COSTS OF LIQUID MANURE TRANSPORTATION AND INCORPORATION USING MOBILE TRANSPORT AGGREGATES

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Abstract. The article presents the research in the most typical technologies of liquid manure transportation, spreading and incorporation using mobile aggregates. The technological versions are compared in terms of the consumption of work of the workers, exploitation costs and the possible reduction of ammonia emissions. In the research it was stated that the specific consumption of work for transportation and incorporation of liquid manure as well as the specific costs calculating per one hectare depend on the distance where the liquid manure is transported. If, for instance, this distance increases from two to five km, the specific costs increase by approximately 50 %. The least liquid manure transportation and incorporation specific costs are in the case, if the manure that is spread on the field is incorporated at once simultaneously with cultivation. Plowing in or incorporating manure with special aggregates (in the depth of 15-30 cm or 4-6 cm) these costs increase by approximately 10 %. In terms of the possible reduction of ammonia emissions deep incorporation of manure is economically more efficient (in the depth of 15-30 cm). Still, analogous results can be obtained if the spread manure is plowed into the ground immediately.

Keywords: liquid manure, incorporation, mobile aggregates, exploitation costs.

Introduction

The Directive 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants determines the aims and measures for the member states to reduce ammonia emissions [1]. In this directive special attention is paid to reduction of ammonia emissions in agriculture as they produce 93 % of the total amount of ammonia emissions [1]. For elaboration of the measures to reduce these emissions it is advised to use the guidelines of the *United Nations Economic Commission for Europe* [2].

The most part of ammonia emissions caused by agriculture are produced by application of farm manure (spreading and incorporation) [3; 4]. Therefore, different measures for reduction of ammonia emissions are worked out in this sphere [2-6]. Correct farm manure incorporation is of special importance [7]. If manure is left on the field for a long time after its spreading, the amount of ammonia emissions considerably increases and the fertilizing value at the same time decreases. Therefore, in the Regulations No. 834 of the Cabinet of Ministers of the Republic of Latvia it is stated that farm manure after spreading should be worked in the soil not later than within 24 h, but liquid manure and slurry – within 12 h [8].

In practice, different farm manure incorporation methods are used: plowing, continuous cultivation, incorporation in furrows etc. For all of these methods the approximate reduction of ammonia emissions has been stated compared to leaving manure on the field without any processing [9]. Besides, the amount of these emissions depending on the time interval between manure spreading and incorporation also has been determined [2-5]. Immediate incorporation of liquid manure into the soil (rapid incorporation) can reduce ammonia emissions by 70-90 % [9].

In order to choose the most rational method of liquid manure incorporation it is necessary to know its realization costs. Still, the manure incorporation technology involves also manure transportation from the farm manure storages as manure spreading can be performed by its transportation aggregate as well as by the incorporation aggregate. Therefore, manure transportation, spreading and incorporation in soil should be considered as a uniform technological process. At present, in scientific literature there is not sufficiently wide information summarized on this issue. Therefore, this article describes investigations related to economic evaluation of usage of mobile aggregates in liquid manure transportation, spreading and incorporation in soil.

Materials and methods

For comparison of liquid manure transportation and incorporation technologies we have assumed that manure has to be incorporated in the area of 100 ha, its incorporation rate being 40 $m^3 \cdot ha^{-1}$ and the transportation distance from the manure storage to the field is 2; 5 or 8 km. In all the compared versions for performance of the work the aggregates are used, for assembling of which the following machinery is operated [10-12].

