices for conventionally-grown products, realizes a higher income for organic farmers. Organically-grown dairy and meat products are quite often sold in conventional market channels at regular prices. Concerning the whole farm, animal production is often subsidized by plant production.

In Germany, organically-grown products are usually sold in farm shops and markets by specialized retailers and "natural-food" stores. German producer organizations still have reservations about serving the conventional distribution systems and supermarkets. On the other hand, it is only in this way that more organically grown produce can find its way into the markets and to consumers.

Fulfilling the standards and regulations of a producer's association, a farmer will be able to mark his products as "certified organic" with the seal of his contracting organization. A national commission has been formed by these associations to develop German standards. Beginning in l993, EC regulations on organic agriculture will also have to be fulfilled in order to seal and to sell any produce as organic, including imported products.

Methods and Concepts

At the Faculty of Agriculture in Bonn, a broad range of subjects is under investigation to optimize specific production elements in favor of the whole organic production system. The special scientific objective of the Institute of Organic Agriculture is to develop strategies and methods, which can be integrated into the production management of private farms as well as working with the university on "organic agriculture" for educational purposes. The results derived from these investigations are also integrated into the production system of the "Experimental Farm for Organic Agriculture - Wiesengut" in order to design a productive, site-oriented, and environmentally- sound model farm.

Closed Nutrient Cycle

Detailed measurements have been undertaken to quantify the nutrient and organic matter cycles on organic farms. Judging the potential gains and losses in the nutrient cycle across a farm is essential not only to avoid negative impacts on air and water quality but also to keep up with internal farm productivity. Figure 2 shows a model of the nutrient cycle on farms.

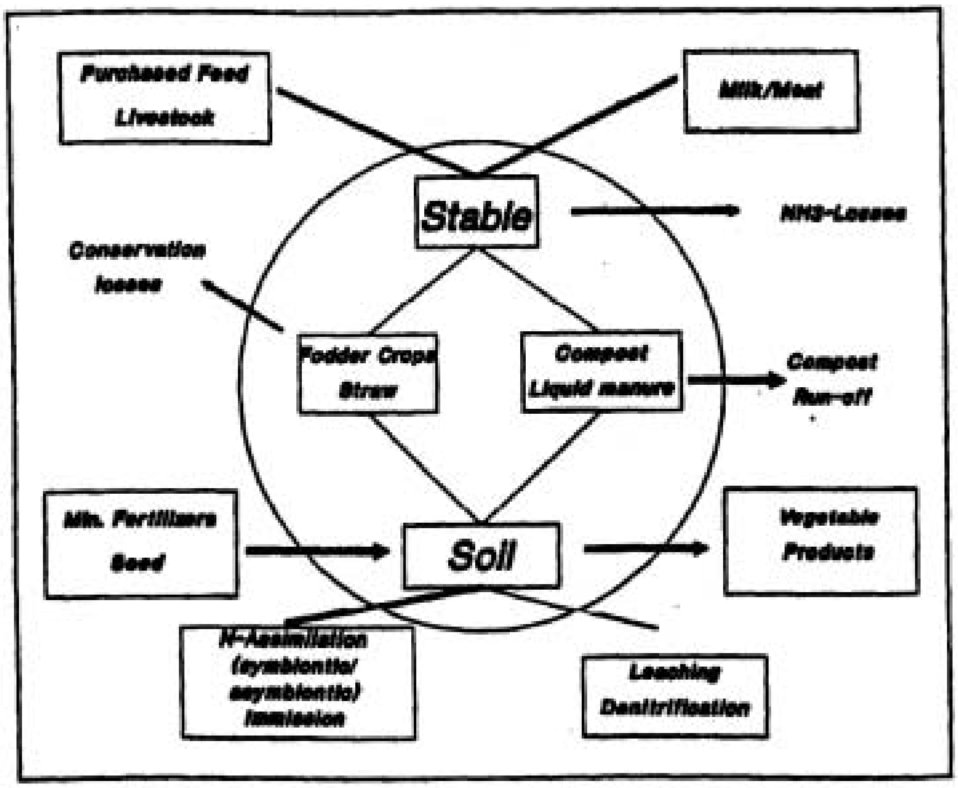


Figure 2. Model of the Overall Nutrient Cycle on an Agricultural Farm (Nolte and Werner, l992).

Nearly all balances calculated on a total of the so called "farm-gate balance" base show an equilibrium of N, P, K input-to-output ratios (Kuecke and Sauerbeck, 1990). However, specific losses of the three main nutrients by sales, as well as within-farm and field losses can be detected by examining nutrient balances within a farm or even within a single field (Table 1).

Table 1. Contribution of Nutrient Losses by Selling, Within Farm and On-Field-Losses to the Overall Loss (= 100) Calculated for the "Boschheidehof" Farm, State of Northrhine Westphalia Germany, (Nolte 1990).

% Losses	N	P	K
By selling	27	73	14
Within the farm	38	23	78
Field	35	4	8

Only a small percentage of K is lost through the selling of agricultural products but a high percentage disappears within the farm due to accumulation processes under compost-heaps. Therefore, we try to develop strategies to minimize nutrient losses during composting of farmyard manures.

Closed Nutrient Cycle: Nitrogen (N). Synthetic mineral nitrogen fertilizers are renounced in organic agriculture. Apart from nitrogen imported with manures or nitrogen in seeds, organic farming systems rely on symbiotically-fixed nitrogen for their nitrogen input. Therefore, it is crucial to organic agriculture to maximize N_2 fixation by leguminous crops while minimizing losses of N by nitrate leaching from the fields (onsite losses) or from farmyard manure or compost piles (offsite losses).

