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Grass silage preparation – comparison of systems on small-scaled dairy-cattle farms

Farms have different harvesting systems for grass silage for selection. There are a number of comparative studies on the harvesting method, but they usually are performed under standardized test conditions. Which of these information can find an application on practical farms with small and inconvenient shaped meadows? Therefore, the harvest preparation with own machinery in comparison to paid work and the harvest in the harvesting chain versus a loading wagon were tested on the conditions in two Bavarian dairy cattle farms. The results show that the publicated parameters can not be easily transferred to small scale farms.

Keywords
Process comparison, grass silage, harvest chains

Abstract
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Informations related to characteristics in the silage preparation can be found in many investigations. As early as 1998 [1] numbered the cutting performance on 0.7 to 1.0 hectares per hour (ha/h) per meter of working width. Moreover, the performances of tedders are specified with 2.5 to 9.0 ha/h and the performance of swathers at up to 5.5 ha/h with the single rotor [1]. In harvesting, the forage harvester is often called the more efficient method [2], [3], [4]. The crop performance of a forage wagon with 40 m³ at a farm-field distance of 1 km is classified at about 5 ha/h, for a fielddistance of 5 km it drops to 2 ha/h. In a forage harvester with 331 kW the crop performance remains almost constant at around 7 ha/h [5].

How is the grass silage preparation performed in practice on small to medium-sized dairy cattle farms with meadows of differing sizes, topography, soil types and farm-field distances? How can the different harvesting solutions distinguish themselves and on which of these systems should such farms base their harvesting?

To answer these questions, the problem has to be transferred to the situation of many small-scale farms. For this reason, two Bavarian dairy cattle farms with the described surface structure are selected. Despite comparable surface facilities and harvest amount these farms use fundamentally different approaches in the food supply.

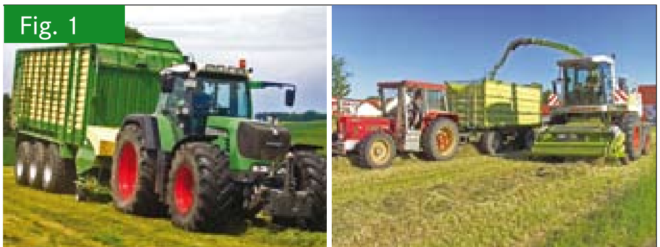
The aim of the investigation is to verify the theoretical performance characteristics of crop chains in practice and to identify process complexity and costs in ordert o find the advantages and disadvantages to make a statement for regions with small-scaled farms.

Material and methods

The selected farm A is using self-mechanized harvest preparation with mower, tedder and swather for years. The used tractors provide a power within 37 and 66 kW (Kilowatts). The mowers have a working width of 4,5 meters, the tedders working width is 5,5 meters and she swather works at a width of 3,5 meters. The forage harvester has 320 kW power, for transport there are used three tractor-trailers with up to 18 m³ volume and tractors with 60, 66 and 74 kW power.

Silage preparation on farm B goes on with a 225 kW-tractor with 43 m³ forage wagon. The mower before harvesting is a self-propelled mower with 9,7 meters working width, conditioner and a power of 260 kW.

Fig. 1



The grass silage preparation with the load carriage (left) and in the harvesting chain

Table 1

Overview oft he basic engineering data

	Betrieb A/*Farm A* **Eigenmechanisierung, Häckselkette** ***Self-mechanisation, harvesting chain***	**Betrieb B/*Farm B*** **Lohnarbeit, Ladewagen** ***Paid labour, loading wagon***
Erntefläche [ha]/Total Harvesting area [ha]	12,9	13,6
Flächengrößen [ha]/*Area size [ha]*		
Minimum	0,6	0,7
Maximum	5,8	6,3
Mittelwert/Mean	1,6	2,1
Hof-Feld-Entfernung [m]/*Farm-field distance [meters]*		
Minimum	15	70
Maximum	2 600	4 800
Mittelwert/Mean	1 900	2 300

Table 1 contains process characteristical data oft he investigated farms. The harvested area of about 13 hectares and area distribution are very similar at both farms and are a good base for a comparison of the harvestsystems.

The datarecording is based on neutral, previously established and defined standards. The data are collected at the first pasture harvest in 2009 on both farms. The areal data are taken from the field records, driving distances are measured online in an application oft he bavarian survey office.

Time recording on both farms is only manually with calibrated stopwatches and time synchronized clocks. Especially in use of self-mechanization working hours for maintenance, care and setting up the machine are measured because of their later influences on the cost of the harvest process. In all working steps travel time, setup time, process time and downtimes can be distinguished.