- Tractors *Deutz Fahr 6210*, with the engine power 210 Hp, the purchasing price 80 000 EUR (excluding VAT).
- Liquid manure spreading cisterns *Joskin Euroliner 26 000 TR* with the volume 20 m^3, transportation speed up to 40 $km \cdot h^{-1}$, operation speed – 20 $km \cdot h^{-1}$, manure spreading width – 12 m, cistern filling and draining pump DUAL STRON with the capacity 8 000 $l \cdot min^{-1}$ at the rotor revolutions 1000 rpm. The price – 52 000 EUR (excluding VAT).
- Liquid manure transportation cisterns (from the manure storage to the end of the field) *Poly 240*, with the capacity 20 m^3, transportation speed 40 $km \cdot h^{-1}$, capacity of the filling pump 7000 $l \cdot min^{-1}$, the price (excluding VAT) - 55 000 EUR.
- Cistern - compensator (for work on the field) *Joskin Qadra 20 000 TS*, with the capacity of the cistern 20 m^3, the price – 50 000 EUR (excluding VAT).
- Plow *Gregoire Besson* with 5 bodies, the working width 2.75 m, working speed 10 $km \cdot h^{-1}$. The price of the plow – 22 000 EUR (excluding VAT).
- Stubble-field cultivator *Kverneland CLC pro Cut 350* with the working width 3,5 m, working speed 10 $km \cdot h^{-1}$. The price 8 000 EUR (excluding VAT).
- Liquid manure spreading cistern *Joskin Quadra 20 000 TS* with the capacity of the cistern 20 m^3, transportation speed 40 $km \cdot h^{-1}$, working speed 10 $km \cdot h^{-1}$, working width 6 m, working depth 15-20 cm, capacity of the filling pump 6000 $l \cdot min^{-1}$. The price – 110 000 EUR.
- Liquid manure spreading cistern *Joskin Quadra 20 000 TS* with the capacity of the cistern 20 m^3, transportation speed 40 $km \cdot h^{-1}$, working speed 10 $km \cdot h^{-1}$, working width 6 m, working depth 8 cm, capacity of the filling pump 6000 $l \cdot min^{-1}$. The price – 110 000 EUR.
- For comparison four different technologies have been chosen (Fig. 1).

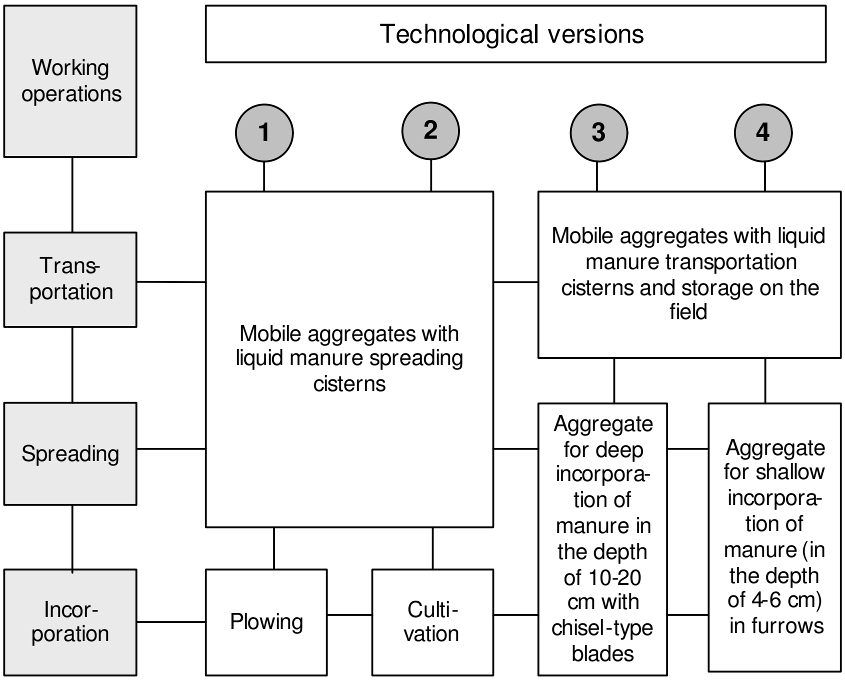

Fig. 1. **Technological versions of liquid manure transportation and incorporation chosen for comparison**

Using the first and second technological versions liquid manure is transported from the storage to the field and spread by tractor aggregates assembled with liquid manure spreading cisterns. But in the case of the first version the spread liquid manure afterwards is incorporated into soil by plowing, although in the second version it is done by cultivation. In turn, in the third and the fourth versions the mobile transportation aggregates transport liquid manure to the storage in the field, but manure is incorporated into soil by a separate mobile aggregate: in the third version the aggregate is assembled with deep incorporation plate-type blades (depth of incorporation 15-20 cm); in the fourth version – with shallow incorporation shoe-type blades (depth of incorporation 4-6 cm).

The technological versions were compared in terms of the consumption of work of the workers, exploitation costs and the possible reduction of ammonia emissions. The necessary input data were obtained from the technical characteristics of the chosen tractors and working machines, the information supplied by the machinery distribution companies, the data of our timing as well as considering the fuel price and the rate of wages existing in the country. The calculations were performed in the following sequence.

