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Determination the volume of transport operations when harvesting wine grapes from small areas

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Abstract: - Grapes are an indispensable raw material for the production of alcoholic beverages, raisins or for direct consumption. In order to be able to process it, it is necessary to tear off the ripe grapes from the plant and transport them to the place of processing. Large arrays are processed by machine. Small arrays (mostly family heirlooms) are handpicked by family and friends. There is no data on the volume of transport operations for this organization. The volume of transport operations for a 7da vineyard is 7.675 t.km.
Keywords: - Grape, technology, transport, volume of transport operations

I. INTRODUCTION

The cultivation of areas planted with vine plants in the lands of today's Republic of Bulgaria has been known since ancient times. There are murals with painted stages of wine production - from planting young vines, by picking and transporting ripe grapes to ready -made wine. Both in ancient times and now the transport of grapes from the field to the place of processing is accompanied by the same tasks to solve, namely: the way of tearing the grapes from the vine plants; the harvest vessels and packaging used for removal; overload in a larger vehicle and transportation to the processing point. Before and now, roads on which vehicles move are the so -called dirt roads, which become difficult to pass in the spring and autumn months. Another indisputable fact that it is necessary to take into account is fluctuations in grape yields associated with climate change. Under these conditions, road transport is only possible, and in the near future it is expected to become autonomous.

Transport is a major structure-determining branch (Barbov T.S., Lambev I.D. 1976; Breshkov I. 1993; Vasilev V. 2004; Directives of the EU regarding transport policy, by types of transport; Tsankov St. 1994). According to Radkov (2005), the factors that have a direct or indirect influence on the state and development of transport can be generally defined as internal and external. External factors can be conditionally divided into global, regional and external to the transport system within the country. Internal ones in the context of international integration are of national and local importance.

According to https://eurocode.bg/... in properly arranged forms, packages or piles, the volume weight for grapes is γ=5.0 kN/m^3 = ~ 500 kg/m^3. When picking wine varieties, placing the grapes in the packages is not in a certain order, but chaotic. According to Vezirov & Kozlev (2002; 2006) grapes have a volume density of 220 to 300 kg/m^3.

The dense boxes are not overfilled, but 80 – 86 % of their volume is used so that they can be loaded on top of each other. The solid cartridges used are of the type shown in Fig. 1. The mass of an empty cartridge is m_{0k}=2.5 kg, the load capacity is 40 kg, the external dimensions are 600x400x320 mm, the capacity is 58 *l*. (q=0.058 m^3) according to the manufacturer's data (https://www.mmfruit.net/kasa-de).

Figure 1: Solid cash register dimensions 600x400x320, (source: https://www.mmfruit.net/kasa-de)

According to ORDER No. 16 of 31.05.1999 on physiological norms and rules for manual work with weights, the weight of the load does not exceed 15 kg for women and 50 kg for men for a single load when lifting, supporting, moving and carrying a distance of 2 m and 4,000 kg for women and 10,000 kg for men - total for change (https://www.gli.government.bg …)..

In his book "Advanced technological complex of machines for the production of grapes for wine", Panayotov (1988) defined different schemes for harvesting grapes. Due to the wide variety of different types of technique, none of them is applicable to date in all cases for small plantations, but only for large vineyards.

The areas planted with vines of the wine variety vary widely: from 1–2 to 10 da of farmers (most often family heirlooms) grown as a hobby to large tracts owned by alcoholic beverage factories processed mechanized and all operations are calculated in advance.

The volume of transport operations in small farms up to 10 da remains unspecified.

II. MATERIAL AND METHOD

The aim of the present study is to determine the volume of transport operations when harvesting wine grape varieties for further processing from small family farms up to 10 da.

For small vineyards up to 10 da, the technology is used: removal and distribution of empty dense cassettes in the inter-rows of rows to be picked from a trailer-platform pulled by a small vineyard tractor; manual picking of the grapes in dense cassettes; loading the full dense cassettes into a platform trailer pulled by a small vineyard tractor for removal from the interrows; reloading full dense cartridges into the body of a truck parked outside the array or pouring the full dense cartridges into larger vessels (containers) previously loaded on the truck body; loading the empty solid cartridges (just poured) onto the flatbed trailer pulled by a small vineyard tractor for return to the interrows; distributing them between the rows of the rows to be picked.

The vineyard tractor with the platform trailer moves between the rows through one. Each picker is responsible for one line. The dense cassettes are placed close to the roots of the vines so that the tractor with the platform trailer can pass.