Strategies for Maximizing Symbiotic Nitrogen Fixation

Faba Beans and Pulse Crops in General

In pulse crops the amount of symbiotically-fixed nitrogen is closely correlated with the amount of N in grains. Figure 3, for example, shows that nitrogen input was maximized by using the cultivar "Minica", which gave higher yields than the cultivar "Kristall".

Further net increases of N can be achieved by selecting those varieties which are best adapted to given site conditions. Farmers ought to know their individual site conditions, whether they may expect higher yields from peas or from faba beans. Another important procedure consists in narrowing the distances between rows which can also boost nitrogen gain because of higher yields (Figure 4). Therefore, it can be safely asserted that all strategies which increase yields of pulses will simultaneously maximize nitrogen fixation. This should hold true also for tropical and sub-tropical pulses such as soybeans, phaseolus beans and chickpeas.

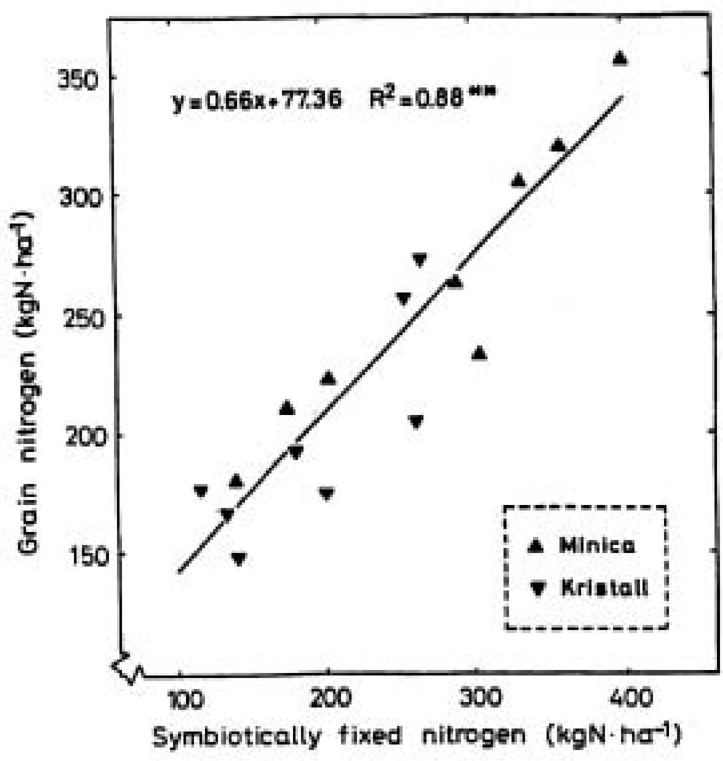
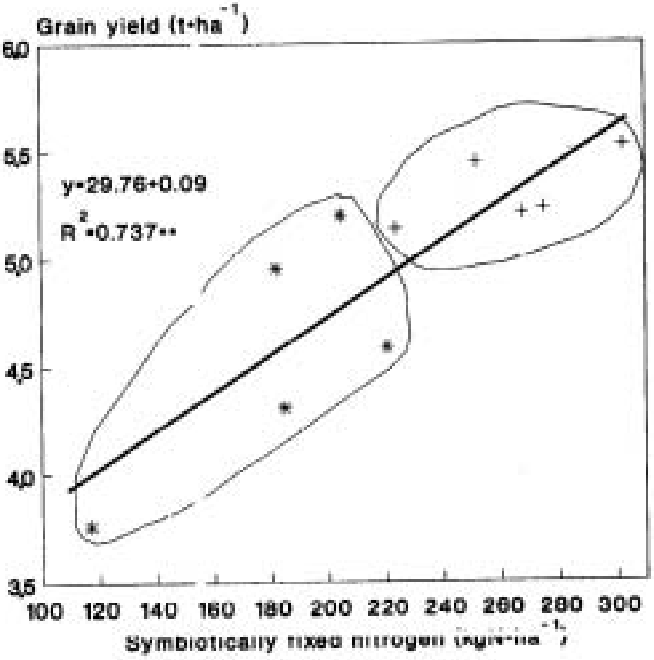


Figure 3. Relationships between Grain Nitrogen and Amounts of Fixed Nitrogen of the Faba Bean Cultivars "Minica" and "Kristall" (Köpke, 1987).



*wide rows (55 cm) + narrow rows (27.5cm)
Row distance

Figure 4. Faba Beans: Relationship between Grain Yield, Amount of Fixed Nitrogen and Row Distances (Data from Justus, 1993, Pers. Commun.)

Grass/Clover Mixtures and Fodder Legumes in General

The same strategies can be applied to fodder legumes; N_2 fixation can be maximized by selecting those varieties and cultivars which are well-adapted to conditions at a given site. Figure 5 reveals a clear relationship between dry matter yield and nitrogen fixation by red clover.

Besides nitrogen, soil fertility must be based on the production and recycling of soil organic matter and the nutrients it contains. Farm-grown legumes combined with grass have a marked ability to generate soil organic matter. Therefore, organic crop rotations rely heavily on the combined cultivation of fodder legumes and grasses. Figure 6 shows that the higher the percentage of clover in grass/clover mixtures and yield of those stands, the higher the amount of symbiotically-fixed nitrogen.

By using illustrations, practical farmers can estimate the amounts of nitrogen which are symbiotically-fixed by either grain or fodder legumes. In the case of faba beans, which can fix approximately 8 percent of total nitrogen uptake under temperate conditions, the amount of symbiotically-fixed nitrogen corresponds approximately to the amount of grain-exported nitrogen. Therefore, nitrogen fixation could then be estimated on the basis of grain yield and mean nitrogen content of the grains (Köpke, 1987).

