Evaluation of Major Agrotechnical Factors in Sustainable Crop Production

L. RUZSÁNYI, P. PEPÓ and M. SÁRVÁRI

Department of Crop Production, University of Agricultural Sciences, Debrecen (Hungary)

Hungarian crop production was characterized by dynamic development in the seventies and eighties. The technical conditions were improved, the introduction of new varieties was accelerated, only good- or high-quality varieties/hybrids were grown, the adaptation of new farming techniques was carried out by the agricultural companies and the amount of chemicals used in agriculture was also increased. This intensive phase of crop production has yielded advantageous results and disadvantageous consequences as well. The increases in yield and in commodity stocks and the enhanced exploitation of means of production are advantageous results, but the absoluteness of quantity production and the lack of energy- and cost-saving are considered as undesirable effects. The endangerment and deterioration of the environment are also harmful consequences. The modification of the climate and the stereotyped farming system have increased (and will possibly further increase) the climatic sensitivity of crop production and, besides incorrect farming techniques and other human interpositions causing unfavourable changes in the soil, have affected Hungarian agriculture.

When setting up objectives for the future the above-mentioned problems and the changed requirements of agriculture should be taken into consideration.

The changes in ownership and the establishment of small-, medium- and large-scale farms affect or will affect the crop production system. Regarding these changes the objectives of alternative and sustainable crop production are complex. The idea of diversifying the relatively simple former crop production system is gradually gaining ground. The transformation of the "industry-like" crop production technologies, which were based on high energy and chemicals use, will become inevitable, resulting in an improved input/output ratio of production. Production methods will have to meet the requirements of environmental protection and the quality standards of crop products to a greater extent. The main objective of production will be profit-maximization instead of quantity production.

The above-mentioned yield increasing trend was focused on yield and yield-increase, so this traditional crop production system needed more and more inputs originating from industrial sectors. This means that during the last 30-40 years, agriculture in the developed countries (which should include Hungary during the last 10-20 years) has become more intensive, mechanized, energy- and chemical-consuming. Although these developments have resulted in large increases in productivity, they have often been accompanied by detrimental side-effects of an environmental and social nature. This development in crop production has decreased the biological, agronomic and economic efficiency and has caused a lot of harmful effects in current agricultural practice, including the following (focusing attention on crop production):

- it damages soil structure and soil fertility;
- it decreases crop production diversity;
- it relies less and less on the natural resources of crop production;
- it increases the genetic vulnerability of crop production;
- it is an energy- and chemical-intensive system;
- it damages the environment;
- it creates potential health hazards in food;
- it has brought about a reduction in food quality;
- it is economically costly to farmers and society.

These problems have resulted in the agricultural policy agenda in West-European and North-American countries being increasingly influenced by concern for various new alternative agricultural production systems (low input, sustainable, ecological, organic, etc.) during the past two decades. Governments are becoming increasingly sensitive to the environmental and human-health risks associated with current modes of agricultural production. They therefore support environmentally-sound crop production both in research and practice.

A different situation is met with in crop production in Hungary. Yields and yield-surplusses are still important goals in Hungarian crop production, but environmental pollution, the use of natural resources (to become self-sustaining) and profitable production (to be economically viable) are growing more and more important nowadays. We are at the beginning of this process of change and probably these changes will be very gradual. By presenting the results of long-term experiments, it is hoped to promote this process of change. It is intended to show how harmful effects can be reduced, how the biological-economic efficiency of traditional crop production can gradually be increased through study; and how the interactions between the genetic, ecological and agrotechnical factors can be exploited.

Elements of Water-saving Agricultural Technologies

One of the most important objectives of sustainable crop production, especially on the territory east of the river Tisza, is to work out and develop water-saving elements of crop production. Water-saving technologies can be used where the soil stores more than 100-150 mm plant-available water in the fertile layer or where the water content can be made available by loosening the soil (Figure 1).