1. Applying the general formulas and the methodology developed in the result of our research [13; 14] the liquid manure transportation, spreading and incorporation technological parameters were calculated: the amount of the incorporated liquid manure, the necessary number of routes and the transportation aggregates, actual time for accomplishing of the work. Besides, it was assumed that processing of the field of 100 ha should be done within maximally 50 h.
2. According to the methodology established in economics [9] the aggregate machine costs, salaries for the workers and exploitation costs of realization of every technological version, EUR·ha^{-1}, were calculated.
3. The labour-intensity of the workers (aggregate drivers) calculating per one unit of the field to be processed, man-hours·ha^{-1}, was calculated.
4. The specific costs of liquid manure transportation, spreading and incorporation calculating per one percent of reduction of ammonia emissions were calculated.

Results and discussion

The necessary numbers of tractor aggregates for incorporation of manure for different technological versions are summarized in Table 1.

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Table 1

The necessary number of tractor aggregates for incorporation of liquid manure depending on the distance of transportation

Version No.	Number of transportation aggregates depending on the distance of transportation, km			Number of tractor aggregates for incorporation of manure
	2 km	5 km	8 km	
1.	3	5	6	1
2.	3	5	6	1
3.	2	3	4	1
4.	2	4	5	1

The number of transportation aggregates necessary for every technological version depends on the distance of manure transportation. In the first two technological versions it is determined by the restricted time limit – 30-35 working hours for processing of the whole field of 100 ha, but in the third and fourth versions – by the productivity of the manure incorporation aggregate. In turn, for incorporation of manure in all versions one tractor aggregate is used: in the first version it is a plow, in the second version – stubble-field cultivator, in the third and the fourth versions – respective machinery for incorporation of manure in the depth of 15-30 cm and 4-6 cm.

Labour-intensity for implementation of separate versions is shown in Fig. 2.

Labour –intensity for transportation, spreading and incorporation of liquid manure depends on the number of machinery units used for the work. If the liquid manure transportation distance increases by 3 km, the necessary number of transportation aggregates changes by 1 – 2 units but the specific labour-intensity increases in average by 0.6 man-hours·ha^{-1}. Besides, at equal distance of transportation the specific labour-intensity is approximately the same in all versions. An exception is only the version 2. In that case incorporation of manure is done with continuous cultivation and therefore the specific labour-intensity is by 18 – 28 % less than in the other versions.

The costs of liquid manure transportation, spreading and incorporation are summarized in Fig. 3.

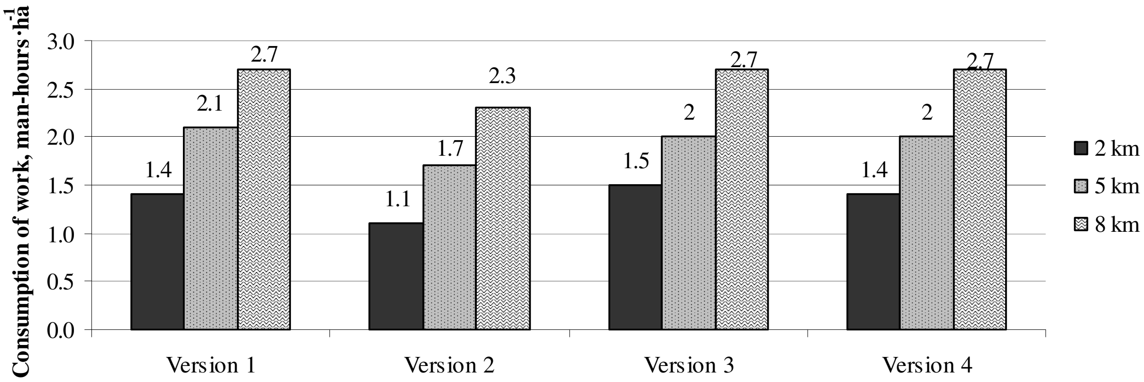

Fig. 2. **Labour-intensity of workers using different technological versions, man-hours·ha^{-1}**