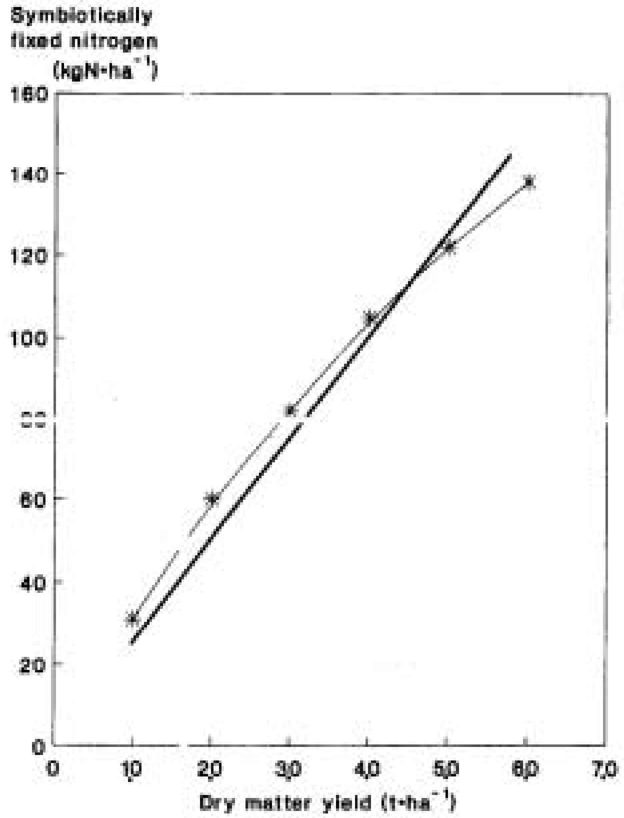


Figure 5. Red Clover: Relationship between Symbiotically Fixed Nitrogen and Dry Matter Production (Yield Per Cut) (Data Derived from Boller, 1988).

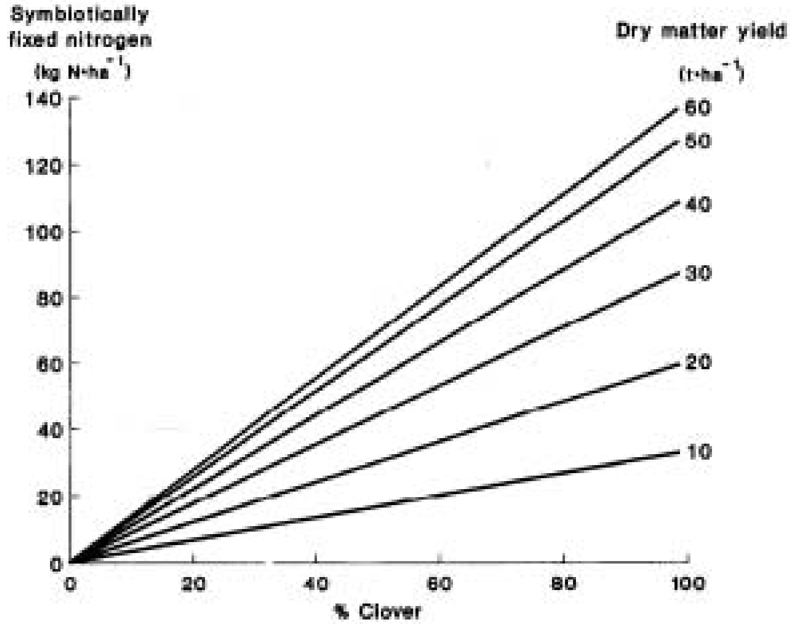


Figure 6. Relationship between the Amount of Symbiotically Fixed Nitrogen, Percentage of Red Clover and Grass/Clover Mixtures, and Dry Matter Yield (Yield Per Cut) (Boller, 1988).

Strategies to Reduce Nitrate Leaching

Onsite Losses

Faba Beans and Pulse Crops. During the cultivation of faba beans, and especially after their harvest, the amounts of accumulated nitrate in the soil rises significantly above the level measured in the soils of non-leguminous crops. This is caused by lower rooting-density, heterogeneous root distribution, and lower rooting depth of faba beans. Residual soil nitrate is expected to leach during the winter and might, therefore, pollute ground water and drinking water. This has caused extensive debates in Germany about a possible legal ban on the cultivation of legumes in water conservation zones. In field trials with faba beans, we compared three different strategies to reduce the high levels of soil nitrate that occur during and after the cultivation of faba beans. One approach is to make the faba bean root distribution more homogeneous by employing narrow rows compared with the normally wide-row spacing. Rooting density and rooting depth could be increased even further by inter-cropping with cereals, or by undersowing non-legumes as catch crops. Such changes in cultural and management practices would allow plant roots to absorb most of the nitrate before it moved below the soil-root zone.

During the vegetative period a remarkable nitrate gradient occurred under the wide-spaced rows (row distance 55 cm). The soil nitrate content between the rows was nearly twice that measured directly under the rows. Under narrow-spaced rows this gradient was smaller. With inter-cropping treatments, no gradient existed. Undersown *Brassica* spp. completely eliminated the gradient in contrast to ryegrass (Justus and Köpke, 1990). This result supports the hypothesis that the heterogeneous rooting-density of faba beans caused a higher soil nitrate content because of their uneven nitrate uptake.