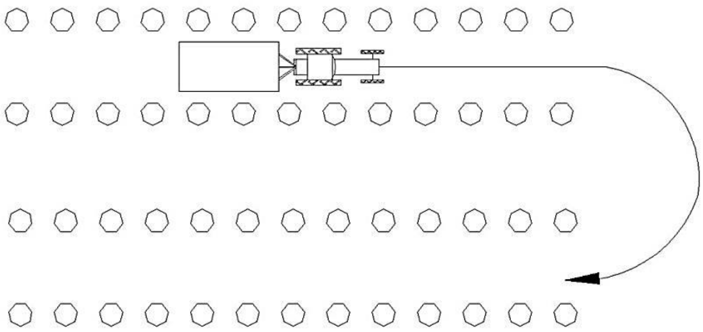

Figure. 2: Scheme of movement of a tractor with a trailer in the vineyard

When determining the transport operations, it is taken into account that the tractor with the platform trailer leaves empty from one end in the interrow. At a certain distance, the load on the trailer-platform grows, due to the fact that two full solid cassettes (one on the left and one on the right) are loaded. Next is a turn and heading into the next row. When the trailer is full and leaves the lane, it goes to the place of reloading the cartridges or dumping them into the body of a large truck. Back in the interrows, the load of the trailer-platform full of empty cartridges decreases by the same step. Two empty crates are taken down.

- *The volume of transport activities for each operation is determined by the dependence:*

$$Q = L.M, \tag{1}$$

where: Q - transport volume [t.km]; L – transport distance [km]; M – mass of transported material [t].

- *Total mass of pickers is calculated according to dependence (2):*

$$M_B = \frac{2.n_B.g_B.n_D}{1000}, \tag{2}$$

where: M_B – total mass of pickers during the grape harvest period of the given vineyard, t; n_B – number of pickers, pcs; n_D – required number of days for harvesting the vineyard, pcs; g_B – average value of the mass of one picker, kg;

According to the National Statistical Institute of the Republic of Bulgaria (https://www.nsi.bg/....), the average weight per person for the Republic of Bulgaria, considered by gender, is: men - 79 kg and women - 66 kg.

The entire family and friends participate in the grape harvest of small plots. Both male and female in a 2/1 or 3/2 male/female ratio.

Pickers are transported by private cars, 8+1 seater bus or bicycles.

Dense cartridges are filled to 80% of their volume and their usable volume is $\boldsymbol{q_1}$=0.8$\boldsymbol{q}$=0.0464 m^3;

The average mass of the harvested grapes in one cassette is: $\boldsymbol{m_{1k} = q_1.\gamma}$;

The gross mass of a full cartridge is: $\boldsymbol{m_k = m_{0k} + m_{1k}}$;

The average number of vines to fill one crate is: $\boldsymbol{n_k} = \boldsymbol{m_{1k}} / \boldsymbol{m_{loza}}$;

To fill one cassette with an inter-row distance of 1.2 m, a length of $\boldsymbol{l_k} = 1.2\boldsymbol{n_k}$ is required

From one row, the following number of cartridges are filled: $\boldsymbol{n_r} = \mathrm{int}(\boldsymbol{l_r} / \boldsymbol{l_k}) + 1$, with the last cartridge being filled to about 65% of its volume;

One row yields grapes with mass $\boldsymbol{m_r} = (\boldsymbol{l_r} / \boldsymbol{l_k})\boldsymbol{m_{1k}}$;

The required number of empty cartridges is $\boldsymbol{n_{0k}} = \mathrm{int}(1.15\boldsymbol{n_r}.\boldsymbol{n_{er}})$ where ner is the no. simultaneously operating pickers. 1.15 is an insurance factor with a larger number of cartridges to replace the damaged ones.

The total mass of the empty cartridges is $\boldsymbol{M_{0k}} = \boldsymbol{n_{0k}}.\boldsymbol{m_{0k}}$.

