SUSTAINABLE PRODUCTION IN WESTSIK'S CROP ROTATION EXPERIMENT

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Abstracts.*The best known and most remarkable example of continuous production in Hungary is the Westsik's crop rotation experiment established in 1929, which is still in use to study the effects of organic manure treatment, develop models and predict the likely effects of different cropping systems on soil properties and crop yields. Such experiments are costly to maintain, but their cost can easily be justified if they serve a number of different objectives and provide data to improve agricultural practice. The aim of this study is to examine the potential for sustainable agriculture in Hungary, and to draw attention to the importance of long-term field experiments in the study of agronomic sustainability.*

Current concerns about soil and water quality deterioration, the limited availability of fossil fuels, the loss of biodiversity, the viability of rural communities, and in general the sustainability of modern agricultural production practices, all point to the need to work out methods of sustainable agriculture. The goal of sustainable agriculture is to bring together people and resources, to promote an agriculture that is efficient, profitable, socially acceptable and environmentally sustainable for the indefinite future. The primary objective is to provide a model where the agricultural system and community are taken into account as a whole, in which agriculture is not separated from the natural ecosystem of a region. The most critical challenge is to consider the needs of agriculture and society, and to provide an educational environment for local inhabitants. In order to meet this challenge, we need research that examines the principles of sustainable agriculture.

In this respect, Westsik's crop rotation experiment provides data of immediate value to farmers concerning the applications of green, straw and farmyard manure. The experiment also provides a resource of yield, plant and soil data sets for scientific research, whether into plant and those soil processes which control soil fertility, or into the sustainability of production. Moreover, maintenance of Westsik's crop rotation experiment can also be used to illustrate the value of long-term field experiments.

Key words: Long-term crop rotation experiment, Sustainable agriculture

INRODUCTION

For many years, farmyard manure has been the key element in the maintenance of soil fertility (Johnston 1987, Keeney 1989). Composted manure increased its value, stabilised the nutrients and reduced the risk of environmental pollution. Composting provides more stable humus, which improves soil aeration, water infiltration and water holding capacity. The high temperature of the composting process destroys micro-organisms, the seeds of most weeds, and reduces water contents and total volume. In sustainable agriculture, crop and livestock systems should maximise for mutual support. Crop residue is an excellent feed for animals. Livestock manure can be composted and returned to the fields as a source of plant nutrient. Various crop and livestock components can be integrated to minimise the effects of weather-related adversities, as they can be crucial for the survival of a farm.

In sustainable agriculture, where the use of synthetic chemicals is reduced or eliminated, the action of soil micro-organisms becomes a major factor in nutrient cycling and also plant growth (Lazányi 2005). Sustainable agricultural cropping systems should reduce non-farm inputs to decrease environmental and health hazards associated with the use of agricultural chemicals and, at the same time, offset rising production costs and maintain soil fertility. The reduction of leguminous plants in the cropping system results not only from the availability of fertilisers, but also from the use of fossil energy as a source of power in agriculture. Because of these changes, farmers are no longer compelled to use one part of their land for the production of forage and grain for their draft animals. In Hungary many farms has eliminated all livestock from their operations, moving to cash grain enterprises and making them entirely dependent upon fertilisers and other chemicals. However, when nitrogen fertiliser is expensive or not available, the producers depend on the nitrogen fixed by legumes to maintain the nitrogen cycle and to improve the fertility of the soil. The quantity of nitrogen fixed varies greatly, from zero to several hundred kilograms per hectare, according to the soil type, structure, soil pH and nutrient content, temperature, water regimes and management of the legumes.

There are other benefits from using legumes in the crop rotation, but they are often disregarded because of the difficulties in quantifying them. The yields of cereals grown after a leguminous crop or in crop rotation are greater than those grown in monoculture, regardless of the amount of fertiliser applied. This response is often referred to as the leguminous effect in crop rotation. As additional nitrogen does not eliminate this yield difference, most of the response must be due to factors other than nitrogen availability. Crop rotation breaks the weed and insect cycles that often predominate in continuous cropping. Crop rotation also enhances soil structure and improves water regime. In this way, leguminous crops have long-term benefits in crop rotation, resulting in enhanced soil organic matter content, which not only improves nitrogen availability, but also improves soil structure, by reducing soil erosion and cultivation costs.

High input agriculture is relatively new in Hungary. Crop rotation was introduced in the last century, extensive use of chemical fertilisers and pesticides became important only in the second half of the 20th century. Agricultural production has become efficient per unit of human labour and per unit of land. However, when efficiency is measured against other criteria - capital, fossil fuel, energy, economic or social equity - the results are less clear. The crop rotation experiment established by Vilmos Westsik in 1929 offers an excellent possibility to study soil fertility management. The experiment, consisting of 15 treatments, makes it possible to study sustainability of agricultural production under different applications of green, straw and farmyard manure treatments, to study the ecological impact as well as economic aspects of different production methods.

