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# Comparison of logistic, energy and exploitative parameters of compost and manure application by spreaders

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**Abstract**

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This article deals with comparison of composts and manure use from the viewpoint of handling, transport and application on agricultural land. The published values were established by measurements under working conditions and afterwards converted on the basis of the content of nutrients defined in laboratory. Compost contained a greater share of nitrogen, phosphorus and potassium and had higher dry matter content and lower volume weight. Direct consumed energy expressed by recalculation of the consumed diesel fuel in case of composts moved from 5.12 MJ/kg (potassium) up to 16.19 MJ/kg (phosphorus). In case of manure it was higher and moved from 10.49 MJ/kg (nitrogen) up to 29.79 MJ/kg (phosphorus). The greatest share in energy consumption occupies transport, which was considered uniformly at the distance of 5 km. The study confirmed the feasibility of use of compost in agriculture as a partial substitute of conventional organic fertilizers; for its handling, transport and application the standard mechanization used for manure may be utilized.

**Keywords**: organic fertilizer; compost application; organic farming; organic matter; soil; plant nutrition

The soil is a fundamental means for the nourishment of mankind. From the perspective of human life length. it is non-renewable. Therefore, it is necessary to protect it and reduce its loss. It is important to maintain the organic matter content in soil at an acceptable level, as it is a way to ensure the soil fertility and reduce water and wind erosion (Chiara et al. 2016; Mujdeci et al. 2017).

To maintain or increase the organic matter content is, of course, a global problem Lai et al. (2017). According to Lu and Tian (2017), the reason is a massive use of mineral fertilizers at the expense of organic fertilizers. This imbalance occurs particularly due to economic reasons. Another reason is the lack of traditional organic fertilizers due to a decrease in livestock production. Liebig et al. (2017) suggest that it causes reduction of organic fertilizer production and distortion of nutrient cycles.

The lack of traditional organic fertilizers can be partially replaced according to Sharma et al. (2017) by the production of composts. According to Teutscherov et al. (2017) the composts enable to enrich the soil with stabilized organic matter and other components in the form of nutrients and trace elements (Adewale 2011).

Taking into account the concentration of nutrients it is obvious according to some authors (Halloran et al. 2013; Wang 2017) that the applica-

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tion of composts is more expensive and logistically more difficult in comparison with fertilization with mineral fertilizers.

However, maintenance of necessary content of organic matter in soil is inevitable according to Teutscherova et al. (2017).

The utilization of composts instead of traditional farmyard manure is possible, according to Marriott (2015), in the regime of conventional agriculture as well as organic farming.

Therefore, from the practical viewpoint, it is better to compare the compost application with the application of other organic fertilizers. However, the comparison of energy and logistic parameters of application on agricultural land has been carried out so far only on the level of theoretical calculations Shu (2005) and experiments without practical tests in field conditions. The both variants were evaluated also from the viewpoint of heavy metals as a harmful factor owing to the contamination of food chains Lakhdar et al. (2009).

Problems related to the compost application on agricultural land were examined by Brown et al. (2011), however, above all in relation to organic matter content, nitrogen content in soil and water regime in soil. Research of the effect of phosphorus content in soil is described also in Maltais-Landry et al. (2015).

The proper application by spreaders is examined and evaluated in scientific literature mainly from the viewpoint of manure quality (Kamionka 2013; Nogalski 2015). Operational parameters of a tractor set with spreader with the loading capacity of 3.5 $m^3$ were examined by Sapkale (2010) during the manure application of 5.5 t/ha. The working capacity ranged between 1.395 up to 1.473 ha/h and fuel consumption from 2.75 up to 3.00 l/h. Experiments with manure and compost application with measurement of the applied fertilizer were also realized by Miclet et al. (2010), of course, without measurement of fuel consumption and a capacity of set. Operational parameters were not monitored in case of experiments with variable dosage on grasslands Nysten et al. (2016), either.

Comparative tests of six types of spreaders were carried out by Loo (1996). The tests were aimed mainly at the quality of work and they were also carried out without measurements of energy and exploitation parameters. The comparison of efficiency of manure and compost application from the viewpoint of working capacity and fuel consumption (energy) are therefore necessary. More intensive use of composts in agriculture as an alternative instead of inaccessible manure will be probably necessity soon.

