EFFECT OF FARMYARD MANURE AND MINERAL FERTILISER ON THE YIELD AND YIELD COMPONENTS OF MAIZE IN A LONG-TERM MONOCULTURE EXPERIMENT IN MARTONVÁSÁR

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In a long-term experiment on continuous maize set up by Béla Győrffy in 1959, changes in biotic and abiotic environmental factors were studied over time. The long-term effects and stability of the cropping systems, the year effects and the genotype × environment interactions were analysed. The original aim of the experiment was to determine whether the NPK nutrients in farmyard manure could be replaced partially or entirely by inorganic NPK fertiliser. In the present experiment the effect of farmyard manure, mineral fertiliser and the year effect on yield and yield stability were studied for four years (2005–2008). Various levels of farmyard manure and mineral fertiliser induced significant changes in the yield, harvest index, thousand-kernel mass, grain number per ear and grain protein content.

Key words: maize, long-term experiment, yield, thousand-kernel mass, grain protein content

Introduction

The long-term continuous maize experiment set up in 1958 includes various nutrient levels, applying equal quantities of active agents in the form of farmyard manure (FYM), FYM + mineral fertiliser and mineral fertiliser. The original aim of the experiment was to determine whether the NPK nutrients in farmyard manure could be replaced partially or entirely by inorganic NPK fertiliser (Berzsenyi and Lap, 2004). It was found that the highest yields were obtained in treatments where half or all the active agent content of FYM was replaced by mineral fertiliser. This suggested that the joint application of FYM and fertiliser was better than that of FYM alone, and was close to, though not better than that of fertiliser alone (Győrffy, 1979; Árendás and Csathó, 2002). Soil fertility in continuous maize can be improved without FYM by the regular application of fertiliser. The long-term mineral fertilisation experiments carried out by Győrffy (1979) clearly illustrated that rising fertiliser doses reached an optimum over time. If nitrogen supplies are satisfactory, it is possible to maintain optimum values of leaf area index and biomass duration, which are favourable for the flow of assimilates into the grain yield (Berzsenyi et al., 2007). Among the yield components of maize, optimum nitrogen supplies made an important contribution to the kernel number per ear, but had little effect on the thousand-kernel mass (Bocz and Nagy, 1981). Grain number was particularly closely correlated with the grain yield under stressed conditions (Egli, 1998). The aim of the studies was to use the long-term experiment on equivalent nutrient quantities in order to obtain data on the extent to which various levels of FYM and mineral fertiliser influence the grain yield and yield components of maize plants grown in a monoculture in years with different weather conditions.

Materials and methods

The long-term experiment was set up on partially eroded chernozem soil with forest residues in Martonvásár in a Latin square design. The treatments were as follows: 1. Control; 2. 35 t ha^{-1} FYM; 3. 17.5 t ha^{-1} FYM + $N_{1/2}P_{1/2}K_{1/2}$ mineral fertiliser; 4. $N_1P_1K_1$ mineral fertiliser; 5. 70 t ha^{-1} FYM; 6. 35 t ha^{-1} FYM + $N_1P_1K_1$ mineral fertiliser; 7. $N_2P_2K_2$ mineral fertiliser. The active agent quantities (kg ha^{-1}) applied each year were N: 66, P_2O_5: 38, K_2O: 75 in treatments 2–4, and N: 132, P_2O_5: 76, K_2O: 150 in treatments 5–7. The indicator plant was the early maturing FAO 380 hybrid Norma SC, which was bred in Martonvásár and has excellent drought tolerance. The years 2005–2008 were included in the present studies. In 2005 and 2008 the weather was extremely favourable for maize, as regards both rainfall and temperature. In 2006 only half the usual rainfall quantity fell during the sowing period, resulting in yield losses. In 2007 the weather was extremely hot, with 58 very hot days and uneven rainfall distribution, leading to poor fertilisation and very high yield losses. The total rainfall during the vegetation period (Apr.–Sept.) was 525 mm in 2005, 246 mm in 2006, 315 mm in 2007 and 483 mm in 2008.

The effect of fertiliser treatments on yield components (kernel number, thousand-kernel mass) was determined from data for five sample ears per plot. The kernel protein content was measured after grinding using an Inframatic 8600 NIR analyser. Kernel yields were converted to 15% moisture content. N supplies to the canopy were estimated after flowering using a hand-held SPAD-502 chlorophyll meter. It was clearly demonstrated by Schepers et al. (1992) that there is a close correlation between SPAD values and plant N supplies. Measurements were made on the leaf next to the ear, for twenty plants per plot. The harvest index (ratio of grain yield to total aboveground biological yield) was recorded at physiological maturity on three sample plants per plot.

