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Cumulative yield surplus of grain crops as an effect of NPK-fertilisation studied in long-term field experiments

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The nutrient uptake of plants is influenced by many different factors (site conditions, first of all soil properties like organic matter content, nutrient status, acidity, water supply etc.). Bergman (1993), Cerling (1971), Kádár (1992), Mengel and Kirkby (1987) and others studied the nutritional disturbances of plants thoroughly and developed useful diagnostic methods. Their scientific achievements greatly contributed to the development of this discipline.

However, the effect of NPK-nutrients on plant productivity does not always manifest itself in marked differences in field fertilisation experiments of 1-2 years. Fertiliser responses of plants can be assessed more reliably in long-term fertilisation trials, since the nutrient status of the experimental soils becomes stable only after several years' fertilisation (Sarkadi 1975; Debreczeni and Debreczeni 1994; Körschens 1994; Powlson 1994) and others studied the long-term effect of fertilisation on crop productivity providing meaningful information to our understanding of important relationships.

The objective of our study was to investigate the cumulative yield differences of winter wheat and maize at four different sites of the National Long-term Field Fertilisation Trials after 28 years (7 crop rotations) as an effect of 10 different NPK fertilisation treatments.

Materials and Methods

In 1967 long-term fertilisation field trials were set up with four-year crop rotations of winter wheat – maize – maize - winter wheat biculture and with maize monoculture at four experimental sites representing different agro-ecological regions of Hungary. Table 1 shows the main soil characteristics at the different experimental sites. Twenty fertiliser treatments were uniformly applied on small plots (50 m^2) at all sites in every year. One half of these treatments included different combinations of increasing NP-doses. The other half of the fertilisation treatments consisted of different combinations of NPK-doses. In the present study, the effect of NPK-treatments was evaluated.

Fertiliser treatments:

Nitrogen: 0-50-100-150 kg N/ha/year (coded: N_0-N_1-N_2-N_3)
Phosphorus: 0-50-100 kg P_2O_5/ha/year (coded: P_0-P_1-P_2)
Potassium: 0-100 kg K_2O/ha/year (coded: K_0-K_1)

Evaluation of the yield data:

The grain yields of ten different NPK fertilisation treatments were averaged for each of the 4-year crop rotations and these averages were regarded as basic data. In the figures, these averages were plotted as zero points (zero line of the system of co-ordinates). As compared to these basic data, the positive or negative yield differences were calculated and added for each of the different fertilisation treatments and in each crop rotation (positive or negative cumulative yield differences). Then the cumulative yield differences were plotted against the basic data for each of the 7 crop rotations of the fertilisation experiment. The plotting of the increasing yield surpluses and yield losses resulted in a fan shape. The curves of the cumulative yield losses caused by the stress effect of the nutrient deficient treatments, took place under the abscissa, while the curves of the cumulative yield surpluses gained by the yield increasing treatments, took place above the abscissa.

Results and Discussion

Due to limited space, results are shown only for two sites. Figures 1 and 2 show the effect of NPK treatment combinations on the cumulative yield differences of winter wheat and

Table 1. Main soil characteristics of the control plots, long-term annual precipitation and soil types at the sites of the long-term fertilisation trials.

Site	Soil type (USDA taxonomy)	Clay (%)	pH (KCl)	Humus (%)	Precipitation (mm)
Bicsérd	Luvic phaeosem	27	5.7	1.9	661
Hajdúböszörmény	Luvic phaeosem	35	6.1	3.5	585
Iregszemcse	Calcaric phaeosem	18	7.2	2.4	619
Putnok	Ochric phaeosem	24	4.9	2.0	581

