

The effect of large doses of organic fertilisers on maize

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Abstract: Organic fertilisers are among the important factors increasing soil fertility. Their use belongs to sustainable technologies. As part of the field experiment, the effect of high doses of organic fertilisers on the parameters of the cultivated crop was monitored. The experiment was established using manure, compost and digestate. Monitored dosages were 40 and 200 t·ha⁻¹. The field trial was based on a light cambisol. The cultivated crop was maize. A blade cultivator was used in all cases to incorporate fertilisers. The qualitative parameters of the fertilisers were evaluated, as well as the maize yield and the quality of the resulting crop. The results indicate the beneficial effect of fertilisation on plant yield, quality parameters and other factors. Even in variants with high doses of fertilisers, no significant damage to the stand was recorded.

Keywords: quality parameters; soil; soil plant analysis development (SPAD); yield

When applying organic fertilisers to the soil, it is assumed that they have a beneficial effect on the stability of soil aggregates, a contribution to maintaining a stable humus content in the soil and an overall favourable effect on biological processes in the soil. However, it is evident that the influence of organic fertilisers on hydrophysical soil properties is not at the center of interest in the literature. In terms of agriculture in the Czech Republic, the number of cattle has decreased by more than half over the past 30 years, which has been reflected in a serious decrease in the production of quality organic fertilisers (Sálusová 2018). However, there is a production of a new category of substances usable for fertilisation (digestate from biogas stations)

and an increase in compost production from biodegradable municipal waste.

In order to assess the effect of organic fertilisers on soil properties, doses of fertilisers that are not realistic in practice and acceptable in terms of ecological risks were also used in the experiments. Golabi et al. (2007) tested the application of farm compost in doses of 0, 74, 148, and 296 t·ha⁻¹. At high doses, a favourable effect on the hydrophysical properties of the soil was found. Suzuki et al. (2007) reported an improvement in soil water retention after applying high doses of compost. Pandey and Shukla (2006) found an increase in soil water retention in a two-year experiment with a dose of 100 t·ha⁻¹ of compost. Also, in a two-year trial at seven sites, Weindorf

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et al. (2006) the contribution of compost application to the improvement of water infiltration into the soil is probably due to the improvement of the soil structure. Improvements in soil water retention and stability of soil aggregates due to compost application in a three-year trial were reported by Gonzalez and Cooperband (2002).

Soil organic matter content is a fundamental factor influencing soil productivity and health (Voltr et al. 2021). Weil and Magdoff (2004) report that organic matter increases the ability of soil to retain physiologically usable water for plants. Rayne and Aula (2020) summarize information from multiple sources: the effect of organic fertiliser application on soil water retention is not clear-cut. Minasny and McBratney (2017) showed a small increase in available soil water with increasing soil organic carbon (C). However, other works show a significant effect of organic fertilisation on water retention. Ankenbauer and Loheide (2016) found that the effect of organic matter on soil water retention was significant in low-clay soil. Other work showed that organic matter increased soil water-holding capacity in perennial grasses (Yang et al. 2014). The modelling of these phenomena is discussed by Rawls et al. (2004).

According to Timmermann et al. (2003), the duration of action of organic fertilisers in the soil is proportional to the duration of their repeated application.

However, there are also data in the literature showing that even after two years of compost application, no increased water retention capacity of the soil was detected (Evanylo and Sherony 2002). Schnug and Haneklaus (2002) mention the contribution of even small changes in water penetration into the soil to the severity of floods due to the large area of agricultural land.

Asmus (1992) compares the so-called humus formation coefficients (the ratio between the amount of C in newly synthesised humus and the amount of C applied to the soil in the form of organic fertiliser) for organic fertilisers: 0.12–0.20 (green manure), 0.24 (straw), 0.35 (manure) and 0.43 (quality compost). High doses of organic fertilisers are associated with the risk of greenhouse gas emissions (Gutser and Ebertseder 2002). Zhang et al. (2016) draw attention to the problem of NH_3 emissions during self-composting. An overview of the benefits and risks of adding organic matter to the soil with composted biomass is given by Cerda et al. (2018). Requirements for composting biodegradable waste and recommendations for applying compost to the

soil were developed by Plíva et al. (2016). This study was created in order to compare the effect of organic fertilisers on the production capacity of maize plants in erosion-prone areas.