The experimental data were subjected to biometric analysis using the method of Sváb (1973). The data were processed using the MSTAT-C programs.

Results and discussion

In all four years the yield was significantly the lowest in the control treatment. In 2005, 2006 and 2008 similar tendencies were observed for the yields in the various treatments, with the highest yields (9.8, 7.7 and 9.7 t ha^{-1}) in treatment 7, where the whole of the 70 t ha^{-1} FYM dose was replaced by NPK fertiliser, while in 2007 treatment 5 (70 t ha^{-1} FYM) gave the highest yield (3.4 t ha^{-1}), indicating the positive effect of FYM in dry years. In 2007 the yield obtained with a high rate of mineral fertiliser (2.4 t ha^{-1}) was not significantly different from the control yield, demonstrating the yield-limiting effect of severe rainfall deficiency. In years with favourable rainfall supplies, the effect of FYM + NPK (treatments 3 and 6) on the yield was significantly better than that of FYM alone (treatments 2 and 5), though it did not equal that of the same NPK active agent quantity applied in the form of mineral fertiliser (treatments 4 and 7). The effect of the treatments on the grain yield of maize between 2005 and 2008 is illustrated in Table 1.

The effect of the treatments on the protein content of the grain was similar to the yield response (Table 1). The highest grain protein content was obtained with high rates of NPK fertiliser in favourable years (treatment 7: 8.96–9.70%), while the lowest values were recorded in the control and at low rates of application (6.00–7.58%). In the dry year an outstandingly high grain protein content was measured at the high rate of NPK mineral fertilisation (9.95%), while there were no significant differences between the other treatments. The lowest grain protein content was observed in treatments where only FYM was applied (treatments 2 and 5; 7.49–7.55%).

Table 1. Effect of fertiliser treatments on the grain yield, grain protein content and harvest index in different years (2005–2008)

Treat-ment	Grain yield (t ha^{-1})				Grain protein content (%)				Harvest index (%)			
	2005	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**
1.	4.26	3.99	2.49	5.70	6.16	6.44	7.89	7.59	48.81	43.76	42.20	49.31
2.	5.96	4.88	3.01	7.84	6.01	6.78	7.55	7.76	50.94	47.84	42.06	52.03
3.	7.67	6.01	3.18	8.58	6.89	7.59	7.99	8.37	54.61	54.07	45.63	56.20
4.	7.97	6.28	3.11	9.71	7.35	7.65	7.60	8.80	55.24	53.76	43.25	57.16
5.	6.81	5.17	3.35	8.30	6.76	7.56	7.49	8.29	53.57	49.00	45.38	55.45
6.	9.22	6.26	2.44	8.99	8.94	8.61	7.58	9.24	55.18	49.49	42.23	56.07
7.	9.82	7.69	2.32	9.73	9.36	8.96	9.95	9.70	55.07	53.12	41.98	56.72
$LSD_{5\%}$	0.94	1.19	0.57	1.06	0.57	0.52	0.45	0.39	2.88	3.82	4.35	0.91

Treatments: 1. Control; 2. 35 t ha^{-1} FYM; 3. 17.5 t ha^{-1} FYM + $N_{1/2}P_{1/2}K_{1/2}$ mineral fertiliser; 4. $N_1P_1K_1$ mineral fertiliser; 5. 70 t ha^{-1} FYM; 6. 35 t ha^{-1} FYM + $N_1P_1K_1$ mineral fertiliser; 7. $N_2P_2K_2$ mineral fertiliser.

The harvest index (HI) gave a good reflection of both the fertiliser effect and the year effect (Table 1). This index (the ratio of grain yield to biomass production) was lowest in the control treatment, averaged over the years (46.0%), significantly rising in the 2nd treatment (48.2%) and again in treatments 5. 6 and 7, which were statistically at par with each other (50.9, 50.7 and 51.7%, respectively). Averaged over the years, the highest HI was obtained in treatments 3 and 4 (52.6 and 52.4%). Averaged over the treatments, the highest HI was recorded in wet years (2005: 53.3%, 2008: 54.7%) with significantly lower values in 2006 (50.2%) and 2007 (43.2%). The most favourable HI values (55.2 and 56.7%) were found at high rates of NPK fertilisation in wet years, and in the FYM treatments in dry years (54.6 and 45.6%).

