Economic effectiveness of mulching machines operations

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ABSTRACT: The paper deals with main factors influencing the decision on machine innovation. The machine is chosen on the basis of technical and economic parameters, way of utilisation and external economic conditions of the agricultural enterprise. The paper presents a model solution to the choice of an appropriate machine set for mulching of inter-rows in orchards and vineyards on 5 sets determined for identical operation.

Keywords: vineyards; machine sets for mulching; minimal operation; operational costs

A shift in ecological perception and availability of suitable mechanisation enable to make the first step from conventional to integrated growing. This generally leads to trends of utilisation of technological processes with grassing down of the earth in vineyard cultivation (SEDLO 1994; COOMBE 1993).

The advantages resulting from grassing down of the inter-row space are focused particularly on a reduction in working costs and fuel consumption. The agro-technical effect is also very favourable (VANEK 1996):

- grassing down of the inter-row space almost removes soil erosion and strongly reduces nutrient leaching,
- continuous grass cover creates the sufficiently solid and flexible earth resistant to the traffic of tractor wheels even in the period of intensive rainfalls without risk of great compaction and damage of the soil structure in the row, which enables to carry out spraying and harvest in time,
- from the aspect of vegetation nutrition the green matter of mulching is an effective substitution for farmyard manure and provides a permanent source of humus,
- grassing down is also the first step to ecological viticulture and creates conditions for the use of products of biological protection and prevention.

Generally, 3 variants of technologies are applied in viticulture:

- grassing down on the whole area (suitable mainly for soils threatened by erosion with at least average total amount of rainfall),
- grassing down of every other row, i.e. a frequently used variant enabling partial cultivation of strips around the plants, traffic of machines even under unfavourable conditions (after rain) at simultaneously lower competition of grass cover (suitable for arid areas with lower total amount of rainfall, a major drawback is the need of 2 mechanised operations – cultivation, mulching),
- grassing down of the inter-row space with mechanical cultivation of strips around the plants, i.e. a modern variant used also in this country enabling to exclude band spraying of herbicides. It is replaced by mulching of the inter-row space, and cultivation of strips around the plants is provided by mechanisation equipped with swinging units (both operations can be combined but a high-performance tractor should be used).

The machines for mulching are called mulchers. Their operating units mulch the aboveground parts of plants, crush and spread them on the earth. The construction design of some mulchers enables their use for vine chipping placed after cutting in the inter-row space.

The main requirements for mulchers are (WALG 2000; ZEMÁNEK 1998):

- perfect crushing of aboveground plant parts,
- easy adjustment and maintenance of the rotor operating height,
- regular spreading of crushed matter on the earth,
- simple exchange of operating units (for crushing or mulching) and processing of all matter placed in the inter-row space,
- easy attachment to the tractor.

The aim of this paper is to assess and determine minimum justified annual utilisation of mulching machines of various manufacturers from the economic aspect. A prerequisite was maximum objectification of input data determined by monitoring of these machines under comparable conditions of viticultural enterprises.

The published results are a part of the Research Project Mendel University of Agriculture and Forestry, Brno, Faculty of Horticulture, No. MSM 435100002.

MATERIAL AND METHODS

Mulchers are classified according to the operating units:

- **Mulchers with vertical axis of rotation,** consisting of 2–3 rotors fitted with overhung knives (or hammers or chains) with the vertical axis of rotation. These machines are exclusively used for mulching of green matter and can be aggregated with standard vineyard tractors or small tractors.
  An advantage of the vertical axis construction is mainly lower total weight of the machine and lower energy consumption (by 40–50%) in comparison with crushers with the horizontal axis of rotation at the same working width. A drawback is the more complicated construction of mulchers with wider working width (need of 2–3 rotors).
- **Mulchers with horizontal axis of rotation,** where the operating unit is a horizontally mounted robust rotor with rotary fitted operating units – knives or hammers of different shape. The most frequently used operating units are curved knives, double curved knives, massive hammers with normal or toothed edge. Some types are equipped with laterally sliding frame enabling the operating unit to approach the strip around the plant.