Both increased rooting-density from inter-cropping with cereals and underseeding with non-legume catch crops considerably curbed the nitrate content for up to two months after harvest (Figure 7). Oil-radish reduced the nitrate content of the soil profile from 53 kg N/ha (100 percent) to 8 kg N/ha (17 percent) as compared with pure stands of faba beans. White mustard and ryegrass were less efficient (39 and 75 percent, respectively). These results correspond to the nitrogen up-take of underseeded crops. The findings illustrated in Figure 8 show that potential losses of nitrate can be decreased more efficiently by undersowing brassicas in faba bean stands during the flowering stage. Soil nitrate which has not been taken up by the faba beans can be protected from leaching and conserved for use by the following crops.

The reduction of nitrate losses and maximizing symbiotic nitrogen fixation are not contradictory aims, even if at first they might appear to be. As shown in Table 2, a narrow-row spacing gave higher grain yields but did not reduce nitrogen fixation. Obviously, higher amounts of soil nitrate were taken up without reducing nitrogen fixation. In contrast, inter-cropping with cereals, especially with oats, decreased grain yield and N_2 fixation by faba beans because of competition for water. Compared with pure stands of faba beans, grain yield and N_2 fixation were not influenced by undersown brassicas. On the other hand undersown ryegrass clearly reduced both grain yield and N_2 fixation.

Optimizing Preceding Crop Effects of Faba Beans. By selecting the appropriate site specific strategy, an efficient use of N fixed by a previous legume crop is ensured by the following summer crops. As shown in Figure 8, the brassica-underseeded strategy resulted in higher yields of the following oat crop than any of the faba bean treatments.

Concepts for Green Fallows, Grass/Clover Mixtures and Fodder Crops. Under a standing grass/clover mixture Hess (1989) found that 12 kg N/ha was leached during the winter. When the 2-year grass/clover mixture was sown in early fall, the loss increased up to 55 kg N/ha. During the following winter under winter ryegrass 23 kg N/ha were lost. To avoid losses of soil-borne nitrogen after sowing the grass/clover mixture, the nitrogen has to be taken up completely by the following crops. This transfer can be optimized by keeping pre-winter mineralization as low as possible by proper timing of certain operations such as postponing the plowdown of the grass/clover crop; reducing the tillage intensity (depth, frequency), while maintaining the standard crop rotation (wheat following grass/clover); changing the crop rotation using catch crops following grass/clover to fix pre-winter mineralized nitrogen; or cultivating main crops with a high nitrogen consumption before winter (e.g., rtpeseed) (Hess, 1989; 1990).

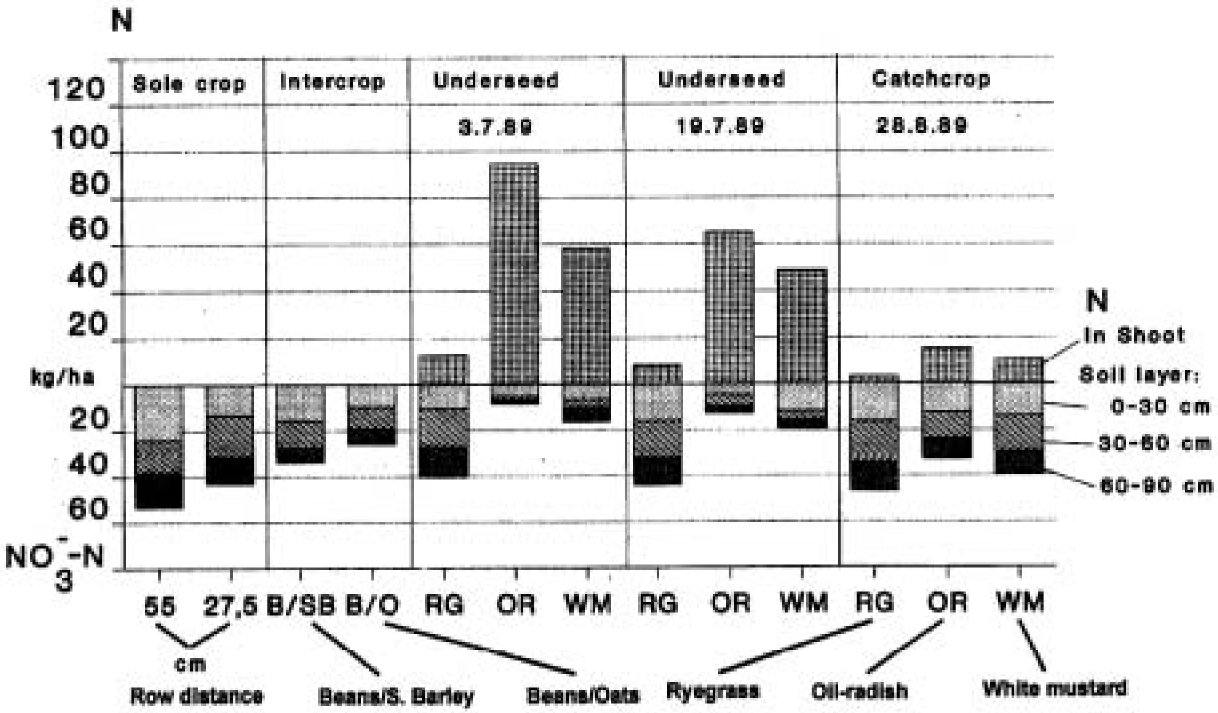


Figure 7. Soil Nitrate Content Two Months after Harvest of Faba Beans as Affected by Row Distance, Intercropping with Cereals, Sowing Date of Underseeded Crops and Catch Crops (Stubble Crops), Nitrate Uptake in Shoots of Underseeded Crops and Catch Crops; October 19, 1989 (Justus and Köpke, 1990).