MATERIAL AND METHODS

The field experiment was established in the Nesperská Lhota locality (GPS 49°41'25.4616"N, 14°48'48.2436"E). The piece of land consent light, loamy-sandy cambisol. The average altitude of the plot was 447 m, and the average inclination was 5.29. Meteorological data were recorded from a station located at the edge of the plot. In May 2021, the average precipitation was 97.4 mm, in June 68.7 mm, in July 116.6 mm, in August 78.4 mm, and in September 13.0 mm. The average annual temperature was 8.4 °C. The average temperature recorded in May was 10.8 °C, in June 18.3 °C, in July 19.1 °C, in August 16.1 °C, and in September 13.8 °C. The pre-crop grown at the field experiment site was winter wheat. In the fall, the plot was ploughed to a depth of 0.2 m. The plot was prepared in the spring of 2021, using skids and nail harrows. Seven experimental plots were selected on the plot. The slope of individual parcels was recorded using a digital inclinometer (Inclitronic 80; BMI, Germany). The slope of the plots was from 4.5 to 8.7°. The size of one experimental plot was set at 3 m × 3 m, and a distance gap of 5 m was omitted between individual plots. The application of fertilisers to individual plots is recorded in Table 1.

The field experiment was carried out with pig manure and compost, which were produced in the local environment of Nesperská Lhota. The digestate was produced regionally at the biogas station in Čechtice. The mentioned fertilisers were produced under standard conditions in agricultural production. For organic fertilisers (manure, digestate, compost), a basic dose of 40 t·ha⁻¹ and an extreme application dose of 200 t·ha⁻¹ were chosen.

Table 1. Fertilisers and doses of organic fertilisers

Plot	Fertiliser	Dossage (t·ha ⁻¹)
M 40	manure	40
M 200	manure	200
D 40	digestate	40
D 200	digestate	200
C 40	compost	40
C 200	compost	200
0	no fertiliser	0

Table 2. Main indicators of fertilisers (C_t and N values are given in dry matter)

Fertiliser (%)	Manure	Digestate	Compost
Dry matter	6.180	22.580	32.880
C_t	38.270	37.790	23.650
N	16.021	2.341	1.829

C_t – combustible carbon; N – nitrogen

The reason for choosing an extremely high dose was to assess the influence of soil properties even with a dose that is not realistic in practice.

In order to determine the properties of fertilisers, samples were taken, and laboratory analysis was carried out using the methodology used according to the compost standard ČSN 46 5735. The results are recorded in Table 2.

Determination of the qualitative parameters of fertilisers was carried out using a Niton XL3t analyser (Thermo Fisher Scientific, USA). The results are recorded in Table 3. The contents of macroelements and microelements are important but sometimes underestimated qualitative data of the fertiliser.

A blade cultivator (Kromexim, Czech Republic) was used to incorporate organic fertilisers, the depth of incorporation was 15 cm. The working speed of the tiller was $12 \pm 0.2 \text{ km}\cdot\text{h}^{-1}$. The time range of incorporation of fertilisers from the application was from 2 to 6 hours. After the fertilisers were incorporated, maize was sown – a mid-early KWS (FAO S 280). Maize was sown on May 10, the areal seed den-

sity was 80 000 seeds per hectare, and the sowing depth was 50 mm. The decisive criterion was the soil temperature (at least 8–10 °C at a depth of 0.1 m). For better emergence of maize plants, experimental plots were rolled with Cambridge rollers. Maize cultivation was in accordance with agrotechnical procedures used in the territory of the Czech Republic (Nesperská Lhota). During the growing season, the greening of individual plants was measured with a SPAD-502 Plus chlorophyll meter (Conica Minolta, Japan) (SPAD – soil plant analysis development). This handheld sensor calculates the SPAD value, a numerical expression of the spectral absorbance relationship in two regions of the electromagnetic spectrum – in the red band (600–700 nm) as one of the chlorophyll absorbance peaks and in the near-infrared band (700–1 400 nm).

Samples were harvested once using manual forceps. From each maize plot, a representative homogenised sub-sample was taken from the three middle (harvest) rows. Analyses were performed according to the ISO 16948:2015 standard.

Table 3. Selected elements contained in applied fertilisers (values are given in dry matter)

Elements (ppm)	Manure	Digestate	Compost
Zn	44.39	8.15	46.80
Cu	11.02	9.95	6.97
Ni	22.39	20.93	10.43
Co	26.33	19.76	–
Fe	990.42	144.03	992.12
Mn	95.12	54.10	–
Cr	16.19	14.93	15.55
Ti	14.14	33.33	–
Ca	3 128.36	1 837.28	5 375.20
K	5 925.96	4 047.01	6 282.16
Al	108.90	200.09	–
P	1 545.63	1 010.94	623.44
Si	1 710.56	3 088.32	–
Cl	965.93	1 013.29	–
S	1 137.55	556.22	1 799.46
Mg	776.06	604.39	26.60

