



Timeliness Costs for the Silage Harvest in Conventional and Organic Milk Production

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Timeliness costs, a time-related penalty decreasing the total revenue in crop production, are associated with risk and arise when an operation is performed at a non-optimal time or with non-optimal capacity of the equipment, affecting the quality or quantity of a crop or both. Timeliness costs are needed to determine the optimal machinery system. The aim of this study was to estimate timeliness factors for silage production for the feeding of dairy cows. By calculating timeliness and machinery costs, the use of the timeliness factors was demonstrated on silage production on a dairy farm. Timeliness factors were calculated by estimating the economic value of forage harvested at different times by considering consequences in ration formulation, fodder costs and milk yield.

This study showed that first harvest causes higher timeliness factors and thus higher timeliness costs, mainly due to higher yields and faster crop development. Moreover, total timeliness costs were substantially higher for organic silage production, compared with conventional, and similar to labour costs. Timeliness costs were particularly affected by changes in number of workers and transport distance.

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1. Introduction

Timeliness costs can be described as a time-related penalty decreasing the total revenue in crop production. This penalty, associated with risk, arises when an operation is performed at a non-optimal time or with non-optimal capacity of the equipment, affecting the quality or quantity of a crop (Witney, 1995). Timeliness costs arise in all crop production since it is not possible to operate all crops and fields at the optimal time; nevertheless having high machine capacity can reduce the costs. Generally, timeliness costs are higher in areas with short growth season or high precipitation or both (Lund, 1996). Since the size of the timeliness penalty depends on the capacity of the machine used for the field operation, timeliness costs are often, together with direct machine and labour costs, considered as part of the machine cost. Increased capacity is associated with

higher direct machine investments and decreased labour costs (de Toro & Hansson, 2004).

In milk production, it is essential that the harvested forage be of high quality, *i.e.* good hygienic quality, high-energy content and high content of crude protein (Jafner, 1991). Moreover, in organic milk production the quality demands of forage are higher (Tvedegaard, 2002), particularly because of restricted possibilities to compensate for low quality of forage with concentrates. Compared with conventional feeding, feeding of ruminants in organic production is subjected to restrictions, *e.g.* in Sweden to follow the standards developed by KRAV, the national certification body for organic production (KRAV, 2003).

Forage legumes provide the basis for grassland farming throughout much of the world and for northern Europe the importance of forage used for silage production in dairy farming has been emphasised

(Doyle & Topp, 2004). It is well known that some components in forage plants change with phenological development and time of year, important examples being protein and energy (Pettersson, 1997). Crude protein and energy contents of forage, its development during growth season and its dependence on harvest time have been thoroughly examined or modelled, or both, in Sweden by Tuvešson (1988), Andersson (1989), Fagerberg and Ekbohm (1995), Gustavsson (1995a, 1995b) and Arnesson (2000). Forage often consists of a mixture of grass and leguminous plants such as clover, characterised by high yields and high protein content (Fogelfors, 2001). This is particularly true for organic forages since the main supply of crop nitrogen, besides organic manure, is biological nitrogen fixation from leguminous plants. Provided good management practices resulting in high health status of the cows, Rinne *et al.* (1999) state that both metabolisable energy and protein greatly influence the milk yield of dairy cows and thereby economic output. Delayed harvest, due to wet weather at optimal harvest time or low harvest capacity, results in a decrease in energy and protein contents of forage (*e.g.* Fagerberg, 1988). If the machines for harvesting forage have high capacity, a larger area can be harvested before the rain and consequently the losses can be reduced. Thus, by calculating the value of the forage at two different harvest times it is possible to determine the timeliness losses at delayed harvest. The result is timeliness factors for forage harvest, influenced by changes in both energy and protein content of the forage, expressed as percentage loss per day (% day⁻¹) where a low value of the timeliness factor is advantageous. Other studies such as that of Soegaard and Soerensen (2004) state the need for more research estimates of timeliness factors.