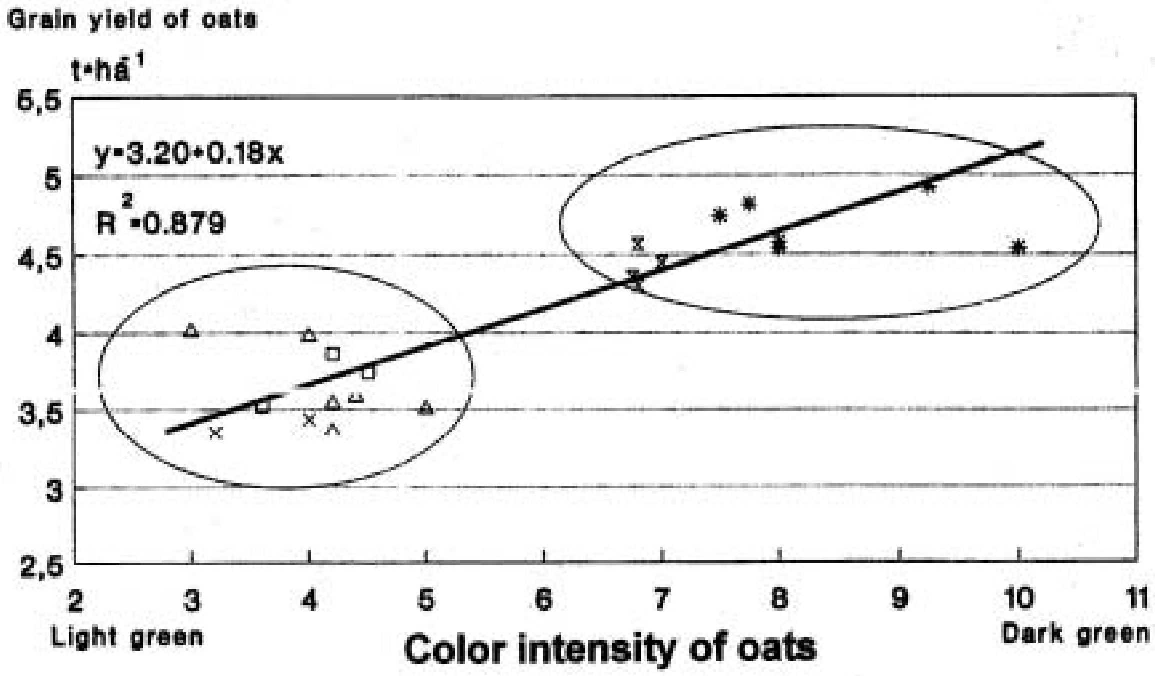


Figure 8. Relationship between Grain Yield and Foliage Color of Oats as Affected by Different Faba Bean Treatments (Derived from Aerial Picture Taken on May 29, 1990) (Justus and Köpke, 1991).

Table 2. Grain Yield and N_2 Fixation by Faba Bean Treatments (Unpublished Data).

Row Distance (cm)	Treatment	Grain Yield (dt ha^{-1})	N_2 Fixation (kg N ha^{-1})
55	Pure stand	37.5	125
27.5	Pure stand	38.7	127
	Intercropped oats	11.7	50
	Intercropped barley	16.7	79
55	Underseeded ryegrass	30.4	95
	Oil-radish	33.9	124
	Mustard	34.8	119

Green fallow consisting of grass and clover can be used in set aside programs of the EC for transition to organic farming. Amounts up to 275 kg N/ha have been accumulated by a grass/red clover mixture (Dreesmann and Köpke, 1991). Since shoot mass of green fallow cannot be harvested, mineralization of green fallow residues produces a soil nitrate content of more than 200 kg NO_3-N/ha in a 0-90 cm soil profile in June following growth of sugar beet. Considerable amounts of this nitrate may be leached during rainy summers. In addition to the grass/clover strategies mentioned above, proper management of green fallow must be concerned with the composition of the stands (reduced percentage of clover) in order to control the N source, or to use grass/clover cuts for manuring and soil covering in adjoining strip-cropped cereal stands. The latter procedure ought to be legalized, since it may be a truly efficient way to produce organic cereals which does not threaten the ground water with any "untimely" mineralized N out-side the growing season.

Offsite Losses of Nutrients

Other strategies to reduce nutrient losses will be developed at a newly constructed composting facility at the Wiesengut experimental farm. Resembling a lysimeter in function, this facility was designed to gauge leaching from compost heaps and farmyard manure under defined conditions. Different composting conditions, shelters, additives, water and straw contents and other factors will be investigated to develop strategies that diminish losses by leaching (Falter and Köpke, 1992; Köpke and Schenke, 1991).

Cereal Production Management

Seed Quality

The efficient use of preceding legumes by the following cereal crop can be achieved by optimizing cereal production management. Since lower plant densities are typical in organic agriculture, single-plant development and yield performance need to be focused upon if the overall yield and interspecific competitive ability is to be improved. Strategies toward achieving these goals are based on seed quality, a key factor in organic agriculture. Of greatest concern are those situations where seed-borne diseases cannot be controlled by chemical seed dressings or fungicide applications during the growing season; low plant densities are not compensated by increased tillering because of a low mineralization rate of soil-borne nitrate in the spring; low population densities as a consequence of poor emergence lead to increased weed growth; and plant development, especially during early stages, is determined by seed quality (Piorr, 1990).

Figure 9 shows that winter wheat seed (cv. Kronjuwel) infected by *Fusarium* spp. resulted in a lower emergence rate as well as a reduced number of ears, which led to an increase of weed growth compared with a lower rate of infected seed (cv. Sorbas). Therefore, special emphasis is placed on seed quality. Seed size has an important effect on grain yields (Figure 10). Calibration of winter wheat gave greater increases in grain yield compared with the effects of seeding density. Better seed health and competition toward weeds were gained because the plants were growing more vigorously from larger seeds.