According to data published on the website https://izvangabaritni.bg/izvangabaritni-tovari, the permissible maximum height of all types of public transport vehicles (road vehicles) for movement on roads open to public use is 4.00 m. In order to comply with this condition, it is necessary to calculate the total height of the platform trailer and the transported cassettes. According to factory data, the height of the board of the platform trailer above the ground is $\boldsymbol{h_r}$=0.720 m. The trailer-platform has a load capacity of 1,670 kg and accommodates 15 cassettes of this type in 1 row. The cassettes are 0.320 m high (according to factory data). The number of rows of cassettes is determined by the relation: $\boldsymbol{N_{0k}} = \mathrm{int}(\boldsymbol{n_{0k}} / 15) + 1$. The height of the cassette rows is $\boldsymbol{H_{0k}} = \boldsymbol{N_{0k}}0.32$. The total height of the transport vehicle loaded with cartridges is $\boldsymbol{H}=\boldsymbol{h_r}+\boldsymbol{H_{0k}}$. If the permissible height is exceeded, it is necessary to transport the cassettes twice or to look for other ways of transporting them to and from the array.

III. RESULTS AND ANALYSI

The object of the research is a plantation with vines of a wine variety, located in the land of the village of Katunitsa, region Plovdiv, with characteristics: area – $\boldsymbol{S}$ = 7 da; row spacing – $\boldsymbol{b}$ = 2.5 m; inter-row distance – $\boldsymbol{b_1}$ = 1.2 m; number of rows – 26 pcs.; average row length – 98.52 m; average number of vines in a row – 82.1 pcs.; average amount of grapes harvested from one vine for the last year - $\boldsymbol{m_{loza}}$ = 1.8 kg. According to data from 2023, the average value of the volumetric weight of grapes is $\boldsymbol{\gamma}$ = 407.2 kg/m^3.

The vineyard in question is located 3.6 km from its owner's base.

The equipment available to the owner of the vineyard is a vineyard tractor with a platform trailer, a bicycle and a bus with 8+1 seats. 8 pickers work on the vineyard, 2 responsible for the dense cassettes and 1 driver of the vineyard tractor. 8 rows are picked simultaneously.

Using the dependencies developed in the MATERIAL AND METHOD section, the following were calculated:

The average mass of the harvested grapes in one cassette is $\boldsymbol{m_{1k}}$ = 18.9 kg;

The gross mass of a full cartridge is $\boldsymbol{m_k}$ = 21.4 kg;

The average number of vines to fill 1 cassette is $\boldsymbol{n_k}$ = 10.5 pcs.;

Length $\boldsymbol{l_k}$ = 12.6 m required to fill 1 cassette;

The average length of the rows e $\boldsymbol{l_r}$ = 98.52 m;

The following number of cassettes are filled from 1 row: $\boldsymbol{n_r}$ = 8 pcs.;

Grapes with mass $\boldsymbol{m_r}$ = 147.8 kg are obtained from 1 row;

The required number of empty cartridges is $\boldsymbol{n_{0k}}$ = 74 pcs.;

The total mass of the empty cartridges is $\boldsymbol{M_{0k}}$ = 185 kg;

The number of rows of cassettes on the platform trailer is $\boldsymbol{N_{0k}}$ = 5 pcs.;

The height of the cassette rows is $\boldsymbol{H_{0k}}$ = 1.6 m;

The total height of the transport vehicle loaded with cartridges is $\boldsymbol{H}$ = 2.32 m.

The trailer loads the harvested grapes from the 8 rows in one course and transports them to the waiting truck with 2 x 5.5 m^3 containers pre-loaded. After picking the 8 rows, the pickers have a 30 min break and move to the next 8 rows. During the pickers' break, the tractor with the platform trailer and two workers enter the interrows and load the full cassettes, following the pattern shown in Figure 2, and spread the empty cassettes to the next rows.

Sequence of operations

In the morning at 6:30 a.m. 1 cyclist and a vineyard tractor with a trailer-platform loaded with 74 empty cassettes driven by 1 driver leaves from the base in the village of Katunitsa, to the vineyard. At 7:00 a.m. bus 8+1 seats, together with 8 pickers and 1 driver (the owner of the vineyard) departs from the base to the vineyard. After the arrival of the van with the pickers, there is 15 min - organizational time, briefing and movement to the starting points of the picking.

- Volume of transport activities for the tractor with the trailer:
  - -- From the base to the vineyard and back:

    2 x 3.6 km x 0.185 t = 1.332 t.km
  - -- When collecting full cassettes of grapes:

The tractor with the trailer moves behind the pickers and loads the full crates one after the other. Two crates with a mass of 42.8 kg are loaded every 12.6 m. The last crates loaded during the first work shift have a total mass of 36 kg. A 7.5 m long turn follows and the second working stroke begins. Already at its beginning, 2 crates with a total mass of 36 kg are loaded. After that, two cassettes with a mass of 42.8 kg are loaded every 12.6 m. Reaching the last crates of the second working run, the transport unit travels the distance of 12.6 m in the row, makes a turn of 7.5 m and enters the next row at a distance of 12.6 m until the first 2 crates are loaded. The third work move further repeats the activities as in the first. The fourth operation differs from the second in that after the last 12.6 m of the row, the unit moves another 10 m to the transport vehicle and begins unloading the full crates.