The application of compost is described by Favarato et al. (2012). The extensive set of measured and normative values for transport and application of compost is also published by Syrový et al. (2008). The data in this work are divided into transport and manure application by spreaders for two different values of specific mass.

## MATERIAL AND METHODS

The objective of the measurements was to compare energy intensity and exploitative parameters of compost and manure application on arable land in case of a concrete working set of tractor with manure spreader as semi-trailer. Determination of energy and exploitative parameters spreader operation was carried out by means of measurements under working conditions. Determination of analytical properties of manure and compost was carried out in laboratory from the samples of the applied fertilizers. On the basis of the results from the measurement of exploitative parameters, energy intensity and analytical properties of manure and compost the model cases of application were elaborated. This application was considered for necessary doses of nutrients (N, P, K). To the calculated values belong the unit consumption of diesel and time period necessary for loading, transport and application.

During the realization of measurements, the following quantities were monitored:

– momentary diesel fuel consumption of tractor and handling means used to the manure and compost loading into the spreader. The values of diesel fuel consumption were determined by means of flow meters.
– time recording of the work of tractor set with spreader carried out and time recording of leader;
– monitoring the movements of machinery (by means of GPS) in order to determine the speed of operation used at fertilizers application on arable land, check on setting up energy means for individual variants of measurement;
– actual area of application;
– weight of the applied fertilizer by weighing on weight-bridge.

From the measured values the following parameters were determined by calculation:

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Unit consumption of diesel fuel was calculated as:

$$V_e = V_{sp(t_n,t_d,t_c)}/m_s \quad \text{(l/t)} \quad (1)$$

where: $m_s$ – weight of the processed material (t); $V_{sp(t_n,t_d,t_c)}$ – total consumption of fuels and lubricants for a given time segment; $t_n$ – time of loading; $t_d$ – time of transport; $t_c$ – time of application

Consumption of diesel fuel per hour was calculated as:

$$V_e = V_{sp}/t \quad \text{(l/h)} \quad (2)$$

where: $t$ – time period of realization of work (h); $V_{sp}$ – total consumption of fuels úer realization of work

Weight performance was calculated as:

$$q_m = m_s/t \quad \text{(t/h)} \quad (6\ )$$

where: $m_s$ – weight of the processed material (t); $t$ – time (h)

For application of composts and manure the area capacity $q$ was determined:

$$q_s = S_s/t \quad \text{(ha/h)} \quad (7)$$

where: $S_s$ – area of application (ha); $t$ – time (h)

At transport means theaverage transport performance was determined:

$$q_s = m_s \times s_d/t \quad \text{(tkm/h)} \quad (8)$$

where: $m_s$ –weight of the processed material (t); $t$ – time (h); $s_d$ – transport distance (km)

Total consumed energy was determined as:

$$W_{sp} = m_{pal} \times Q^t_{i\ pal} \quad \text{(MJ)} \quad (9)$$

where: $m_{pal}$ – weight of the consumed fuel (kg); $Q^t_{i\ pal}$ – calorific value of the consumed fuel (MJ/kg)

Specific consumed energy was determined as:

$$W_e = W_{sp}/m_s \quad \text{(MJ/kg)} \quad (10)$$

where: $W_{sp}$ – total consumed energy; $m_s$ – weight of the processed material (kg)

For application and transport of composts and manure the spreader WESTERN 12 DS in set with tractor John Deere 6190 R were used. Gross weight of the spreader was 8.5 tons. The working width during the application moved from 6.3 up to 10.2 m.

At compost and manure application the following values were determined analytically:
– water content (according to the standards (ČSN EN15934:2013;
– nitrogen content (according to the standard ČSN EN 15104:2011);
– potassium content (according to the standard ČSN 465735:1991);
phosphorus content (according to the standard ČSN 465735:1991).

The obtained data were evaluated by ANOVA, using the software Statistica CZ v.12.

## RESULTS AND DISCUSSION

For the application of manure and compost the areas were traced on arable land. Weight of the material applied on arable land moved from 4.74 up to 6.25 t. The transport distance was 4.1–4.9 km. The rate applied on arable land moved between 3.7 and 18.5 t/ha. The set (tractor and spreader) moved in the area with the elevation between 470 and 585 m a.s.l., and the application site was in lower elevation than the site of loading – handling.