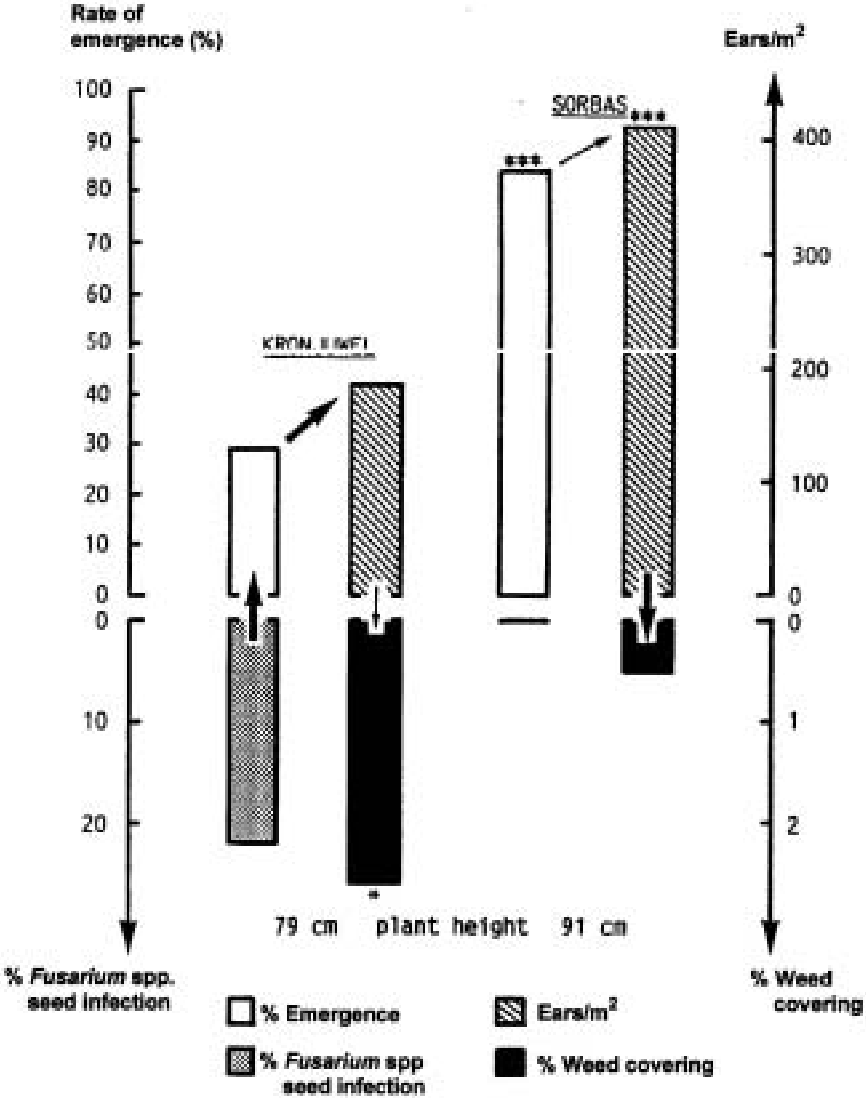


Figure 9. Weed Coverage, Rate of Emergence and Plant Density of Two Winter Wheat Varieties Having Different Seed Infection Levels of *Fusarium* spp. (Piorr, 1991).

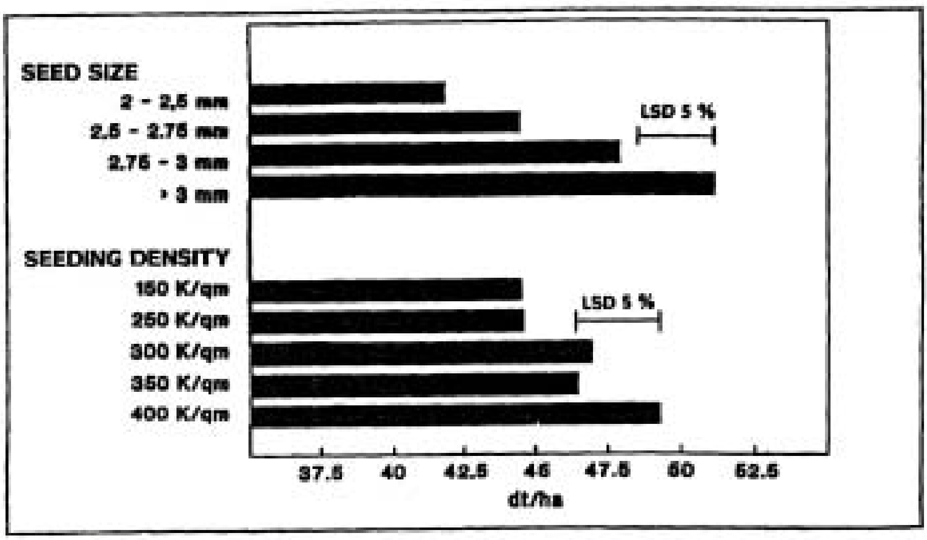


Figure 10. Grain Yield of Winter Wheat (cv. Granada) as Affected by Seed Size and Seeding Density (Piorr, 1991).

Several times we have found differences between conventional certified and organic second generation seeds. Fungal infestation with *Septoria nodorum* was often higher in organic seeds compared to conventional seeds, while the reverse was found for *Fusarium* spp. (Figure 11); however, both pathogen infestations were reduced when larger seeds were selected.
Therefore, guidelines for the certification of seed quality exceeding the existing seed standards have been developed to match the specific demands of organic agriculture. They will, in particular, cover seed-borne diseases, acceptable levels of infection, seed sizes, and other criteria. Certificates for organically-produced cereal seeds are issued by the Institute of Organic Agriculture after seed samples have passed certain quality tests. Investigations were carried out to define optimum locations for organic seed production (Dornbusch *et al*., 1992). Seed-borne diseases are not only important under the aspects of organic seed quality standards, but a loss from a product quality standpoint since mycotoxins might occur as a result of *Fusarium*-infested kernels (Schauder *et al*., 1992). Initial results have shown that the *Fusarium*-infection level was generally lower in organic seeds.