In technological processes with grassing down triple mulching is normally assumed during the vegetation period. Machines with the horizontal axis of rotation are versatile and are used either for mulching or for vine chipping. It only requires to exchange the operating units. This approach enables better annual utilisation of these machines.

Under operational conditions of viticultural enterprises of the Velké Pavlovice viticultural area the investigation was focused on mulchers with the horizontal axis of rotation. For mulching of the grassed inter-row space at medium spacing of vineyards (2.5 × 1.0 m) these machine sets were verified (Table 1).

The methodology for time-sharing record measuring (ČSN 4701 20 *Structure of machine operational time*) was used for evaluation. Further, fuel consumption was investigated (l/h; l/ha) by fuel filling to the fuel tank by means of a measuring cylinder of 2000ml volume with the uniform acreage of cultivated area (1 ha).

The values of the percentage utilisation of engine output (V_m) were calculated from the relationship for fuel consumption (S_h) as presented by (SYROVÝ 1997).

$$S_h = (5.055 + 23.37 \frac{V_m}{100}) \cdot \frac{P_m}{100} \cdot \frac{S_m}{250} \qquad \text{(l/h)}$$

$$V_m = \frac{100}{23.37} (S_h \cdot \frac{100}{P_m} \cdot \frac{250}{S_m} - 5.055) \qquad (\%)$$

where: S_h – fuel consumption per hour (l/h),
P_m – nominal output of tractor engine (kW),
S_m – specific fuel consumption (g/kW/h).

For the presented parameters (output, fuel consumption, motor output utilisation) arithmetic means and standard deviations were calculated from total measurements for each set. Besides the arithmetic means of evaluated parameters limits of confidential intervals were also determined (for significance level $\alpha = 0.05$). The results of output and fuel consumption for 5 sets investigated in operational conditions and their statistical evaluation are presented in Table 2.

To ensure that model calculations will take into account practically achieved parameters to the largest extent, the values from the range of these confidential intervals were used to calculate the operational costs of the machine sets.

Model calculations of the operational costs were carried out for five machine sets for vineyard mulching. For the reason of comparability of results these sets were built of one type of power vehicle (tractor Z 5213) and five different types of mulchers of identical output but different purchase price. The database programme AGROTEKIS was used for model calculations (ABRHAM 2002).

Using the programme AGROTEKIS these additional values were included:

- engine output utilisation 42% and 55% (interval limits),
- fuel consumption 8.12 l/ha (mean value),
- performance of machine sets 0.65 ha/h (mean value),
- annual tractor utilisation 1000 h/year (utilisation in a medium-size or larger viticultural enterprise),
- mulcher annual utilisation 100–600 h/year (utilisation in a medium-size or larger viticultural enterprise),
- price of mulching on the market of services was determined on the basis of research in Velké Pavlovice area in 2003 on the level of 600 CZK/ha (calculations of operational costs of model sets are without costs of operators, thus the price of services is also presented without costs of operators. Therefore different costs

Table 1. Mulching sets verified under operational conditions

Tractor	Manufacturer	Type
MT 8-150.32	INO	MMT 130
Zetor 5211	Hammerschmied	FU
Zetor 5211	UNI	160
Zetor 5213	Agrimaster	KP 1500
Zetor 5213	Hammerschmied	EU

Table 2. Summarised survey of average values of parameters investigated in machine sets