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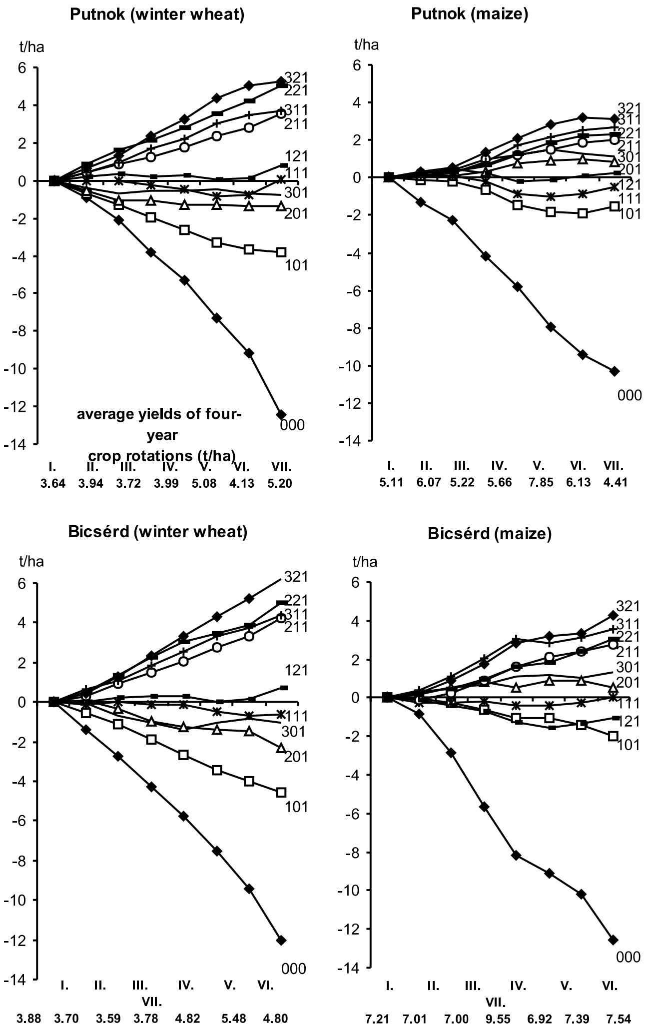

Figure 1. Cumulative yield differences in maize – winter wheat biculture.

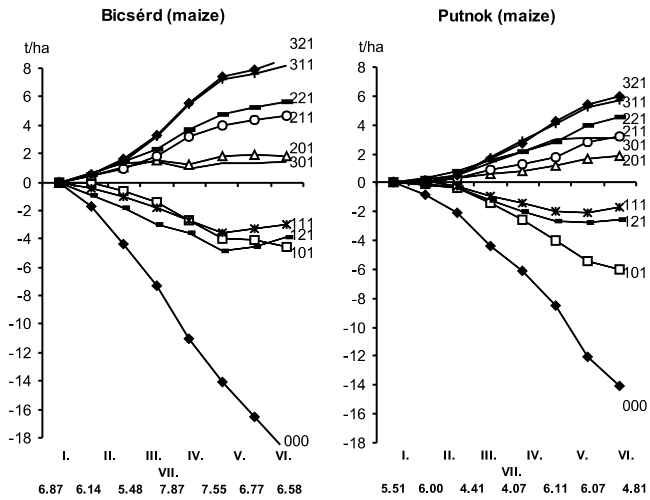

Figure 2. Cumulative yield differences in maize monoculture.

maize in maize - winter wheat biculture and maize monoculture, respectively. The applied way of plotting reflects the nutrient responses very well. One part of the different combinations of NPK-doses proved to be beneficial (by balanced nutrient supply), while the other part effected a nutrient stress (by nutrient deficiency or nutrient surplus) for the plants.

The figures show that the many years' fertilisation effect was considerably different with the crops tested. Winter wheat responded to P-deficiency more markedly than maize grown in crop rotation. The curves obtained for P-deficient treatments demonstrated the yield decreasing effect of P-deficiency well: They took place under the abscissa in most cases. Higher N-doses could not counteract the effect of P-stress either. The nutrient responses of maize grown in monoculture were similar to those of winter wheat.

To sum up, the following can be concluded. The cumulative yield differences reflect the effect of long-term fertilisation better than the comparison of yearly yield data. The nutrient response of maize was much different in monoculture and in winter wheat-maize biculture. The differences observed in the long-term fertilisation effect between the different soil types could help the home fertiliser recommendation system to develop site-specific fertilisation strategies.

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