In order to determine the transport parameters, it is necessary to take into account the passage with a load to the application site and the passage with empty transport means back to the loading site. Transport distance is distance from the loading site to the application site.

At the division into particular working operations handling (loading), transport (passage to the plot and return) and application were considered separately.

Data determined for particular monitored operations are mentioned in Table 1; all the data are related to the quantity of fertilizer and application area.

From the monitored operations, transport is the most demanding from the viewpoint of energy and time. The specific consumption of diesel fuel related to the transport of 1 t of compost and distance of 1 km ranges around the level of 0.303 l/tkm and in case of manure it is around 0.278 l/tkm. However, the transport distance is longer than 1 km in practice. In the conditions of the Czech Republic it is very often between 5 and 10 km.

Table 2 shows the average content of the monitored elements in applied compost and manure and the specific weight at the mentioned dry matter content.

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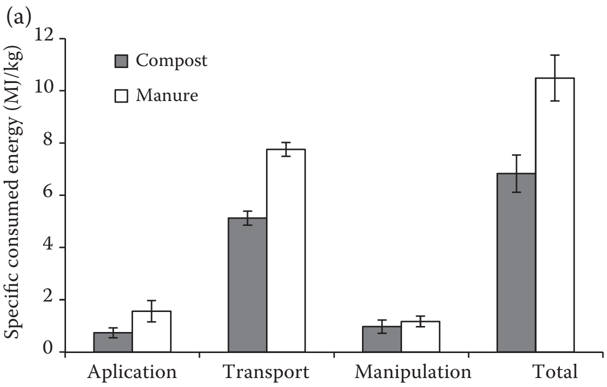
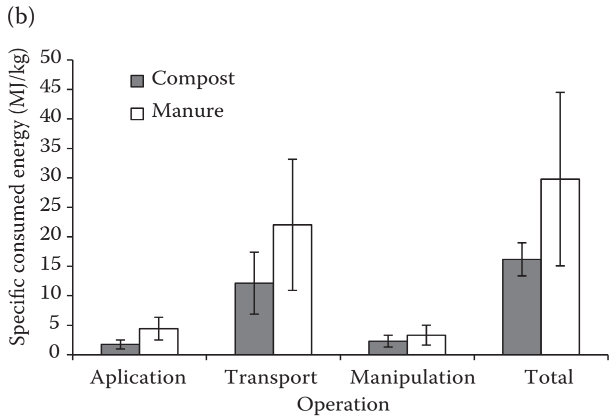
Table 1. Parameters of compost and manure application, transport and compost loading

| Variable | Unit | Compost value | Manure value |
|---|---|---|---|
| **Compost and manure application** | | | |
| Area performance | (ha/h) | 3.842 | 3.842 |
| Average performance | (ha/h) | 3.842 | 3.842 |
| Diesel consumption per hour | (l/h) | 32.175 | 34.200 |
| Specific area consumption of diesel | (l/ha) | 8.760 | 11.300 |
| Specific consumption of diesel | (l/t) | 0.217 | 0.280 |
| **Compost and manure transport** | | | |
| Average transport performance | (tkm/h) | 88.449 | 102.000 |
| Diesel consumption per hour | (l/h) | 26.812 | 28.400 |
| Specific consumption of diesel | (l/tkm) | 0.303 | 0.278 |
| **Compost loading** | | | |
| Average performance | t/h | 99.724 | 124.000 |
| Diesel consumption per hour | l/h | 26.812 | 29.400 |
| Specific area consumption of diesel | l/t | 0.287 | 0.210 |

From the above-mentioned values the difference in dry matter content and specific weight is clear. The compost has lower specific weight (600 kg/m$^3$) in comparison with manure (1,000 kg/m$^3$), but it contains higher share of the monitored elements. The greatest difference is in the content of phosphorus and potassium. Fig. 1 shows the values of specific consumed energy recalculated from the consumption of diesel fuel. The values are related to 1 t of the applied element. The graphs mention the values for individual operations and also the summary value. In all three cases, the transport for a distance of 5 km was taken into account. With this distance, , transport accounts for 75.0% (compost) and 73.9% (manure) of energy consumption. The loading accounts for 14.2% (compost) and 11.2% (manure). The application accounts for 10.8% (compost) and 14.9% (manure) of energy consumption.