The main purpose of this study was to calculate timeliness factors and subsequent timeliness costs for harvesting of forage in organic and conventional milk production. The use of the timeliness factors is exemplified by studying timeliness and machine costs for silage harvesting on a dairy farm. Finally the factors influencing the timeliness costs such as number of workers, machine capacities and transport distances are analysed.

2. Methods

2.1. Calculation of timeliness factors

Timeliness factors were calculated for the first and second harvest in conventional and organic dairy production by estimating the economic value of forage of different nutrient quality harvested at two different

times. The method was as follows.

- (a) Regression analyses of field experiments were used to calculate harvest days and protein contents corresponding with two specified energy contents of the forage.
- (b) Economic value of the forage of different nutrient quality was determined by making fodder plans and calculating fodder costs.
- (c) The difference in economic value between the two forage qualities and the number of days between the two harvest dates were used to estimate timeliness factors.

Timeliness factors can be expressed as the daily amount lost (in kg ha⁻¹ day⁻¹ or € ha⁻¹ day⁻¹) or as the percent of the yield lost daily (% day⁻¹) where using the percentage loss enables comparison between differently yielding fields.

2.1.1. Calculation of harvest days

In this study, results from field experiments performed by Fagerberg and Ekbohm (1995) at six sites in central and southern Sweden during 1985–88 were used to describe the change in energy and crude protein content in relation to time of harvest of grass-clover leys. From regressions from Fagerberg and Ekbohm (1995) for metabolisable energy depending on time and nitrogen fertilisation (Table 1), the harvest days corresponding to energy contents 10.5 and 10.0 MJ (kg [DM])⁻¹ were calculated for conventional and organic leys. For these harvest days the corresponding protein contents were calculated from regression equations for crude protein content depending on time, N fertilisation and clover content (Table 1).

Fagerberg and Ekbohm (1995) states that for mixed leys with clover contents less than 30% the energy content is close to that of grass, therefore time–energy regression for timothy and meadow fescue was used to calculate harvest times corresponding to the required level of metabolisable energy for clover contents less than 30%. Furthermore, time–energy regressions for red clover were used when the clover content exceeded 50%. For the interval 30–50% clover, an average of grass and red clover regressions was assumed.

The mixed leys assumed for the calculations in this study, consisting of timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* L.) and red clover (*Trifolium pratense* L.) were kept for 2 yr and had a clover content averaging 25% for first harvest and 30% for second harvest in the conventional forage. Corresponding values for the organic forage were 40% and 60% clover content in first and second harvest, respectively (Gustavsson, 1989; Fagerberg & Ekbohm, 1995). The conventional leys were fertilised with 70 kg

Table 1
Regressions for metabolisable energy content and crude protein content from Fagerberg and Ekbohm (1995)

Species	Regression	R ²
<i>Metabolisable energy content, y_e, MJ (kg [DM])⁻¹</i>		
<i>First harvest</i>		
Red clover	$y_e = 10.53 - 0.0306x + 0.000022x^2$	0.92
Timothy, meadow fescue	$y_e = 11.30 - 0.0860x + 0.000980x^2 - 0.001z$	0.76
<i>Second harvest</i>		
Red clover	$y_e = 10.46 - 0.0270x + 0.00004x^2$	0.85
Timothy, meadow fescue	$y_e = 10.42 - 0.0066x + 0.0060z - 0.00018xz$	0.71
<i>Crude protein content, y_p, % [DM]</i>		
<i>First harvest</i>		
Timothy, meadow fescue, red clover	$y_p = 15.48 - 0.256x + 0.047z + 0.091u - 0.0005xz - 0.0004zu$	0.93
<i>Second harvest</i>		
Timothy, meadow fescue, red clover	$y_p = 19.28 - 0.330x + 0.002x^2 + 0.015z + 0.037u + 0.001xu$	0.87

x, number of days after May 25 in the first growing period or after July 15 in the second growing period.

z, N fertilisation (kg ha⁻¹); *u*, clover content (%).