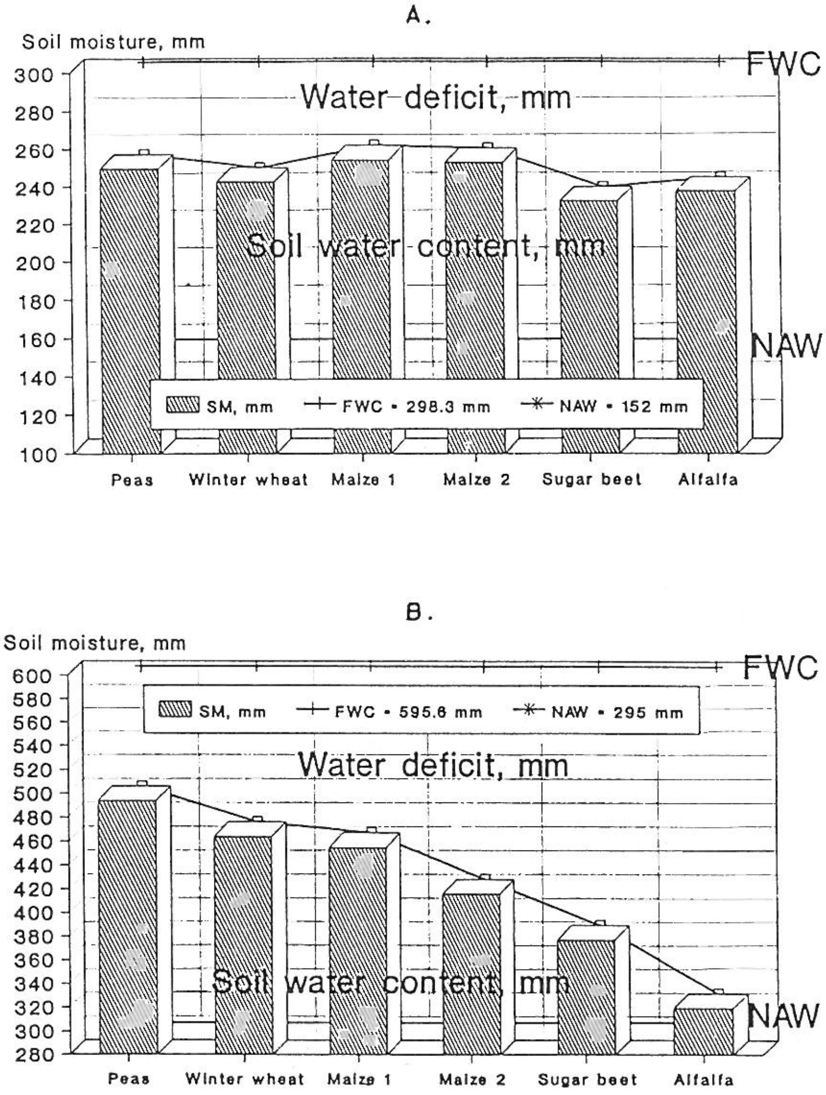

Figure 1

Soil water content and water deficit (mm) after different forecrops in spring time in the 0-100 cm (A) and 0-200 cm (B) soil layers.

Crops respond differently to water deficiency. Their responses are influenced (besides their morphological and physiological features) by the length of the growing season and the date and length of the period when water absorption is at its peak. Consequently, besides the shallow-rooted crops (such as pea, potato, tobacco, vegetables, etc.), the deeply-rooted maize and sugar beet are also sensitive to water deficiency. Furthermore, crops grown for seed are also greatly sensitive. Cereals, which are moderately-rooted and harvested before the warm, dry summer months are less sensitive.

According to an evaluation of crop production technologies from the water-saving point of view, appropriate *crop rotation* and the previous crop are of outstanding importance. Research data show 25-110 mm difference in soil water content in the 0-200 cm layer due to different crop rotations. It is important to note from the point of view of adaptation and utilization that this difference in soil water content emerges mainly below a depth of 100 cm. Therefore, the favourable effects of crop rotation and the previous crop can be of use mainly on soils with good water management and a deep fertile layer.

The second most important element of crop production from the water-saving point of view is *fertilizer application*. Improper fertilizer application increases the water absorption and transpiration of plant species by 20-60 mm. On the other hand, fertilizer deficiency makes the water efficiency worse. Therefore, it is very important to know that an interaction exists between soil water content and fertilizer rate and to harmonize the two factors.

Predicting the water supply for plants on areas where the amount of precipitation is very changeable is impossible. However, if the water management and water capacity of the soil are good, it is possible (if the probability figure is valid) to estimate the water supply for a few plant species in the growing season on the basis of soil water content in spring.

A knowledge of the soil water content in spring helps in the determination of adequate *plant density,* decreasing the drought sensitivity and yield loss of crops sensitive to water deficiency (Figure 2).

Water-saving soil cultivation techniques have been known for a long time. Unfortunately, these techniques are hardly used in practice. According to our observations stubbling, if carried out expertly and without delay, can increase the soil water content by 7-15 mm in the topmost layer of the soil. The increased summer water content of the soil creates favourable conditions for soil life and this will result in a good state of the soil with improved water management and will make summer soil cultivation possible.