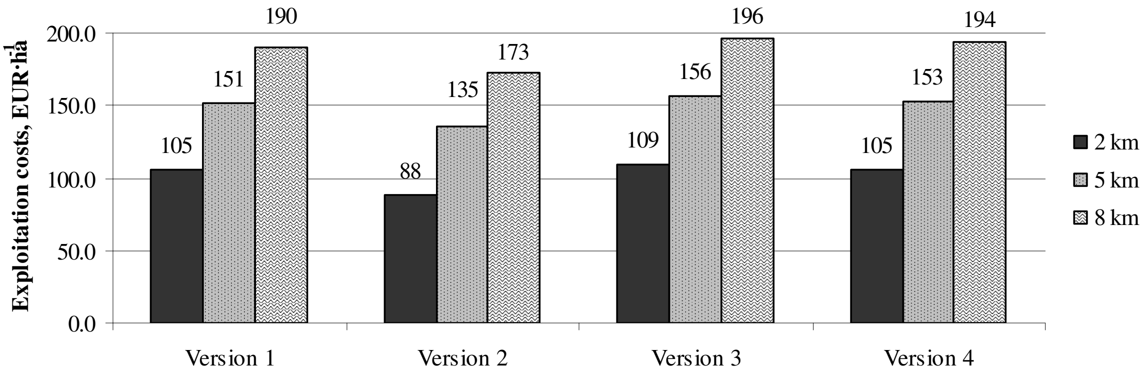

Fig. 3. **Costs of liquid manure transportation, spreading and incorporation depending on the technological version and the distance of transportation**

As it is shown in Figure 3, also the exploitation costs are mostly influenced by the distance of manure transportation. The larger the distance, the larger also the costs. Besides, the amount of these costs does not essentially depend on the technological version. Also in this case the least exploitation costs are for the version 2, i.e. incorporating manure by cultivation. In turn, the largest costs are for incorporation of manure in the depth of 15 – 20 cm (deep incorporation). If manure is incorporated in the depth of about 8 cm, the specific exploitation costs reduce by 2 - 4 EUR·ha^{-1}, but if manure is incorporated by plowing – even for 4-6 EUR·ha^{-1}more.

The costs of liquid manure transportation, spreading and incorporation in relation to reduction of ammonia emissions depending on the version of incorporation of liquid manure are summarized in Table 2.

Table 2

Specific costs of liquid manure transportation, spreading and incorporation calculating per one hectare and the possible reduction of ammonia emissions %, if the distance of manure transportation is 5 km

Version No.	**Method of liquid manure incorporation**	**Reduction of ammonia emissions, %**		**Calculated specific costs, EUR·(ha^{-1}, %$^{-1}$)**
		According to literature [2]	**Assumed in calculations**	
1.	Plowing	30-90*	30 and 90*	5,0 and 1,7*
2.	Cultivation	60	60	2,3
3.	Deep incorporation	90	90	1,7
4.	Shallow incorporation	60-80	70	2,2

**at immediate incorporation of manure into soil*

The data in the table show that the least specific costs are in the case when deep incorporation of manure is used (in the depth of 15-30 cm) with chisel-type blades or disks. Nevertheless, analogous costs are also in the case if the spread manure is immediately plowed into the soil. If, in turn, shallow manure incorporation (in the depth of 4-6 cm) or cultivation is used, the specific costs increase by 30-35 %. But the largest costs will be in the case if manure is left on the field without special incorporation.

Conclusions

1. Every method of liquid manure incorporation depends on the technological version of manure transportation and spreading. Therefore, in economic evaluation of liquid manure incorporation all these working operations are to be considered as one uniform technological process.
2. Specific consumption of labour for transportation and incorporation of liquid manure as well as its specific costs calculating per one hectare essentially depend on the distance of manure transportation. If this distance increases from 2 to 5 km, the specific costs increase by approximately 50 %, but if the distance increases more – from 5 to 8 km, the specific costs increase by 50 % more.
3. The specific costs of liquid manure transportation and incorporation, $EUR \cdot ha^{-1}$, are minimal if the manure spread on the field is incorporated immediately with cultivation. If manure is incorporated by plowing or with special aggregates in the depth of 15-30 cm or 4-6 cm, the specific costs increase by approximately 10 %.
4. If the costs of liquid manure transportation and incorporation for every technological version are considered in terms of the possible reduction of ammonia emissions expressed in %, the deep incorporation (in the depth of 15-30 cm) is economically more profitable. Still, immediate plowing of the spread manure in soil is of the same efficiency. But using shallow incorporation of manure the specific costs increase by 30-35 %.

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