*R*², coefficient of determination.

[N] ha⁻¹ to first harvest and with 50 kg [N] ha⁻¹ to second harvest according to recommendations for mixed leys (Swedish Board of Agriculture, 2003). No fertilisers were applied to the organic leys.

2.1.2. Valuation of forage

For both conventional and organic forage the method for valuing the forage was as follows.

- For the forage qualities of 10.5 and 10.0 MJ (kg[DM])⁻¹, feeding plans were calculated for conventional and organic milk production meeting current regulations as well as nutritious requirements (Table 2).
- The later harvested forage of 10.0 MJ (kg[DM])⁻¹ was assumed a standard price of 0.118 € (kg[DM])⁻¹.
- The yearly cost of fodder ingredients and milk income was calculated for the fodder plan based on the forage with 10.0 MJ (kg[DM])⁻¹.
- The resulting revenue (milk income minus fodder cost) of the fodder plans with forage of 10.5 and 10.0 MJ (kg[DM])⁻¹ was set to be equivalent.
- The cost of all other fodder ingredients and milk income known, the economic value of the earlier harvested forage could be calculated and further used when calculating timeliness factors.

The feeding plans calculated (Table 2) were designed to be based on forage, not concentrates which would have to be bought from outside the farm. The milk yields from the designed fodder plans agree with average values for Sweden (Swedish Dairy Association, 2004). Using the forage from first harvest of 10.5 MJ (kg[DM])⁻¹ resulted in a fodder plan producing a

yearly milk yield of 9181 kg Energy Corrected Milk (ECM) and 8876 kg ECM per cow for conventional and organic production, respectively. Whereas the conventionally fed cows could be fully compensated for lower forage quality by feeding concentrates, with no milk yield loss as a result, organic forage of lower quality resulted in decreased milk yield. The early second organic harvest (10.5 MJ (kg[DM])⁻¹) had a very high protein content, which restricted the use of the forage. One reason for the high protein content is high clover content in organic forages since no chemical fertiliser is added. As a consequence of the high protein content, expensive organic beet pulp must be bought, with the result that it is economically more favourable to delay the harvest. The timeliness factor for the second organic forage harvest was therefore calculated with forage harvested later at energy contents 10.0 and 9.5 MJ (kg[DM])⁻¹. It was assumed that milk composition and consequently milk price, 0.30 and 0.35 € (kg[ECM])⁻¹ for conventional and organic respectively, was not affected by the feeding strategy.

Table 3 presents the time of harvest and corresponding energy and crude protein contents resulting from the regressions of Fagerberg and Ekbohm (1995) mentioned in Table 1. Table 3 also presents the calculated economic value of the forage in € (kg[DM])⁻¹. By multiplying with the yield of the individual harvest, the forage value can also be expressed in € ha⁻¹. From the difference in value between forage harvested at different energy contents (Table 3) the corresponding amount of forage in of high quality (kg[DM] ha⁻¹) was calculated by dividing with the forage value. Timeliness factors were then calculated by division with the number of days between the harvests, also mentioned in Table 3. In this

Table 2
Calculated fodder plans for conventional (CON) and organic (ORG) first and second harvest of silage of varying energy contents

Energy content, MJ (kg [DM]) ⁻¹	Silage, kg [DM] yr ⁻¹	Barley, kg [DM] yr ⁻¹	Beet pulp, kg [DM] yr ⁻¹	Protein concentrates, kg [DM] yr ⁻¹	Minerals, kg yr ⁻¹	Milk yield, kg [ECM] yr ⁻¹
<i>Conventional (CON)</i>						
<i>First harvest</i>						
10.5	3355	1924	193	851*	63	9181
10.0	3065	1945	266	1022†	39	9181
<i>Second harvest</i>						
10.5	3355	1924	193	851*	43	9181
10.0	3065	1945	266	1022‡	38	9181
<i>Organic (ORG)</i>						
<i>First harvest</i>						
10.5	3935	1757	305	500§	34	8876
10.0	4002	1478		678¶	20	8113
<i>Second harvest</i>						
10.0	3986	1711		494§	35	8113
9.5	3599	1630	357	481§	35	7747

*Concentrate *Unik 12* containing 290 g [crude protein] (kg [DM])⁻¹.