In the intensive phase of crop production the effective *control of weeds and diseases* lead to water saving and improved water efficiency. Weeds are aggressive water robbers; moreover, crops cannot compete with their repressive and shading effects. The water efficiency of plant populations suffering from diseases and pests decreases, as does their water absorption, inducing further yield loss.

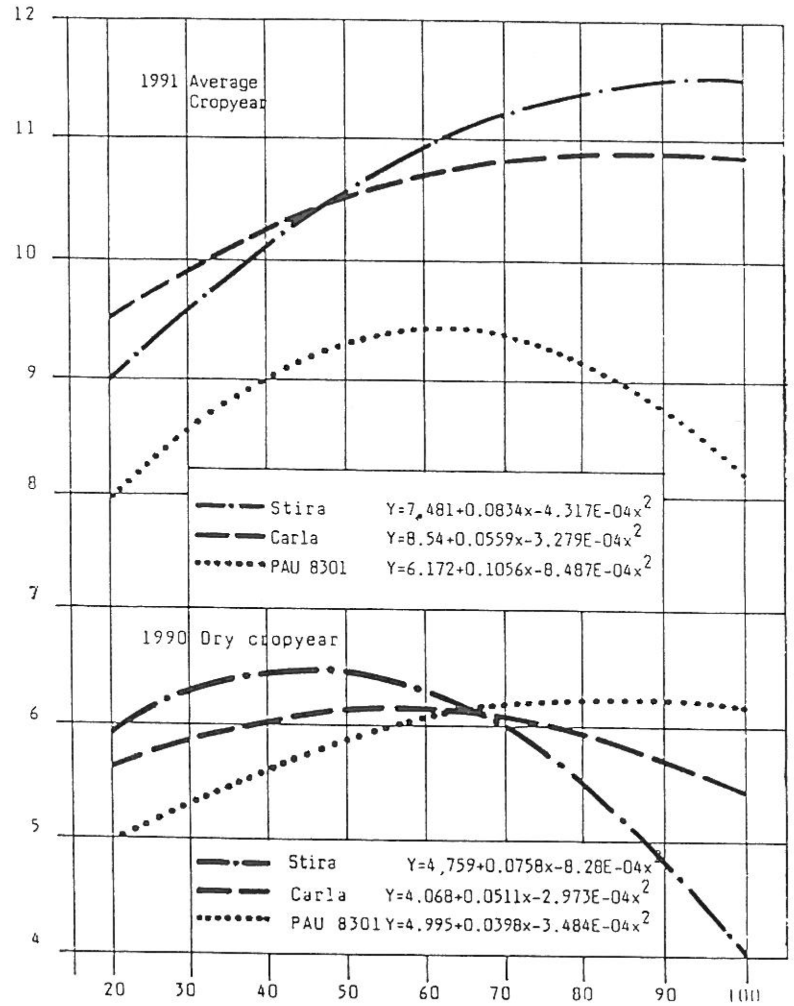

Figure 2
Optimum plant density of maize in different cropyears (FAO, 300, 1990-1991),
Horizontal axis: Plant density, 1000/ha. Vertical axis: Yield, t/ha.

Varieties

The varieties which provide the biological basis for crop production play a very important role in increasing the efficiency of crop production. During the last decades the variety assortment of the most important arable crops has increased to a large extent. But at the same time research data show that great reserves still exist regarding the exploitation of the biological basis. Economic results and efficiency can be increased by finding out more about the productivity, adaptability, stress tolerance, nutrient and water utilization, response to high population densities and other agronomic features of varieties/hybrids without investing additional energy and chemicals. Varieties are very different regarding their utilization of natural nutrient sources and their response to different fertilizer rates.

New types of responses to different fertilizer rates (unpublished so far in the Hungarian and international literature) have been determined both in the case of winter wheat and maize on the basis of long-term experiments. A knowledge of these types contributes to the planning and practical application of economical, environment-friendly fertilization (Figure 3).

The response of varieties/hybrids to irrigation also differs. The results of winter wheat varieties in long-term experiments have presented a good basis for the selection of varieties recommended for irrigated crop production.