Tractor	Mulcher set	Tractor engine output (kW)	Number of measurements	Output (ha/h)	Fuel consumption (l/h)	Fuel consumption (l/ha)	Engine output utilisation
MT 8-150.32	INO MMT 130	24	10	0.54	4.6	8.5	0.50 (50%)
Zetor 5211	Hammerschmied FU	33.1	8	0.66	5.1	7.7	0.45 (45%)
Zetor 5211	UNI 160	33.1	12	0.70	5.4	7.7	0.49 (49%)
Zetor 5213	Agrimaster KP 1500	33	5	0.74	6.1	8.2	0.57 (57%)
Zetor 5213	Hammerschmied EU	33	7	0.59	5.0	8.5	0.43 (43%)
Arithmetic mean		–	–	0.65	5.24	8.12	0.49 (49%)
Standard deviation		–	–	0.07	0.50	0.36	0.05
Confidential interval (Student t-distribution, $\alpha = 0.05$)		–	–	0.55–0.75	4.55–5.94	7.62–8.62	42.35–55.41

of operators in the enterprises of agricultural primary production and services are eliminated).

RESULTS AND DISCUSSION

The result of calculations for compared model mulching sets is fixed, variable and total operational costs for the tractor (tractor utilisation is considered 1,000 hours per year), and variable, fixed and total operational costs for individual types of mulchers (for all types uniform real utilisation from 100 to 500 hours per year was used).

Resultant total costs for individual machine sets and their dependence an the annual utilisation of mulcher for all assessed sets are presented in Fig. 1.

By comparing the course of operational costs for machine sets with service cost minimum economically

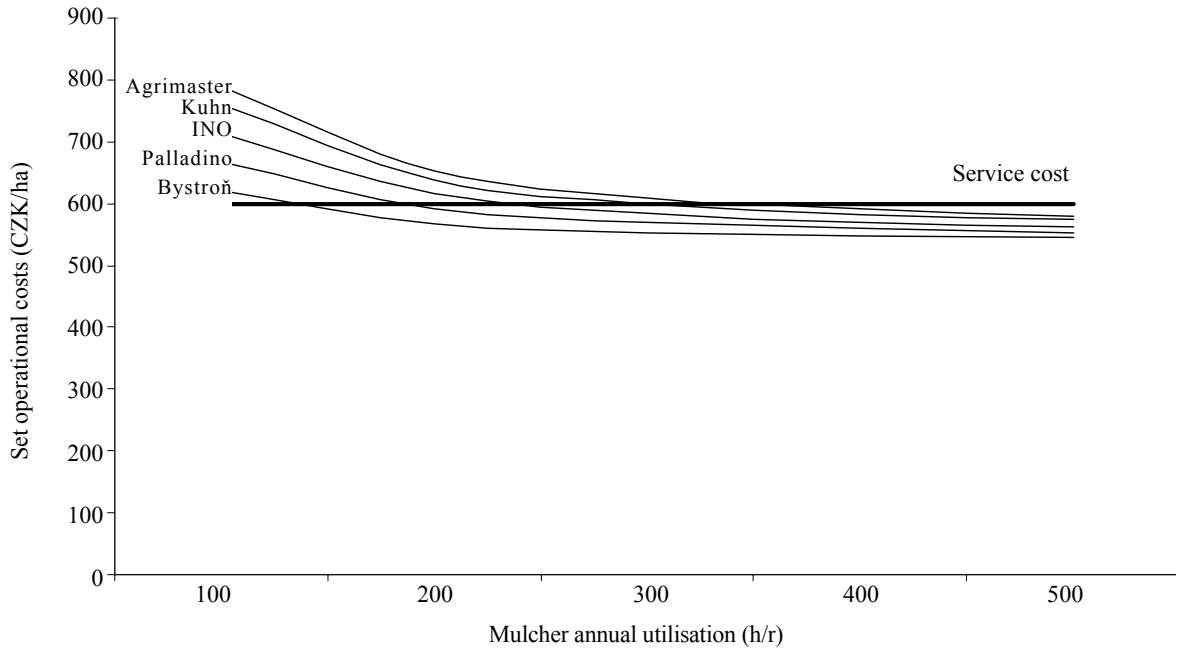

Fig. 1. Course of operational costs of machine sets for mulching (in aggregation with tractor Z 5213)