MATERIAL AND METHODS

The treatments of the Westsik's crop rotation experiment were intended to increase soil fertility using different organic matter amendments, as the original purpose was to evaluate the cumulative effects of organic matters on light sandy soil with a long history of arable cropping (Westsik 1951, 1965). The F-1 block received no fertilisers and organic material treatment except the rye and potato roots and straw incorporated into the soil. The fallow in this block was green, and the plant material produced was ploughed into the soil. The F-2 block represents green manure treatment, where lupine was grown as a main crop and incorporated into the soil 4-5 weeks after flowering. The phosphorus and potassium fertilisers in this treatment were applied the previous autumn, before the lupine was sown. The F-3 represents lupine root manure treatment, where lupine was grown for grain and the total organic material, except for the grain, was incorporated into the soil. Blocks F-4 - F-7 represent straw manure treatments. In the F-4 block, rye straw was applied as mulch. In blocks F-6 and F-7, straw manure was fermented without nitrogen, and in block F-6, with nitrogen addition. The straw manure was incorporated into the soil 4-6 weeks before the sowing of rye.

F-8 is the only block with 4 main crops, where lupine grew twice in 4 years; once as a main crop produced for grain and once as a second crop produced after rye and before potato, for green manure. In the F-9 block, lupine was grown as a forage crop and harvested 2-3 weeks after flowering. Blocks F-10 and F-11 represent farmyard manure treatments without and with supplementary fertilisers, respectively. In block F-12, lupine is grown after a green forage crop and sown in May. This block is also evaluated with farmyard manure treatments to measure the comparative effects of the two treatments. Blocks F-13, F-14, F-15 represent green manure treatments, where lupine is grown as a second crop after rye and before potato. The F-15 block received no supplementary fertilisers. The difference between blocks F-13 and F-14 can be found in the time of the incorporation of green manure.

RESULTS AND DISCUSSIONS

Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Sustainable development wants to secure higher standards of living now and for future generations. An important recommendation of the United Nations Conference on Environment and Development held in Rio de Janeiro (1992), was that individual countries should prepare strategies and action plans to implement their part of the agreements (Lazányi 1997). Agenda 21 also lays great emphasis on the need for all sectors of society to participate in the formation of effective national strategies for sustainable development and emphasises international co-operation, in order to make progress on the problems affecting the environment of the whole world. The problem of agriculture is as old as agriculture itself. The core of the problem has always been soil erosion and loss of soil fertility (Várallyay 1995, Lazányi 1997). Today, when energy input into agricultural production has increased, a new aspect has been added to this problem, further exacerbating the old one.

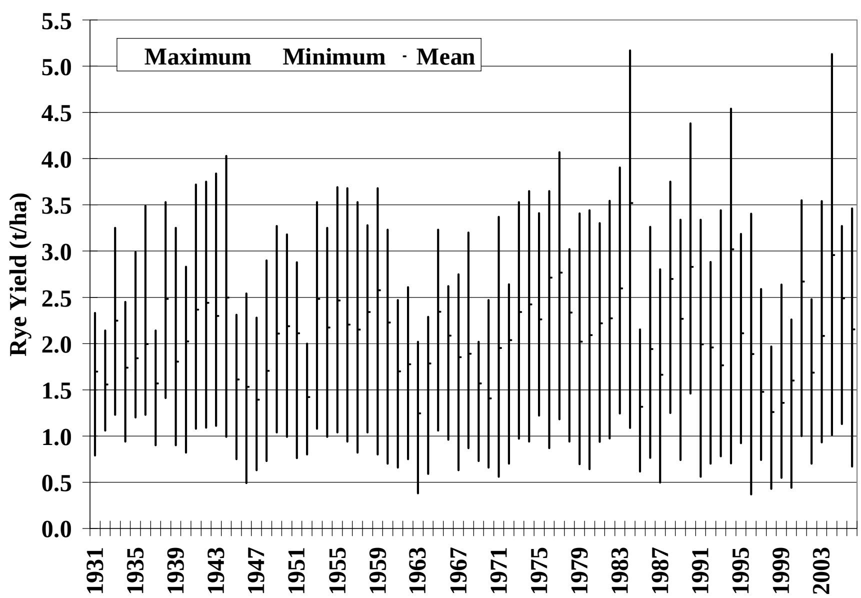

Figure 1: Rye yields in the crop rotation experiment

Minimum and maximum yields have varied considerably during the 75 years of the experiment. Analysing the average rye yields of different treatments, we can conclude that the poorest results were achieved in 1963, when the average of the various crop rotations was 1.23 ton/hectare. The highest yields were harvested in 1984, when the average was 3.15 ton/hectare (Figure 1). The difference is 188 %. The average yield of potato was the lowest in 1972, and the highest, 12 times as much, in 1991 (Figure 2). From the two-plant species, rye proved to be the more balanced in productivity. Its yield variations may be attributed primarily to climatic factors, while, in the case of potato, the variations can be closely related to changes in varieties or in the quality of propagation material. The first improvement in the average yields of potato occurred in the early 1940's, when a growing demand arose for potatoes as an important foodstuff. During and immediately after World War II, the average potato yields decreased in both crop rotation experiments, as well as nationally. The next increase was achieved in the second half of the 1950's, and was related to the development in potato research and in seed potato production at the Research Institute in Nyíregyháza.