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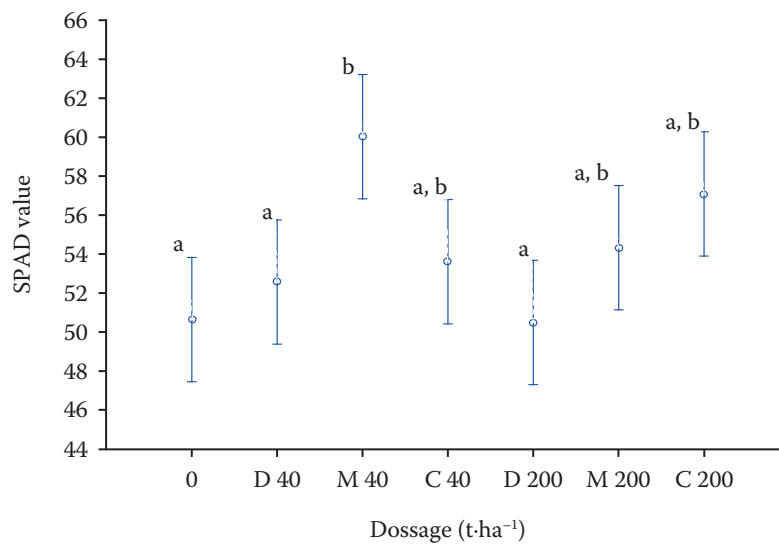


Figure 1. Soil plant analysis development (SPAD) value in BBCH 39

BBCH 39 – evaluation scale for SPAD value, 0 – no fertiliser; D – digestate; M – manure; C – compost; a, b – statistically significant groups; vertical lines indicate 0.95 confidence interval

RESULTS AND DISCUSSION

The graph in Figure 1 shows the values of the SPAD index for all variants. The measurement was taken at the end of the elongation growth (BBCH 39 – evaluation scale for SPAD value). Quite large differences were confused at this stage. Some even were statistically significant. The graph shows the different effects of individual fertilisers on the SPAD value. This is related to the different nitro-

gen uptake by plants from different types of fertilisers. Low values are recorded, especially for variants with digestate. In this phase, the plants were generally slower, but in later phases, this difference was no longer recorded.

Figures 2–4 show graphs of maize quality parameters. The graph shows that with a higher dose of nitrogen, the maize was able to work in the later stages of the vegetation – that is why there is an improvement in the ears with increasing amounts of the

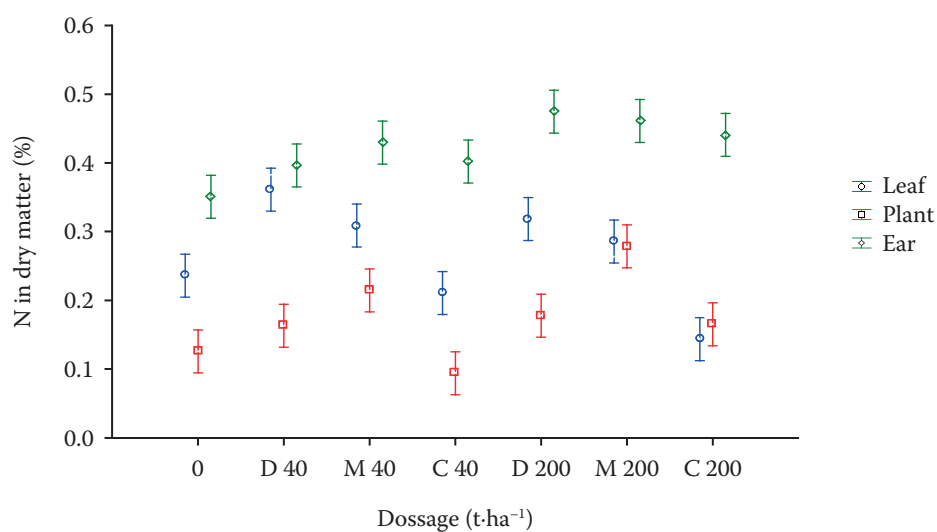


Figure 2. Average values of nitrogen (N) contained in dry matter of maize plants

0 – no fertiliser; D – digestate; M – manure; C – compost; vertical lines indicate 0.95 confidence interval