†Concentrate *Unik 52* containing 290 g [cp] (kg [DM])⁻¹.

‡Concentrate *Unik 32* containing 329 g [cp] (kg [DM])⁻¹.

§Concentrate *Smörboll* containing 389 g [cp] (kg [DM])⁻¹ and concentrate *Akleja 50* containing 348 g [cp] (kg [DM])⁻¹.

¶Concentrate *Akleja 50* containing 348 g [cp] (kg [DM])⁻¹.

Table 3
Data obtained from the forage field trials and from the valuation of forage for feeding of dairy cows, used to estimate timeliness factors for silage harvest

Harvest no.	Time of harvest, day no.	Energy content, MJ (kg [DM]) ⁻¹	Crude protein content, g (kg [DM]) ⁻¹	Value forage, € (kg [DM]) ⁻¹	Value forage, € ha ⁻¹	Difference in value, € ha ⁻¹	Corresponding amount of forage, kg [DM] ha ⁻¹
<i>Conventional (CON)</i>							
1	153	10.5	182	0.129	581	49	375
1	163	10.0	152	0.118	532		
2	207	10.5	183	0.141	423	68	481
2	235	10.0	127	0.118	355		
<i>Organic (ORG)</i>							
1	151	10.5	178	0.182	691	242	1327
1	164	10.0	146	0.118	449		
2	221	10.0	163	0.190	476	180	946
2	244	9.5	137	0.118	296		

study timeliness factors were calculated for the south-central part of Sweden. The conventional yield (7500 kg [DM] ha⁻¹) corresponded to the standard yield for central Sweden (Svealands Slättbygger) with 60% of the yearly yield on first harvest (Statistics Sweden, 1997). Organic forage yield was assumed to constitute 85% of the conventional yield, or 6300 kg [DM] ha⁻¹ (Danielsson *et al.*, 2001; Kirner & Schneeberger, 2002).

2.2. Case study—timeliness and machine costs

To illustrate the use of the timeliness factors and the effect on farm production costs of considering timeliness

costs, timeliness and machinery costs were calculated for forage production on a dairy farm in Uppsala (59.8°N, 17.7°E), which was assumed to be typical of dairy farms for the south-central part of Sweden.

Two systems were compared; conventionally (CON) and organically (ORG) produced forage to cover the annual need of 60 dairy cows plus replacement stock (culling rate was 33%) according to fodder plans designed for this study. The yearly forage requirement, including a reduction of 1000 kg DM per cow due to grazing in the summer, was estimated from the fodder plans calculated in this study and constituted 219 and 264 t DM for cows with recruitment for conventional

Table 4
Data specifications for field and machinery used in this study of conventional (CON) and organic (ORG) milk production

	CON	ORG
<i>Field specifications</i>		
Required area, forage production, ha yr ⁻¹	29	42
<i>Machine specifications</i>		
Field efficiency, forage wagon 1st harvest, %	46	45
Field efficiency, forage wagon 2nd harvest, %	44	42
Field efficiency, mower-conditioner, %	55	55
Time for unloading forage wagon, h	0.028	0.028
Time for loading silo, distribution, packing, h	0.44	0.44
Gross capacity mower-conditioner, ha h ⁻¹	1.8	1.8
Gross capacity forage harvester 1st harvest, ha h ⁻¹	1.0	1.2
Gross capacity forage harvester 2nd harvest, ha h ⁻¹	1.7	1.6
Gross capacity wheel loader 1st harvest, ha h ⁻¹	1.3	1.5
Gross capacity wheel loader 2nd harvest, ha h ⁻¹	1.9	2.3

and organic production respectively, when a 15% DM loss during harvest, conservation and storage was considered (Thylen & Wiktorsson, 1992). The forage was preserved as silage in bunker silos with two harvests per season. Table 4 presents the base scenario, *i.e.* field and machinery data for harvest with a set of machinery consisting of a mower-conditioner (cutting width 3.2 m), forage wagon (35 m³) and a wheel loader.