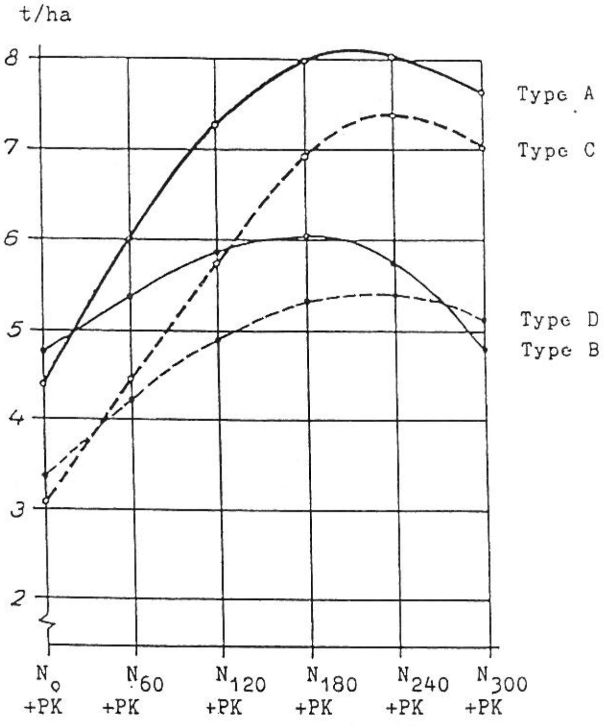

Figure 3
Types of winter wheat on the strength of their fertilizer response

Fertilizer application

Fertilizer application is a very expensive but at the same time a very effective element of crop production technology for increasing yield and improving its quality. Besides the above-mentioned biological factors, the required rate of fertilizer and the fertilizer utilization of an arable crop depend to a high extent on the ecological (weather, soil) and agrotechnical factors, too. Among the ecological factors it is the soil which determines the optimal fertilizer rate and the efficiency of its utilization. This effect is smaller in the case of winter wheat and greater in the case of maize. In the case of maize the optimum rate of N fertilizer is 140-150 kg/ha on meadow soil and 60-80 kg/ha on chernozem. In the case of winter wheat the figures are 100-150 kg/ha on meadow soil and 120-130 kg/ha on chernozem.

The previous crop affects the amount of fertilizer applied to the soil and the fertilizer utilization both in the case of winter wheat and maize production. When winter wheat is grown after leguminous crops only half the amount of fertilizer is required compared to when it is grown after maize. Winter wheat requires higher fertilizer rates when grown after maize. By the application of higher fertilizer rates the undesirable effects of maize can be eliminated and more favourable conditions can be created which are well utilized by winter wheat. The highest fertilizer rates (125-140 kg/ha or 130-160 kg/ha, respectively) are required on both chernozem and meadow soil when maize is grown continuously (Table 1).

The amount of fertilizer applied to the soil can be reduced after a good previous crop (60-80 kg/ha or 120-140 kg/ha, respectively); especially when the favourable effect of the previous crop is enhanced by a good crop rotation it can be reduced substantially (60 kg/ha or 90-100 kg/ha, respectively).

Table 1

Effect of soil type and forecrops on the nitrogen demand of winter wheat (kg/ha) and the effect of soil type and crop rotation on the nitrogen demand of maize (kg/ha)

Forecrops / crop rotation	Chernozem soil	Meadow soil
Forecrops		
Pulses	50-80	50-90
Maize, sunflower	100-120	130-150
Winter wheat	130-150	150-160
Crop rotation		
Monoculture	125-140	130-160
Biculture (maize - winter wheat)	60-80	120-140
Triculture (maize-winter wheat-pulses)	60	90-100

As can be seen from the data in this table, soil characters are very important ecological factors in determining the fertilizer demand of crops, but the cropyear is also an important modifying ecological factor.

The results proved that there was a special interaction between cropyear and forecrop on the efficiency of fertilization in winter wheat. The best fertilization efficiency was obtained in a favourable cropyear after a good forecrop.

The effectiveness of a fertilizer is dependent on its substitution (rate of the major nutrients) and on the method by which it is applied to the soil. In maize trials conducted on meadow soil strong interactions were recorded between N-P-K fertilizers. Without K fertilizer, increased rates of N and P fertilizers did not increase the yield, but when 100 kg/ha K fertilizer was added the yield increased by 3-4 tonnes/ha (Figure 4).