On farm A one person collects all data at the field, especially notices times of arrival and departure oft he tractor-trailers. A second person collects all data at the grass silo at the farm. From this database travel times can be calculated.

The transported masses are estimated by the volume of the transport units and their number. At the arrival at the silo, the trailer-filling is listed as a percentage. To check the results and to approximate the determination of the density in the silo, the silo volume is also measured.

The costs of the procedures are determined by available bills or from the KTBL calculation data of the years 2005 and 2008.

For both harvest methods and each step is built an individual full cost calculation, which includes all bills, according to actual costs, variable and fixed costs of the own machinery, and the wage rates for farmmanagers and other workers. The imputed wage is based on the wage rates for unpaid labor. KTBL (2005), as a basic wage for the farmer to 12.48 € per working hour plus an allowance for the economic value of the farm [6]. The imputed wage of the manager is aligned to a uniform value of 15 €/working hour recognized as common in the usual calculation of costs.

Results

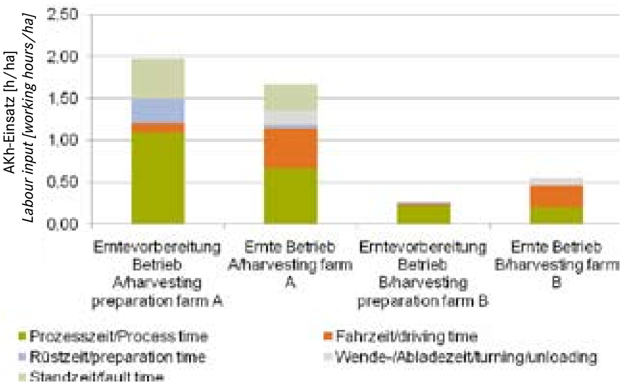
Self-propelled mower is faster and cheaper

Figure 2 summarizes the results. It is clearly seen that farm A with the own machinery must spend much more labor hours per hectare of harvested area. The exact figures to time and required factor inputs are provided in the following section.

Mowing with self mechanization needs 0,76 work hours per hectare. Processtime with 82 % share of time is the largest part of the mowing process, which can be attributed tot he low performance of self mechanization. Furthermore, the driver has to clean the cooler oft he tractor in regular intervals. Additional to the time for mowing is the time for tedding with 0,4 working hours and swathing, what needs over 0,8 working hours per hectare. Over all, the time for harvest preparation adds up to nearly 2 hours per hectare. For only mowing the total area of 12, 9 hectares, farm A spends 9,75 manhours. Harvest preparation with the self-mechanization has a average performance of 0,86 hectares per hour.

The self-propelled mower spends only 0,22 working hours per hectare and needs not even one third of the self mechanized mowers. Tedding is on farm B because of the conditioner not

Fig. 2



Time allocation in harvesting preparation and harvesting on Farm A and B necessary, and for swathing around the complete swathes are 0.25 hours per hectare required. Thus, time for harvest preparation on farm B is reduced by 75 %. The process time percentage of the mower is 70 %, the travel time is almost an hour, or 27 % for a total time of 3 hours in the entire process. On average, the large-area mower provides 4.55 hectares per hour in spite of the small average area size and frequent repositioning. At the top under conditions of small-scale 9.6 ha/h are possible. Thus, an average of 0.4 hectares per hour and meters working width can be managed, in the top 1 ha per hour and meters AB is possible. These results are in the range of values given by Schön in 1998 and under specified conditions achieved only by self-propelled mower.

The expenses in the cutting technique are comparable, according to the invoice the costs of the large-area mower are 37,50 €/ha. In the own machinery, calculation is based on working hours. For swathing the swath of the self-propelled mower 11 €/ha can be calculated. From KTBL values for the machines and the imputed wage approach, mowing costs of € 37.47/ha result [6]. Here, however, costs for tedding (13 €/ha) and swathing of 20 €/ha have to be added, which means a total cost of harvest preparation of 70 €/ha compared with just under 50 €/ha on farm B.

Harvest - duplicate expenses - low performance

Looking at the point of time requirement the advantages, that have to be analyzed more accurate are clearly at the side of the forage harvester. The forage harvester harvests the area of 13 ha in 5,5 hours. This means a performance of 2,4 ha/h. In publications, Values on performance with data of 7 ha/h [5] are related to, which is due to optimally organized logistics independent of farm-field distance.