2.2.1. Calculation of timeliness costs

Timeliness costs for the forage harvest on the case farm was calculated using a method based on mixed integer programming, originally developed by Nilsson (1976). The method was previously used to study the machinery system on a crop production farm by Gunnarsson and Hansson (2004) and on approximately 300 farms by Nilsson (1987). Annual machinery costs are calculated by optimisation of the objective function Z , including timeliness— and labour costs, defined by:

$$Z = \mathbf{c}\mathbf{x} + \mathbf{d}\mathbf{y}, \quad \mathbf{x} = [x_1 x_2 \dots x_n], \quad \mathbf{y} = [y_1 y_2 \dots y_j] \quad (1)$$

where: \mathbf{x} is a vector with binary decision variables indicating if a machine is included in the studied solution ($x_j = 1$) or not ($x_j = 0$), and n is the number of machines to choose among for the optimal solution. The \mathbf{y} vector contains continuous decision variables, defined for each crop, indicating the delay of operation dates such as harvesting compared with the optimal dates for each crop and j is the total number of such events. The \mathbf{c} vector defines the annual costs, including labour, in € for each machine if included in the optimal solution and the \mathbf{d} vector defines the timeliness costs in € day⁻¹ for each day's delay of the operation.

The timeliness costs are divided into two components in the model. The first part of the total timeliness costs is

calculated on the whole area of each crop before an operation starts and is included in the \mathbf{d} vector. The calculation of the second part of the timeliness costs is different. Once the operation has started, for example harvesting, the area not harvested, and thereby still causing timeliness costs, decreases with a factor related to the capacity of the machine. Since these parts of the timeliness costs are related only to the capacity of the studied machine, they are included in the annual cost for the machine, which is described in the \mathbf{c} vector.

Since the aim of this case study was to exemplify the use of the timeliness factors calculated, the forage harvest alone was studied and it was assumed that no other operations competed for resources during the forage harvest, which is particularly true for first harvest. Consequently the harvest was assumed to start on the day that the specified quality was reached and the timeliness costs after the operation has started (S) was calculated in € according to a formula by Gunnarsson and Hansson (2004):

$$S = \sum_{i=1}^m \left(\frac{n_i - 1}{2} \right) k_i p_i l_i n_i \quad (2)$$

where: m is the number of crops to be harvested; n_i is the average number of days to perform the operation (including days that are not workable) on crop i ; k_i is the average area of crop i harvested per day in ha day⁻¹ (also including not workable days); l_i is the timeliness penalty in kg ha⁻¹ day⁻¹ for crop i ; and p_i is the price in € kg⁻¹ of the crop involved. The parameter n_i is calculated by:

$$n_i = \frac{A_i}{BPC} \quad (3)$$

where: A_i represents the total area of the crop; B represents the number of work hours per day; P

represents the workday probability; and C represents the gross capacity of the machine in ha h^{-1} (Table 4). Workday probability was determined from weather data from Uppsala between the years 1980 and 1999. Days without precipitation were considered workable and resulted in a workday probability of 71% for first harvest (May–June) and 63% for second harvest (July–August).