Graphical illustration Figs 1–3 confirms the fact that the main share in energy consumption is that



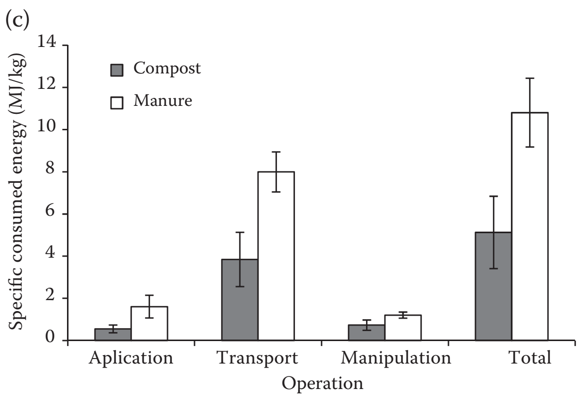




Fig. 1. Specific consumed energy for 1 kg of nitrogen (a), phosphorus (b), and potassium (c) applied in the form of compost and manure, transport is calculated for the distance of 5 km

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Table 2. Average content of nutrients and carbon in applied compost and manure

| | Specific weight (kg/m$^3$) | N (kg/t) | P (kg/t) | K (kg/t) | C (kg/t) |
|---|---|---|---|---|---|
| Compost (dry matter content 50%) | 600 | 10.71 | 4.522 | 14.280 | 151.5 |
| Manure (dry matter content 22%) | 1,000 | 6.5 | 1.364 | 6.308 | 130 |

of the manure transport. From the data in Figs 1– 3, it is also obvious that the supply of all monitored elements in the form of manure is more energy-intensive than it is in the form of compost. The greatest difference was recorded in case of potassium (53.6%) and then at phosphorus (46.8%). The smallest difference was recorded in case of nitrogen (36.22%).

Application of all monitored elements in the form of manure showed also greater requirements for handling (Fig. 2).

The greatest difference in handling was recorded in case of phosphorus (3.40 h/t), the smallest again in case of nitrogen (0.75 h/t). That is the difference of 77%. Energy consumption (diesel fuel) and handling are related very closely to the costs for realization of technological operations and efficiency. Efficiency of fertilization with the monitored elements in dependence on the applied rate is shown graphically in Fig. 3. The considered transport distance is 5 km again.

From the graphically shown data in the figure it is obvious that in case of fertilization with nitrogen in the amount of 40–120 kg/ha, the output of spreader is comparable at using of compost and manure. More considerable differences are at conversion of the values to phosphorus and especially potassium fertilization. From the course of all curves it results that with an increasing dose of the applied material the output of the whole line is reduced and partially also the differences between compost and manure utilization may decrease. Direct comparison

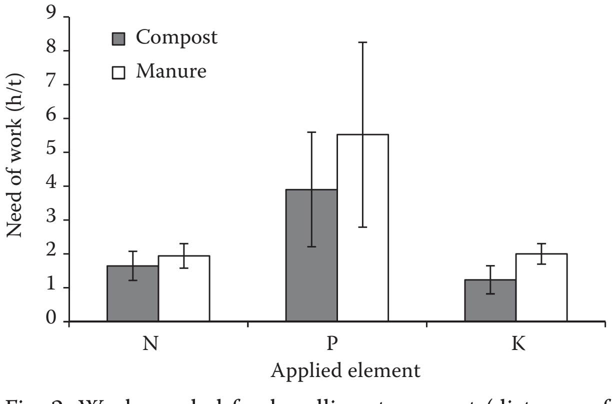


Fig. 2. Work needed for handling, transport (distance of 5 km) and application of the monitored elements in the form of manure

of the measured and calculated values of application, transport and handling with data available in scientific literature is somewhat difficult. Most of the cited sources do not deal with determination of energy and exploitative parameters. These sources solve the given problems from the viewpoint of soil quality, crop nutrition or waste utilization.

Some authors, as Sapkale (2010), published parameters that enable the comparison of results, but with machinery with different performance and construction. Directly measured values such as consumption, speed and performance are therefore different; however, some specific values are comparable. Sapkale et al. (2010) mentions the specific consumption of diesel fuel for manure application of 0.363 l/t; the authors however do not mention if this value includes also the passage with empty spreader to the loading site. In the present study, the value of specific consumption of diesel fuel determined only for application is at the level of 0.280 l/t.