Table 1: Determining the volume of transport operations when removing full crates

1 working move - sections	Start 1	2	3	4	5	6	7	8	Turn
transport distance, km	0	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01032	0.0075
cargo loaded, t	0	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.036
load in the trailer, t	0	0.0428	0.0856	0.1284	0.1712	0.2140	0.2568	0.2996	0.3356
volume of transport, t.km	0	0.0005	0.0011	0.0016	0.0022	0.0027	0.0032	0.0031	0.002517
2 working move - sections	8	7	6	5	4	3	2	1	Turn
transport distance, km	0.01032	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0075
cargo loaded, t	0.036	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0
load in the trailer, t	0.3716	0.4144	0.4572	0.5000	0.5428	0.5856	0.6284	0.6712	0.6712
volume of transport, t.km	0.0038	0.0052	0.0058	0.0063	0.0068	0.0074	0.0079	0.0085	0.00503
3 working move - sections	1	2	3	4	5	6	7	8	Turn
transport distance, km	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01032	0.0075
cargo loaded, t	0	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.036
load in the trailer, t	0.6712	0.7140	0.7568	0.7996	0.8424	0.8852	0.9280	0.9708	1.00680
volume of transport, t.km	0.0085	0.0090	0.0095	0.0101	0.0106	0.0112	0.0117	0.01002	0.00755
4 working move - sections	8	7	6	5	4	3	2	1	To the truck
transport distance, km	0.01032	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.010
cargo loaded, t	0.036	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0
load in the trailer, t	1.04280	1.0856	1.1284	1.1712	1.214	1.2568	1.2996	1.3424	1.3424
volume of transport, t.km	0.01076	0.0137	0.0142	0.0148	0.0153	0.0158	0.0164	0.0169	0.01342

The volume of transport work when loading full crates for 4 working moves is 0.29303 t.km.

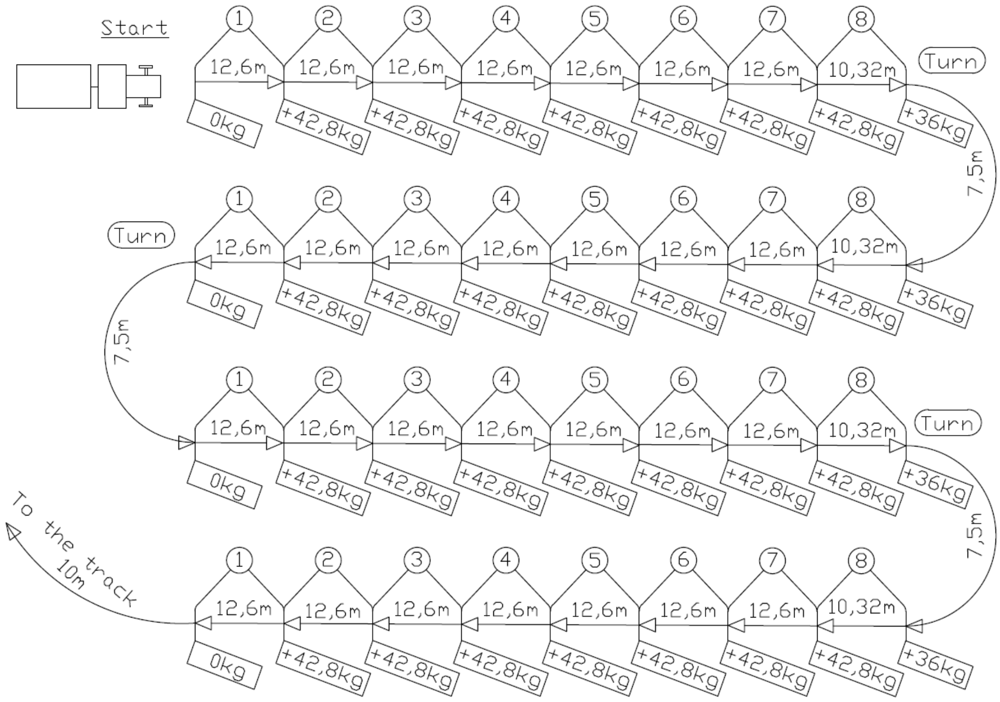

Figure. 3: Scheme of movement of a tractor with a trailer in the vineyard when loading full crates in the rows

From the graph, it is noticeable that after the end of the 1st and 3rd work shift, namely at the 8th section, full crates are loaded, a turn is made and full crates are loaded again. The distance between the full crates is equal to the length of the turn 7.5 m. While between the 2nd and 3rd working stroke the distance between two loads is 32.7 m. This is due to the fact that the vineyard is harvested from left to right.