2.2.2. Calculations of machine costs

The machinery chain chosen for the base scenario functioned more effectively when two people were available to do the work but it was also possible, with lower capacity, for one person to harvest. The base scenario included two people; one person drove the forage harvester and the other person drove the wheel loader. Forage was mowed, left in the swath for approximately 1 day to dry on the field to reach a dry matter content of 30% suitable for conservation in bunker silo (Thylen & Wiktorsson, 1992). A forage wagon picked up the forage from the field and transported it an average distance of 1 km to the farm centre where it was unloaded outside the silo. The transport distance on the field was set to 0.2 km. Subsequently a wheel loader loaded the forage into the silo, distributed it evenly followed by packing. The forage was mowed at a rate ensuring that the daily requirement of the harvest chain was covered, *i.e.* mowing was a non-limiting operation not restricting the duration of the harvest. Due to overlapping when mowing, the practical cutting width was 0.30 m less than the nominal and the field efficiency of the mower-conditioner was set to 55% (Jonsson, 1983). From Jonsson (1986), the density of forage in the forage wagons was set to $72 \text{ kg [DM] (m}^3)^{-1}$. The times for loading and unloading, mentioned in Table 4, also comes from Jonsson (1986).

Field efficiency mentioned in Table 4 is defined as the ratio between theoretical and gross capacity, excluding only major breakdowns and weather delays. Delays due to turnings, interruptions for adjustments and maintenance, and personal time was accounted for as a percentage reduction of the effective capacity (theoretical capacity reduced due to overlapping) (Jonsson, 1986). The gross capacity also account for the time needed for transport of the forage to the silo. The time for turnings was decided as a function of the average distance between each turning, in this study set to 300 m (Jonsson, 1986).

The speed for performing different machine operations was set according to normal practices. As the amount of material passing through the machine affects the speed, the speed of the forage harvester varied for first and second harvest. With 12 km h^{-1} as a maximum value, Agrimach (2000) calculated the speed taking into

consideration yield, cutting width and cutting length. For the first harvest, the speed of the forage wagon was 7 and 8 km h^{-1} for CON and ORG, respectively; for the second harvest, 12 km h^{-1} for both CON and ORG. Mowing was at a speed of 10 km h^{-1} . The speed was set to 23 and 11 km h^{-1} for transport on the road and field, respectively.

Direct machine costs, including both fixed and variable costs, were calculated for the mower-conditioner and the forage harvester with conventional methods using parameters from ASAE (ASAE Standards, 2000b). The parameters used were as follows: depreciation, interest, taxes/insurance, shelter, fuel and maintenance. Machine depreciation was calculated using the straight-line method with the salvage value obtained from a programme for advisors (Stank, 1999); it varied between 15% and 25% of list price depending on age and annual use. Maintenance costs were related to the list price of the machine and to annual use. The annual interest rate was set to 5% (Maskinkonsulenterna, 2003) and data for fuel consumption per hectare for the different field operations were taken from Lindgren *et al.* (2002). Furthermore, labour costs were included in the machine costs at 16 € h^{-1} . The work with the forage harvester was restricted to 8 h day^{-1} ; in addition, time was needed daily for mowing. A tractor of 90 kW was used for all field operation and charged at cost of 13 € h^{-1} excluding fuel (Maskinkalkylgruppen, 2004). The wheel loader was charged at a cost of 27 € h^{-1} including fuel (Maskinkonsulenterna, 2003).

3. Results

3.1. Timeliness factors

The timeliness factors calculated in this study were highest in the first harvest, particularly in organic forage production (Table 5).

3.2. Timeliness and machinery costs

As a result of higher timeliness factor and larger area needed for forage production the farm studied had seven times higher timeliness costs in organic forage harvesting compared with conventional. Direct machine costs were only 10% higher in organic forage production compared with conventional and organic forage production, whereas labour costs were 33% higher in organic production, due to the larger forage area needed. Figure 1 shows the cost distribution calculated per hectare for conventional and organic production.