Of all the yield components, the kernel number had the most decisive effect on the maize grain yield. Optimum N supplies and the year effect made a substantial contribution to the kernel number per ear, while they had less influence on thousand-kernel mass. The effect of the treatments on the thousand-kernel mass and kernel number of maize, averaged over the four years, is illustrated in Figure 1. In the dry year of 2007 there was a significant decrease in the kernel number per ear, averaged over the seven treatments, compared with the wet years. Averaged over the four years, there was no significant difference between treatments 3, 6 and 7.

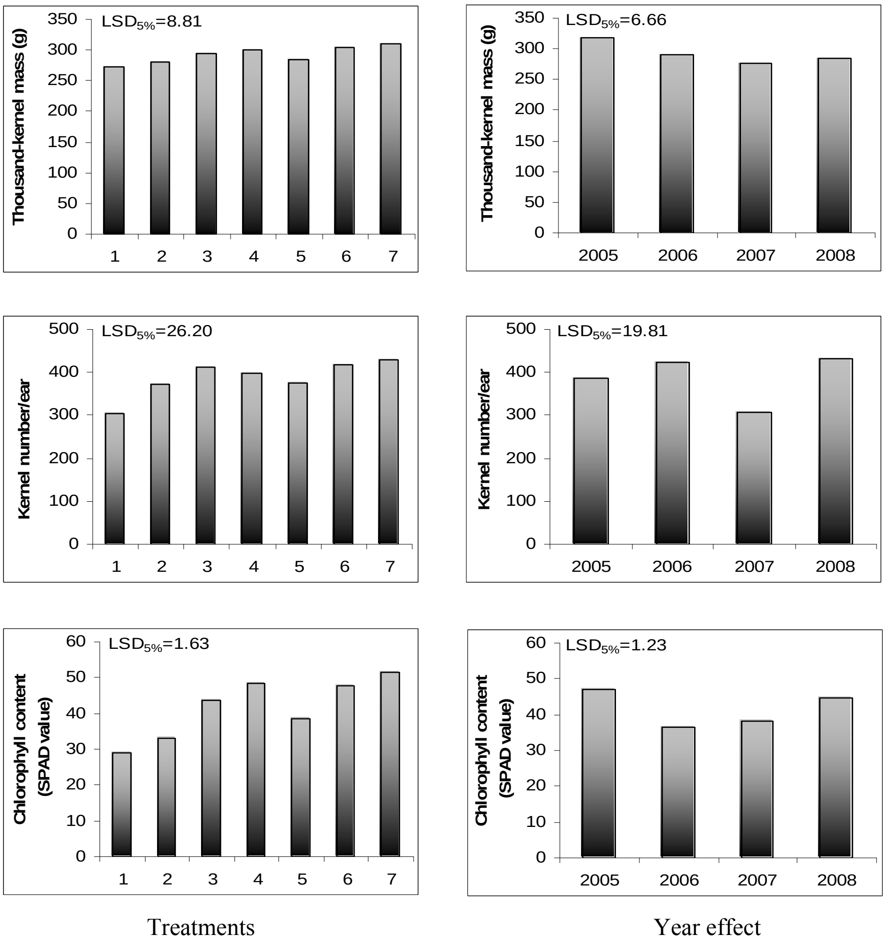

Fig. 1. Effect of fertiliser treatments averaged over the four years, and effect of year, averaged over treatments, on the thousand-kernel mass, kernel number and chlorophyll content
For fertiliser treatments, see Table 1.

The thousand-kernel mass was significantly the highest in 2005, averaged over the treatments. There was no significant difference between the values recorded in 2006 and 2008, while the significantly lowest value was observed in 2007. Averaged over the four years, there was no significant difference between treatments 2 and 5, 3 and 4 or 6 and 7.

Significant changes in the leaf chlorophyll content, or SPAD value, were observed in the various fertiliser treatments. Averaged over the years, there were significant differences between the fertilisation rates, with the following values for the individual treatments: 1: 28.9; 2: 33.1; 3: 43.6; 4: 48.5; 5: 38.5; 6: 47.7; 7: 51.6. A close correlation was detected between the maize grain yield and the SPAD value, but only a loose correlation with the year. The effect of the treatments on the maize chlorophyll content, averaged over the four years, is illustrated in Figure 1.

Analysis of the year effect primarily revealed the substantial yield-limiting effect of rainfall deficiency (a yield loss of 5.56 t ha^{-1} in 2007 compared with 2008), as the result of which the treatments had little or no detectable effect on the yield. Among the yield components, studies were made on the thousand-kernel mass, the kernel number per ear, the harvest index and the grain protein content. It was found that the year caused significant changes in both the grain yield and the yield components, and also in the leaf chlorophyll content.

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