The forage wagon needs for a comparable area with 13,6 ha total size two hours more time and harvests 1,8 hectares per hour. In contrast to the forage harvester, performance changes with the driving range. On meadows near the farm (distance at about 1 000 meters) the forage wagon harvests 3.3 ha per hour, on meadows with higher distance, harvest performance decreases to 1,7 hectares/hour. Despite of its high power with 225 kW and a big forage wagon, the forage wagon reaches neither the publicated values at 5 ha/h performance at low distance, nor the values of 2 ha/h at high distances.

Efficiency increase by 30 % requires a much higher factor input in the harvest chain in comparison to the forage wagon. At the tractor-trailers, travel time has the highest share of time with 37 %. Only 30 % can be seen as process time. With a share of time by 20 percent, unprodictive nonworking time is unnecessary high. The forage harvester is nearly full employed, time of process is 77 %, nonworking times are only by 6 %.

Despite of the less absolute process time, on farm A totally 1,7 manhours per hectare are worked. On farm B are only 0,5 hours per hectare necessary. One fifth of the time on farm A are nonworking times after changing meadows. Working and machine input causes costs of 165 € per hectare on farm A, on farm B, whos forage wagon costs 125 € per hour, 118 € have to be paid per hectare. More characteristical result-data are shown in **table 2**. For the total harvest process, farm B's costs are by 165 €/ha, and thus as high, as only harvesting costs at farm A, whos total process costs 235 €/ha.

Low improvement-opportunities in locistics

High attention in harvesting with a forage harvester is laid on logistic organization. The investigated harvest-chain has been working like this for years, the drivers are also experienced.

Table 2

Procedure-related characteristics of grass silage preparation

	Betrieb A/*Farm A* **Eigenmechanisierung, Häckselkette** ***Self-mechanisation, harvesting chain***	**Betrieb B/*Farm B*** **Lohnarbeit, Ladewagen** ***Paid labour, loading wagon***
Erntevorbereitung/*Harvesting preparation*		
Dieselverbrauch/*Diesel consumption* [l/ha]	11,40	11,33
Arbeitsaufwand/*Labour input* [AKh/ha]	1,98	0,47
Flächenleistung/*Performance* [ha/h]	1,03	4,30
Kosten/*costs* [€/ha]	69,79	48,00
Ernte/*harvesting*		
Dieselverbrauch/*Diesel consumption* [l/ha]	29,61	14,52
Arbeitsaufwand/*Labour input* [AKh/ha]	1,7	0,50
Schlagkraft/*Harvesting performance* [ha/h]	2,39	1,83
Bergeleistung/*Harvesting performance* [t FM/h]	30	22,50
Kosten/*costs* [€/ha]	165,13	117,80
Kosten/*costs* [€/t TM]	38,8	27,20
Gesamtfahrstrecke/*Total distance* [km]	150,7	85,80
Gesamtarbeitsaufwand/*Total labour input* [AKh]	**3,68**	**0,97**
Gesamtkosten/*Total costs* [€/ha]	**234,92**	**165,80**

High fault times arise at the beginning of the process and by changing meadows. Optimized harvest-planning can save one tractor-trailer at some fields, but to fully employ the forage harvester, at some meadwos one trailer more would be necessary. As a result, parts of fault time would only get moved, costs and work input would not get less.

Looking at this results, you have to wonder, why farm A doesn't use the self-propelled mower or the forage wagon. Not at least, the reason are personally preferences of the farmer, who prefers own mechanisation and work. Mechanisation is available on farm A and is busy at hay harvesting, too. To guarantee process stability and high performance, farm A has enough experienced manpower. The foodquality after harvest with the forage harvester is an advantage in the feeding process.

At farm B, the forage harvester is no alternative to the forage wagon. Apart from helpers, additional transport trailers would have to be rented. Many meadows are only to reach by very narrow private roads. The low costs of its harvest process in the present study confirms the choice of the harvest solution by forage wagon.

Summary

An universal and over all conditions optimized harvest method in the grass silage preparation does not exist. Both in this investigation analyzed process chains "forage harvester" and "forage wagon" have their general advantages and disadvantages and can represent their facilities at the respectively farm very well.

Over all, performances on both farms are relatively low, what is caused by the areal situation of the farms with unvaforable shaped and scattered meadows.

The Investigation shows, that the technology in grass silage preparation must be matched, using a forage harvester, optimized logistics moves into the focus.

There is a variety of factors that influence the success of a high-quality grass silage. What system is to choose, must be considered and decided individually on each farm. It depends not at least on personal preferences, but also on the farms equipment.

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