Table 3. Minimum annual utilisation of individual types of mulchers (in aggregation with the tractor Zetor 5213)

Mulchers	Purchase price (CZK)	Minimum annual utilisation (h/a)	Vineyard minimum acreage (ha) (for performance of 0.65 ha/h and for triple repetition of operation)
Bystroň 1500	50,000	138	30
Palladino TST	72,000	187	41
INO TEZ – Slovenia	93,000	250	54
Kuhn VKD 155	115,000	300	65
Agrimaster RMU 160	128,000	347	75

justified annual utilisation of sets can be determined as one of the significant bases for decisions on the machine purchase. These values that can be directly read from the graph or determined by calculation are presented in Table 3.

For individual types of evaluated mulching machines the objective basis of differences in costs of repairs and maintenance is not available, modelling calculations are therefore based on uniform norm (expressed in CZK/h). The performance of these types of mulching machines for operations in the vineyard is also considered equal (given by recommended working speed and inter-time duration). The analysis showed that the resultant economy of machine operations was significantly influenced by the machine purchase price affecting the operational costs by an increase in the fixed costs (depreciations and interest rates particularly). The user can influence these items for a concrete machine type only to a limited extent (e.g. by the choice of a dealer with lower price and way of depreciation).

The second significant factor influencing the economics of machine operation is annual machine utilisation. This factor can be influenced by the owner's (user's) decision to some extent. An increase in the annual machine utilisation leads to a reduction of fixed costs per unit of utilisation. For every type of machine certain minimum annual utilisation can be determined when total operational costs per unit of utilisation are lower than for services use.

The mulcher minimum utilisation determined by calculation can be reached in the own enterprise but also by work offer to other companies. The mulchers with horizontal axis of rotation can be more utilised by their application for vine chipping so minimum needed areas for effective utilisation are smaller.

Besides the above-mentioned main factors that are reflected directly in the machine operational costs some other factors also have to be considered for machine economics assessment regarding its utilisation and innovation. These factors are not a direct part of the operational costs but they consequently influence the production economics. One of the most important factors is machine work quality and its operational reliability (level of construction performance). Difference in the machine work quality for mulching results mostly in increased fuel consumption or necessity to repeat a certain operation.

CONCLUSION

Economics of machine utilisation and innovation depends on many factors. Objective decision in that sphere depends on the acquisition of considerable amount of information and their correct evaluation. With regard to the prices of agricultural mechanisation it is reasonable to pay attention and time to the preparation of this decision.

The mechanisation plays an important role in the economics of viticultural enterprises. A decision on the number of machines and time of their purchase belongs to the most significant and strategic decisions in every enterprise. The investment can be a source of profit but also a burden loading the economics of the enterprise. This study deals with model method of determination of minimum annual utilisation of mulchers from different manufacturers found out by research on the most objective basis.

The objective data on minimum acreage necessary for effective utilisation of the purchased machine serves for a decision on the choice of the machine price category and considerations about its utilisation in the own enterprise, offer of services to other subjects and also considerations about possible capital pooling for machine purchase. These considerations are particularly important for existing viticultural enterprises with dominating acreage from 1 to 5 ha of vineyards.

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Received for publication March 10, 2004

Accepted after corrections May 5, 2004

Ekonomická efektivita nasazení mulčovačů

ABSTRAKT: Příspěvek se zabývá posouzením efektivního využívání mulčovačů o různých pořizovacích cenách. Na základě technicko-ekonomických parametrů jednotlivých strojů byly modelovány jejich provozní náklady, které byly konfrontovány se zjištěnou cenou služeb za tuto operaci. To umožnilo stanovit minimální roční nasazení pro každou z pěti hodnocených strojních souprav. Výsledky slouží jako podklady při pořizování vhodné strojní soupravy pro mulčování meziřadí v sadech a vinicích.

Klíčová slova: vinice; strojní soupravy pro mulčování; minimální nasazení; provozní náklady

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