A more comparable and more precisely defined value of specific consumption of diesel fuel for application of 0.237 l/t is mentioned by Syrový et al. (2008). The normative values mentioned by these authors, which are divided for the spreaders into transport and application, correspond to the results published in this article more exactly. The specific consumption of diesel fuel during the transport is mentioned by Syrový et al. (2008) at level of 0.254 l/tkm (compared to the value of 0.278 l/tkm obtained in this study ).

The determined properties of composts from the viewpoint of analytical content of elements confirmed the claim of Teutscherov et al. (2017) that compost is a raw material containing a quantity of organic matter in the form of carbon. The analysis has shown also a higher content of nutrients in the applied compost than in manure. Mainly phosphorus content was considerably higher, as claims Adewale (2011) and Maltais-Landryet al. (2015).

## CONCLUSION

The obtained results confirm primary assumption that compost represents a suitable replace-

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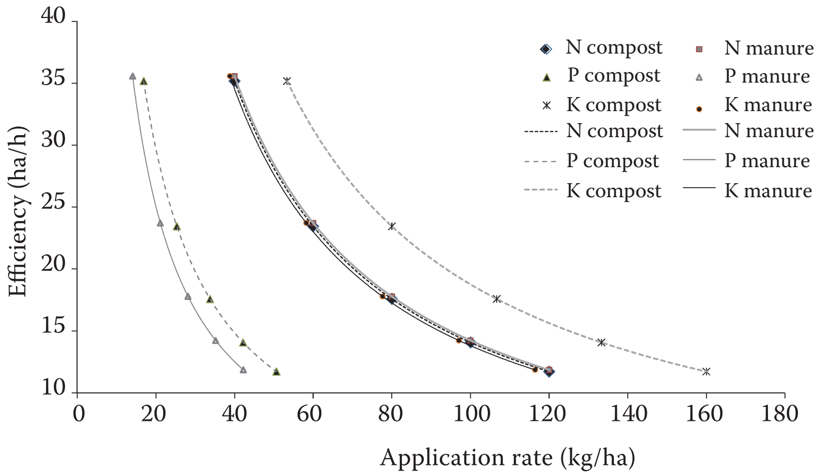


Fig. 3. Efficiency of fertilization in dependence on the rates of N, P and K applied in the form of manure and compost

ment of conventional organic fertilizers. In comparison with manure, compost has lower specific weight and higher dry matter content. However, the quality compost has higher content of nutrients, mainly potassium and phosphorus, in comparison with manure.

In view of the fact that compost has lower specific weight, the efficiency of handling, transport and application is lower, but at conversion to unit quantity of the monitored items the compost shows less handling, lower values of specific consumed energy and higher performance during the monitored operations.

From the viewpoint of soil conservation and revitalization, it is possible to use compost providing higher rates of potassium and especially phosphorus under observance of limits in nitrogen application. In the Czech Republic, these limits are represented mainly by the Nitrates Directive (Council Directive 91/676/EEC of December 12, 1991) that determines quantity of applied nitrogen. During the application of a necessary quantity of phosphorus and potassium in soils with a lack of these nutrients, it was recorded that the application in the form of manure exceeds the nitrogen limits whereas the composts meet these limits.

For example, at the nitrogen rate of 100 kg/ha applied in the form of manure 35.2 kg/ha of phosphorus and 97.1 kg/ha of potassium are applied. At the same nitrogen rate (100 kg/ha) at the fertilization with compost 42.2 kg/ha of phosphorus and 133.3 kg/ha of potassium are applied into soil.

Another verified hypothesis is the fact that the tested manure spreader can be used for the application of compost on agricultural land even with a possibility to regulate its rate. However, it is possible only on condition that the compost has sufficient water content, which prevents the formation of excessive quantity of dust and related losses of weight in the course of application.

In line with the information obtained from scientific literature it is possible to say that the composts represent a perspective possibility to replace partially the traditional organic fertilizers. From the logistic point of view, higher content of nutrients in composts is advantageous, as it has a positive effect on performance and consumption of work and energy expended for their transport, handling and application. The advantage is also the possibility to utilise the standard machinery that is usually used to transport, handle and apply manure.

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