Table 5
Timeliness factors for conventional and organic forage harvesting

Production method	Harvest no.	Timeliness factor, kg [DM] ha ⁻¹ day ⁻¹	Timeliness factor, % day ⁻¹
Conventional	1	38	0.83
	2	17	0.57
Organic	1	102	2.7
	2	41	1.7

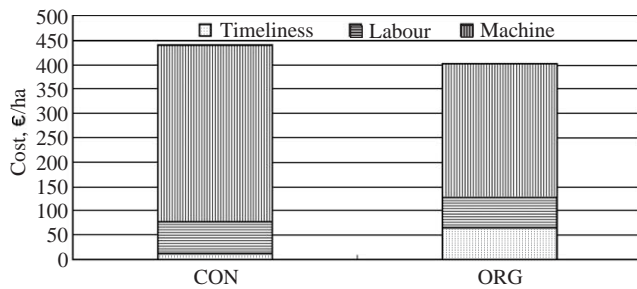


Fig. 1. Costs per ha forage in the base scenario for the conventional (CON) and organic (ORG) production systems

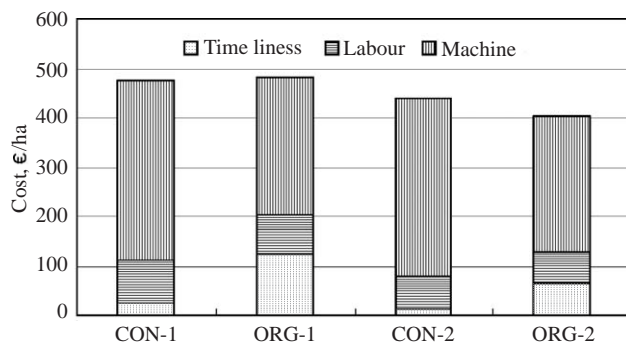


Fig. 2. Costs per ha in the base scenario for the conventional (CON) and organic (ORG) production systems with one or two workers

3.2.1. Number of workers

The harvest capacity depended on the number of people available for the harvest. For some farms where the availability of workers is limited the machinery system studied here allow the harvest to be done by only one person, but with decreased capacity. Only one person harvesting alone increased the timeliness costs to the double (CON 104% and ORG 89%); nevertheless, the total costs only increased by 8% and 19% for conventional and organic production, respectively (Fig. 2).

Reducing the number of workers in first harvest to one worker decreased the capacity of the conventional forage harvester from 1.02 to 0.57 ha h⁻¹ since the worker transporting forage had to stay, unload, change to the wheel loader to load the silo and pack before

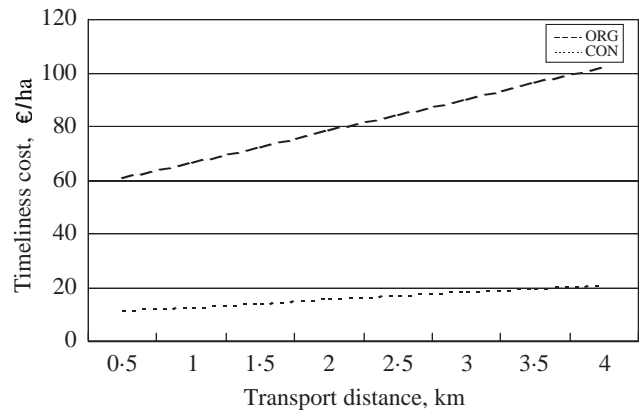


Fig. 3. Timeliness costs when the transport distance field to farm varied between 0.5 and 4 km

driving back to the field. The corresponding values for the harvester of the organic forage were 1.16 and 0.66 ha h⁻¹. Moreover the duration of the whole forage harvest increased; first harvest lasted 4 days (79%) and 5 days (76%) longer for conventional and organic forage, respectively.

3.2.2. Distance field to farm

As expected, increasing the distance between farm and field negatively influenced the harvesting capacity and consequently also costs for harvesting. In particular timeliness costs increased with increasing distance (Fig. 3).