Weed Control Using Competition and Plant Distribution

Since herbicides have been renounced, concepts of weed control are focused on the use of inter-and intraspecific-competition factors. In order to minimize intraspecific-competition and to optimize interspecific-competition of winter wheat, different cultivation techniques can be used in an integrated approach. Elements of cultivation that were tested were the following: seeding rates, row spacing, organic manuring, seed size, and mechanical weed control by hoeing and harrowing (Schenke and Köpke, 1991).
Depending on the "weed pressure" at a given location, the optimal plant distribution, achieved by narrow-row spacing had to be adjusted to the appropriate weed control concept. If weed pressure is low, narrow-spacing of cereal rows can decrease intraspecific-competition and increase interspecific-competition ability of cereal stands. For these conditions, mechanical weed control using a spring-tine harrow may be sufficient. Mechanical hoeing, needed whenever weed pressure is high, can be performed only if row-spacing is at least 17 cm. Hoeing is the most efficient mechanical weed control method, but it has some drawbacks as well. For instance, the interspecific-competition effect declines, while intraspecific-competition is reinforced.
When applying organic manure, one has to consider that the weeds, if given an opportunity, will also make use of the nutrients. Therefore, weed control strategies need to be adapted to local conditions as well. Criteria have been developed to adapt the appropriate weed control concept to a given farm and its specific site conditions (Schenke, 1993).

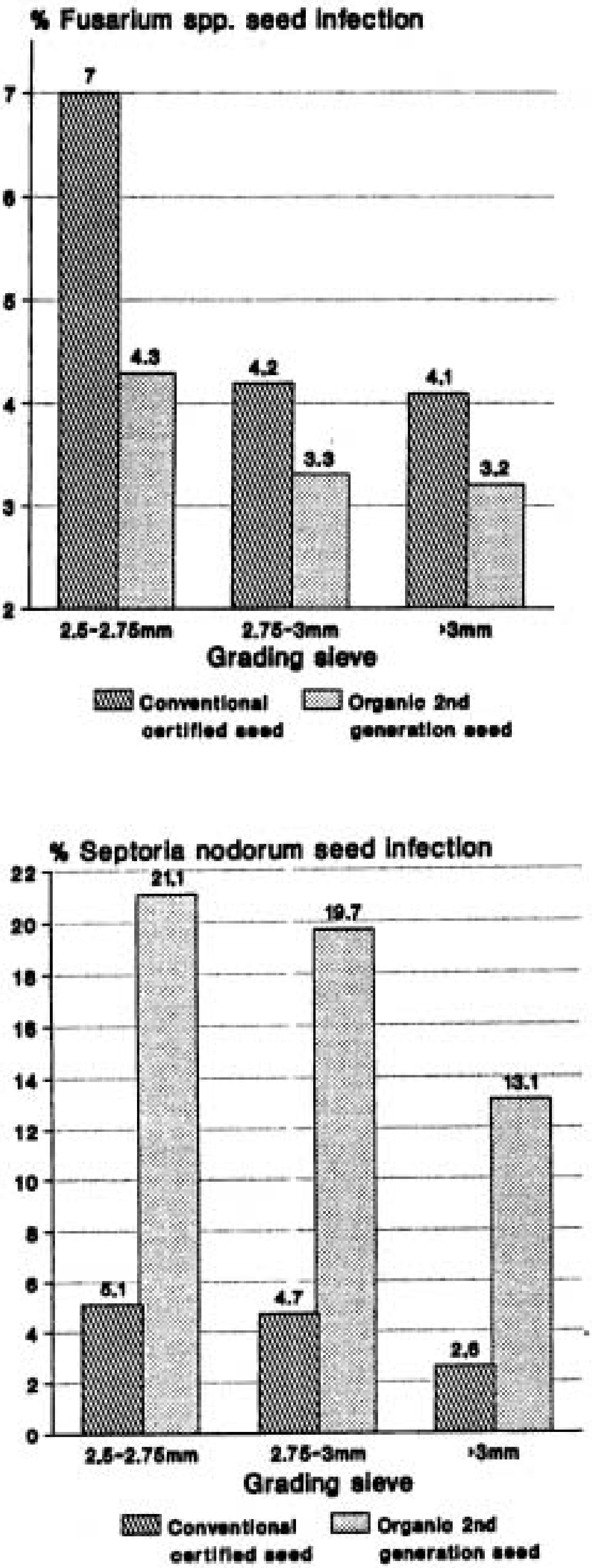


Figure 11. Seed Infestation with *Septoria nodorum* and *Fusarium* spp. as a Function of Seed Size and Provenance (Certified "Conventional" "Organic" Second Generation Seed) (Piorr, 1990).

Weed Control Based on Plant Morphology

Besides cultivation methods, morphological features of the wheat plant were examined with regard to their influence on interspecific-competitive ability by efficient shading, which we expected to suppress weed growth. Field trials were conducted with modern cultivars of winter wheat, differing in leaf inclination and height and employing two-row spacings (13.5 and 22.5 cm) as well as different row orientations (drilling directions north-south, east-west, respectively). Incoming photosynthetically-active radiation was measured simultaneously above the canopy and on the soil surface with a line quantum sensor (Eisele and Köpke, 1990; Eisele, l992).