Choosing adequate N rates in the growing season and applying them to the soil in good time are of great importance in avoiding NO_3 leaching, thus, improving efficiency and protecting the environment. If possible the smallest

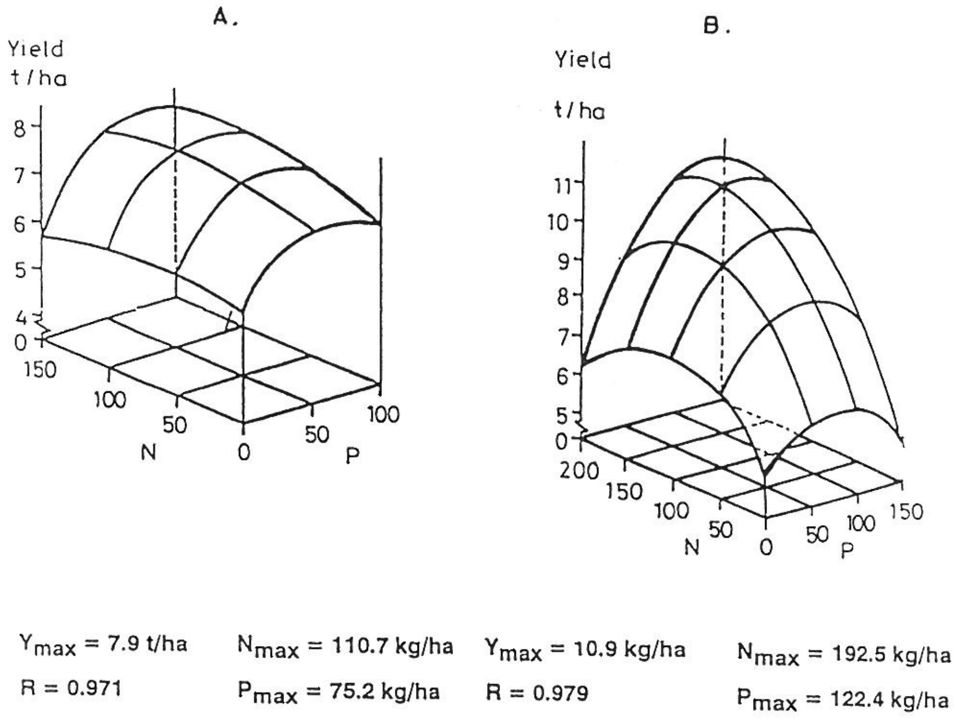

Figure 4

Response surfaces of a maize monoculture to N, P_2O_5 and K_2O (dry year)
A. Without K fertilizer. B. K_{100} kg/ha

amount of N fertilizer should be applied as basal autumn dressing. After a good previous crop and if the soil is of good quality, N application can be omitted and in spring only small amounts of N fertilizer should be used. Figure 5 shows

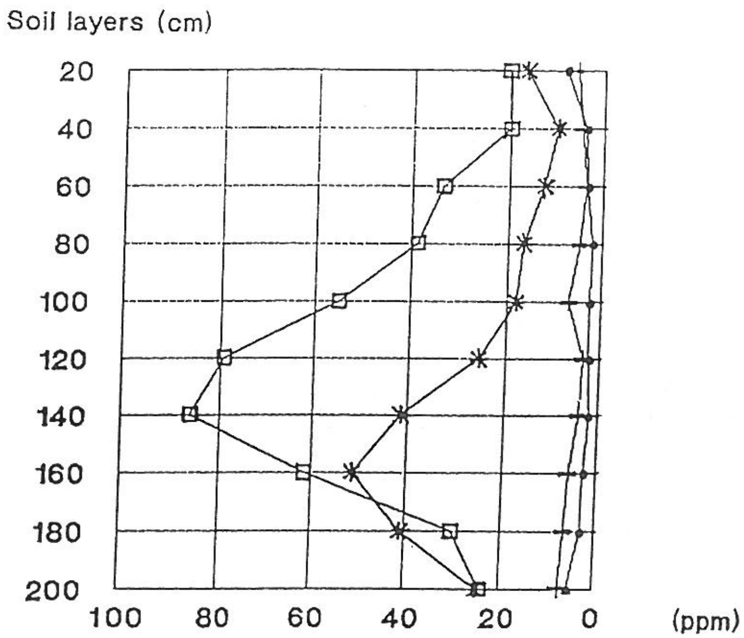

Figure 5
Effect of N fertilizer on the NO_3-content of chernozem soil (ppm), 1990
•: Control; +: N_{60} + PK; *: N_{180} + PK; □: N_{300} + PK

the NO_3 profile in chernozem soil after the harvest of wheat. If the applied N rates are more than the crop demand in the vegetation period, the NO_3 content of the soil (80-180 cm soil layers) will increase greatly and this NO_3 content will be leached into deeper soil layers and the groundwater (Figure 5).