4. Discussion

Since the timeliness factors calculated in this study are intended to be used in linear models such as the MIP-model developed by Nilsson (1976), the yield loss caused by late harvest is assumed a linear function of time. This choice is based on the assumption that the linear function is a reasonable good estimation of the non-linear reality. In ASAE Standards (2000a) timeliness costs are also considered to be linearly dependent on the time between the optimal and the actual time for harvesting. However, Witney (1995) suggests that the

yield loss function is non-linear, which means that depending on how delayed one is from the optimum time, the use of the timeliness factors calculated in this study over- or underestimate the timeliness costs.

Timeliness, *i.e.* harvesting with high capacity at the optimal time, is especially important in organic silage production. The main reasons for the differences in timeliness costs between conventional and organic silage production are feeding restrictions due to regulations, in some cases leading to changed milk yield. This study showed that timeliness costs affected the total revenue for silage production, especially in organic production where they were similar to labour costs.

This study also showed that the majority of the timeliness costs (76%) come from the first forage harvest since the first harvest yield is higher and since the development of the forage is faster early in the season.

It is assumed that the harvest starts on the optimal day but due to variations between years, the crop development varies and hence also the optimal time to harvest for a specific nutrient content. In this study mean values from crop development experiments were used. The curve for mean values derived from regression analysis of the different years and sites are flatter with respect to time compared with individual years (Witney, 1995).

The operation with the lowest capacity decides the duration of the whole harvest, which means that timeliness costs are sensitive to parameters influencing the capacity. This study showed that when the harvest had to be done by one person instead of two, the timeliness costs increased by about 100%. Increasing the transport distance from 1 km to 3 km increased timeliness costs by 42% and 35% for conventional and organic forage harvest, respectively.

The timeliness factors calculated in this study can be compared with findings of Axenbom *et al.* (1988), who found a timeliness factors for the same area of 200 and 90 kg ha⁻¹ day⁻¹ for first and second harvest, respectively. This is higher than the result of this study; however, Axenbom *et al.* (1988) state that their findings are based on very few field trials and are therefore subjected to uncertainties. As a comparison Schuler and Frank (1991) state a timeliness factor of 1.0% day⁻¹ for a mower-conditioner and 2.8% day⁻¹ for a forage harvester, whereas the organic timeliness factors calculated in this study lies in-between. In contrast Hunt (1995) states a timeliness factor of only 0.1% day⁻¹ for green forage harvesting under American conditions.

Since silage normally is not traded it is more difficult to put an economic value on silage than, *e.g.* cereals (Doyle & Topp, 2004). The method used in this study to estimate the value of silage estimated the actual value by considering the fodder plan and theoretical milk yield

achieved using silage of a specified quality. Doyle and Topp (2004) estimated the silage value to 0.175€ (kg[DM])⁻¹ organic grass-red clover silage using a valuation method where the actual value was estimated from observed experimental responses in terms of milk yield. The estimate from Doyle and Topp (2004) agrees with the value estimated for organic silage in this study.

5. Conclusions

This study shows that timeliness costs are similar to labour costs and therefore need to be considered when looking at the total revenue of organic silage production. Calculated per ha forage, timeliness costs were five times higher in organic compared with conventional production.

Mainly as a consequence of the higher value of forage due to feeding restrictions and decreased milk yield, the timeliness factors were three times higher in both first and second harvest of organic forage, compared with conventional forage harvest. In other words, 14 and 5€ ha⁻¹ day⁻¹ more are being lost in organic compared with conventional forage at delayed first and second harvest, respectively.

The operation with the lowest capacity decides the duration of the whole harvest, which means that timeliness costs are sensitive to parameters influencing on the capacity. This study showed that when the harvest was undertaken by one person instead of two, the timeliness costs doubled. Increasing the transport distance from 1 km to 3 km increased timeliness costs by 42% and 35% for conventional and organic forage harvest, respectively.

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