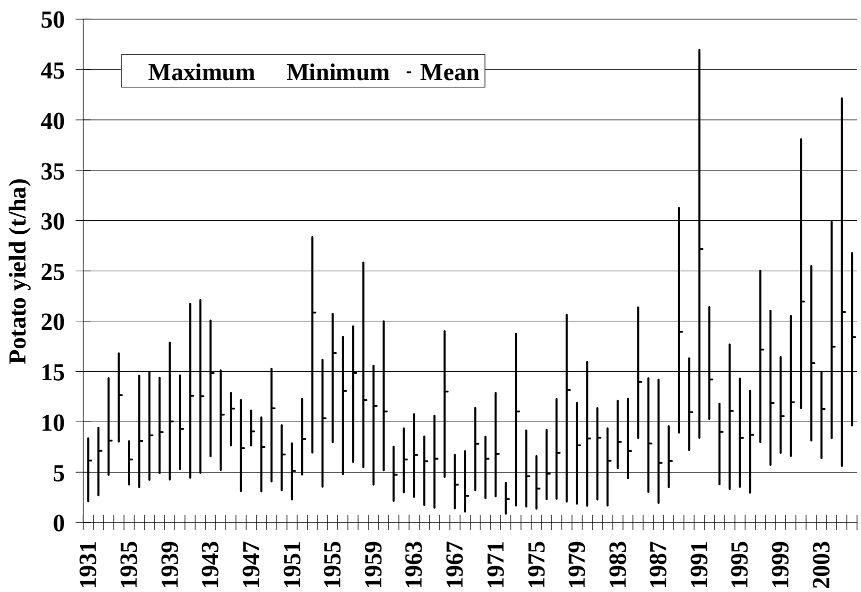

Figure 2: Potato yield in the crop rotation experiment

In Westsik's crop rotation experiments, the average yields of potato increased again in the late 1980's and early 1990's. This success could be explained by the breeding of the virus resistant Boro variety and its involvement in the experiments. Similar yield increases could be noticed during the analysis of Broadbulk's experiments in Rothamsted, where the yields of wheat were doubled within only a few years, by changing the variety and applying pesticides (Johnston 1969, Johnston and Poulton, 1980, Garner and Dyke 1989). Comparing Figures 1 and 2, it is difficult to show any correlation between the yield trends of rye and potato; however, if we express potato yields as a function of the average rye yields, a very strong correlation can be revealed, except for crop rotations F-2, F-3 and F-9. Average potato yields can be characterised with the linear regression: $y = 0.79 + 4.21x$. The correlation coefficient is

r^2= 0.9198. This means that there is no significant difference in the effect of various crop rotations on the yields of rye and potato. Control treatments, where fertilisers were not used in addition to the occasional organic matter management, are on the lower part of the curve. The deviation of F-2, F-3 and F-9 treatments from the regression line means that lupine main crop has different effects on the average yields of potato and rye, independently of the fact whether lupine is grown for green fodder, green manure or seed. Vilmos Westsik, who explained it with the infection of Fusarium species, which are able to decrease the yields of both lupine and potato considerably, described this phenomenon earlier. Furthermore, we have to add that lupine was ploughed under directly before rye, so it was this culture that benefited from the favourable effect of organic matter mineralization. The effects of treatments on potato yield were also expressed as a function of control treatments to reduce variation between years. In this case, the mean value of F-1, F-7, F-10 and F-15 was calculated for each year and studied as to how the increasing mean value effects the value of selected treatments.

CONCLUSIONS

Agriculture in developed countries has moved progressively from traditional practices relying on natural fertility and the regenerative power of the soil, to practices depending on high levels of inorganic fertilisers, the intensive use of chemicals for pest control, and crops produced mainly under monoculture (Lockeretz 1988, Carter 1989). According to Edwards (1987), alternative agriculture is a farming practice avoiding, or at least minimising, the use of non-renewable production inputs, such as fertilisers and pesticides. Lowrance at al. (1986) defined sustainable agriculture as agriculture which does not deplete soil or people.

Sustainable agriculture is both a philosophy and a system of farming. It is rooted in a set of values that reflect an awareness of social and ecological realities. It emphasises management which works with natural processes to conserve all resources and minimise waste, as well as environmental damage, while maintaining or improving the profitability of production based on nutrient and water cycles, energy flows, beneficial soil organisms and natural pest controls. Sustainable systems also aim at ensuring the well being of rural communities, and producing food which is nutritious and not contaminated with products which might be harmful for the ecosystem. A sustainable farming system seeks to reduce or entirely avoid the use of synthetic fertilisers, pesticides, growth regulators and other agricultural chemicals. The system relies on crop rotation, crop residues, animal manure, legume crops and green manure as organic matter, conservation tillage and non-chemical pest control, to maintain the fertility of soil and control insects, weeds and diseases.

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