The results of these investigations showed that shading of morphologically-different winter-wheat varieties was influenced by leaf posture, plant height and leaf area index (Figure 12). Wheat cultivars with lax or horizontal leaf posture can contribute efficiently to weed suppression by reducing light penetration through the crop stand to the surface of the weed leaves.

Eisele (1992) reported that efficient shading causes a decrease in dry-matter production of the weed *Viola arvensis*. Other investigations have revealed that the number of developed generative organs of weeds were reduced. Morphological features may thus serve as additional criteria for choosing wheat cultivars suitable for organic agriculture.

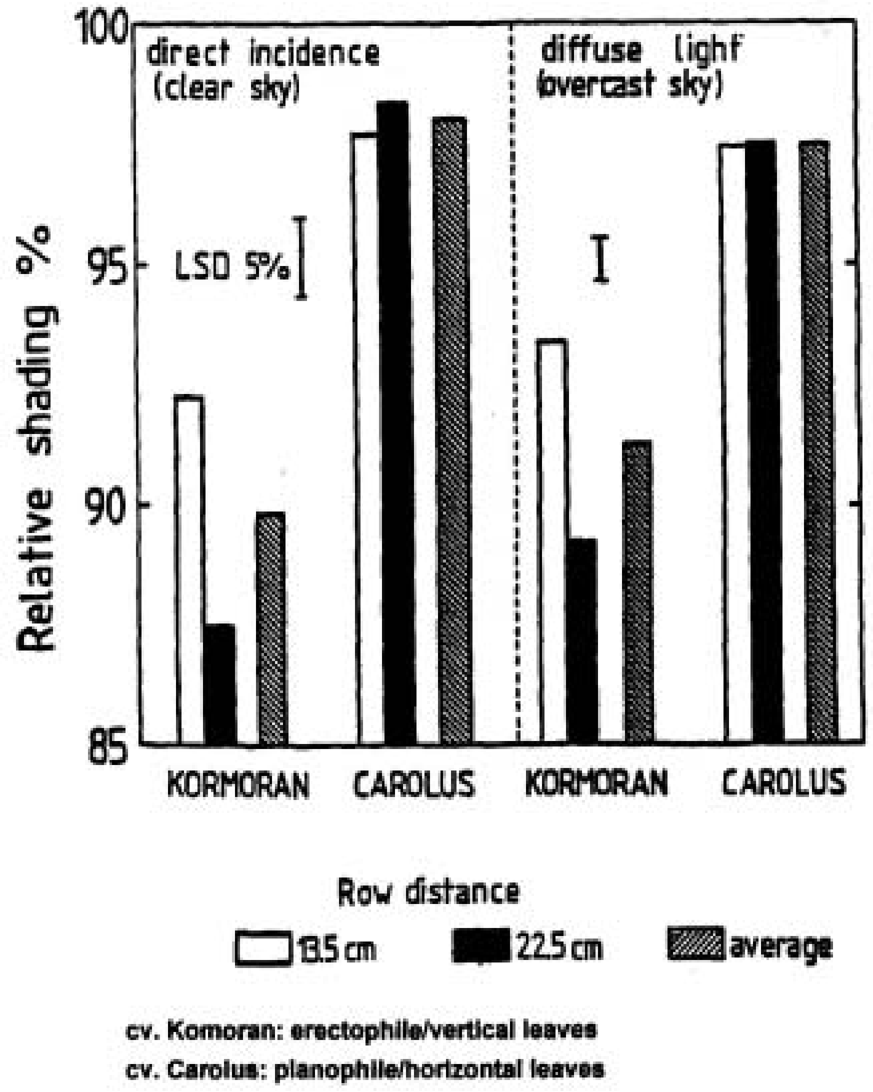


Figure 12. Relative Shading of Two Winter Wheat Cultivars (Kormoran: erectophile; Carolus: planophile) (Eisele and Köpke, 1990). "Relative Shading" is the Amount of Incoming Radiation Absorbed by the Stand.

Maintaining Fertility of Soil

As mentioned before, maintaining fertility of the soil is based on the reproduction of soil organic matter. The most efficient and sustainable way to reproduce the humus content is to apply composted farmyard manure. The need for sufficient quantities of farm-grown forage legumes for feeding, which combined with grass has a marked ability to reproduce soil organic matter, will close the nutrient cycle and allow for much of the legume-fixed nitrogen to return to the soil.

Therefore, cultivating fodder legumes combined with grasses plays a major role in organic crop rotations. This constitutes another argument in favor of mixed farms.

The importance of cattle kept on mixed farms is obvious. Ruminants will support a high level of soil fertility because of their need for forage (making use of pasture and forage plants) besides producing valuable organic manure; both ensure an effective humus reproduction.

However, on many farms there is a definite surplus of protein in the feeding ration of cattle. Thus, investigations were conducted to elucidate how and in what portions high-protein farm feed can be applied without impairing animal welfare (Sundrum, 1991).

Agriculture, Environment, and Quality

A farm that combines features of both crop and livestock farming creates a diversified agricultural production system. Diverse crop rotations with flowering forage legumes linked with the use of hedgerows, pastures with shade trees and other biotopes satisfy the needs of the wild flora and fauna. It will restore and preserve the stability and diversity of a given agroecosystem. The high quality of the environment in which food is produced is one of the major reasons why consumers buy organic produce. Apart from the appearance, technological suitability, and nutritional value ("product quality"), those subjective aspects are considered to have enlarged the definition of the general term "quality" by parameters of the so-called "process quality". These are in accord with the dominant aims of organic agriculture, i.e., teaching consumers to promote environmental quality through the purchase and consumption of organically-grown products.

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