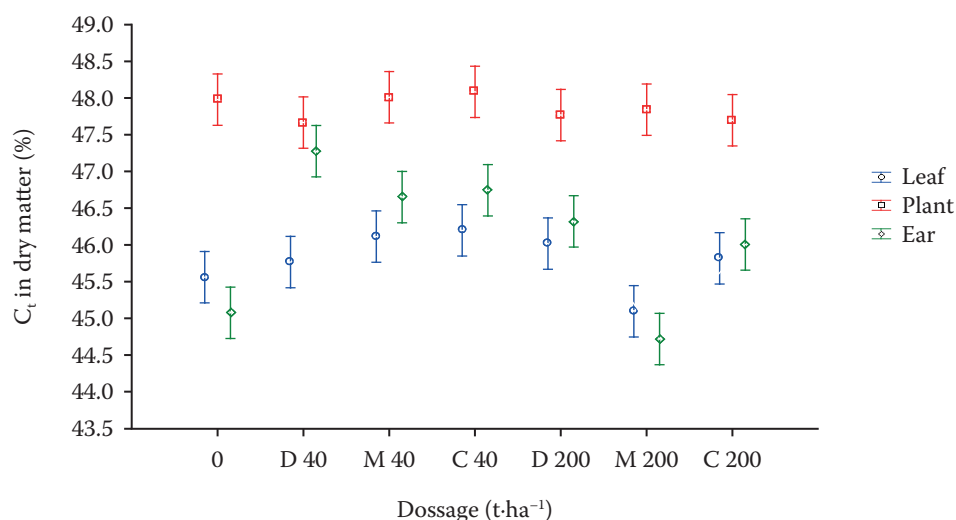


Figure 3. Average values of combustible carbon (C_t) contained in dry matter of maize plants

0 – no fertiliser; D – digestate; M – manure; C – compost; vertical lines indicate 0.95 confidence interval

dose. Which, however, did not show on the plant and leaves in the earlier stages. It is important for the plant how much nitrogen it absorbs in the earlier stages (until the extension growth) – after that, the plant is no longer able to make up for any deficit. The plant is no longer able to metabolise it in the later stages. The values for manure are relatively low because when a large amount of ammonium nitrogen is used, the development of the early stages of the maize plants can be slowed down – the development of the root system is slowed down. The plant only takes the necessary dose.

On sandy soils, the sorption capacity is lower, which resulted in a negative effect at high doses. The highest yield of maize dry matter was recorded for plants grown on a plot with a dose of 200 t·ha⁻¹ of manure, namely 1 593.7 g. A smaller yield of maize dry matter was recorded for plants grown on the plot without any organic fertiliser, namely 711.0 g. Harvest took place on September 7, 2021, and 10 samples of maize were taken from each variant.

Maize yield was also evaluated from the point of view of whole plants. No statistically significant difference was found between the variants in the

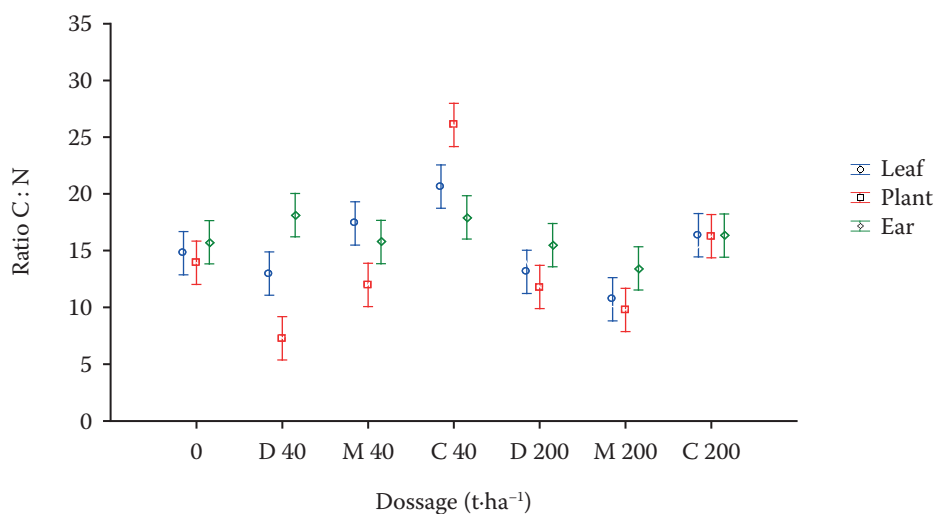


Figure 4. Carbon to nitrogen ratio in maize plants

0 – no fertiliser; D – digestate; M – manure; C – compost; vertical lines indicate 0.95 confidence interval

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2021 season. The average yield was $51 \text{ t} \cdot \text{ha}^{-1}$. Similar research was already carried out by other authors. Chlorophyll content in leaves is one of the basic indicators of plant stress (Křížová et al. 2022). To determine the state of vegetation, it is advisable to use hand-held sensors in small-plot experiments (Tunca et al. 2018). A very important parameter is the yield of maize, but also the quality of the resulting production. Golabi et al. (2007) emphasise the importance of organic fertilisers for the yield and quality of production. Rayne and Aula (2020) point in particular to the sufficient organic matter in the soil as a means of improving the qualitative parameters of the soil and production.

CONCLUSION

The measurements show a positive effect of all types of organic fertilisers on maize production. The chosen doses can be considered extreme, but even they did not show significant phytotoxicity and a negative effect on yield. On the contrary, the difference between individual types of fertilisers was not confirmed. It can be stated that a favourable effect was recorded for most monitored parameters for all types of fertilisers. The results also confirm that the mineralisation of fertilisers in the soil is a relatively long-term phenomenon, and some effects will, therefore, only be noticed in the medium term.

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