At the last point, the distance to the truck with 5.5 m^3 containers is taken - 10 m.

The transport work diagram is mirror image of that shown in Fig. 4.

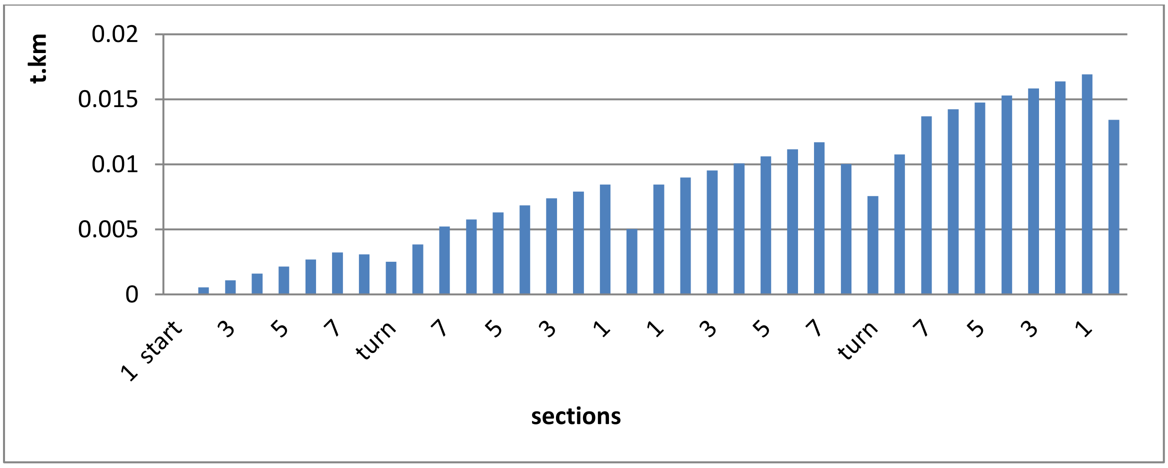

Figure 4: Change in the volume of transport operations when loading full crates from the intermediate rows

After pouring the harvested grapes, the empty crates are loaded into the platform trailer. The tractor with the trailer-platform goes to the median to deliver empty crates, and at 12.6 m they are unloaded two at a time.

Table 2: Determining the volume of transport operations when removing empty crates

1 working move - sections	from the truck	start 1	2	3	4	5	6	7	8
transport distance, km	0.01	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01032
load unloaded, t	0	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
load in the trailer, t	0.1600	0.1550	0.1500	0.1450	0.1400	0.1350	0.1300	0.1250	0.1200
volume of transport, t.km	0.0016	0.0020	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.00124
2 working move - sections	turn	8	7	6	5	4	3	2	1
transport distance, km	0.0075	0.01032	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126
load unloaded, t	0	0	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
load in the trailer, t	0.1200	0.1200	0.1150	0.1100	0.1050	0.1000	0.0950	0.0900	0.0850
volume of transport, t.km	0.0009	0.0012	0.0014	0.0014	0.0013	0.0013	0.0012	0.0011	0.0011
3 working move - sections	turn	1	2	3	4	5	6	7	8
transport distance, km	0.0075	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01032
load unloaded, t	0.005	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
load in the trailer, t	0.0800	0.0750	0.0700	0.0650	0.0600	0.0550	0.0500	0.0450	0.0400
volume of transport, t.km	0.0006	0.0009	0.0009	0.0008	0.0008	0.0007	0.0006	0.0006	0.00041
4 working move - sections	turn	8	7	6	5	4	3	2	1
transport distance, km	0.0075	0.01032	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126
load unloaded, t	0	0.0000	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
load in the trailer, t	0.0400	0.04000	0.0350	0.0300	0.0250	0.0200	0.0150	0.0100	0.0050
volume of transport, t.km	0.0003	0.00041	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001

The volume of transport work when unloading the empty crates in 4 working shifts is 0.03493 t.km. Empty crates are unloaded in the reverse order of full crates being collected.

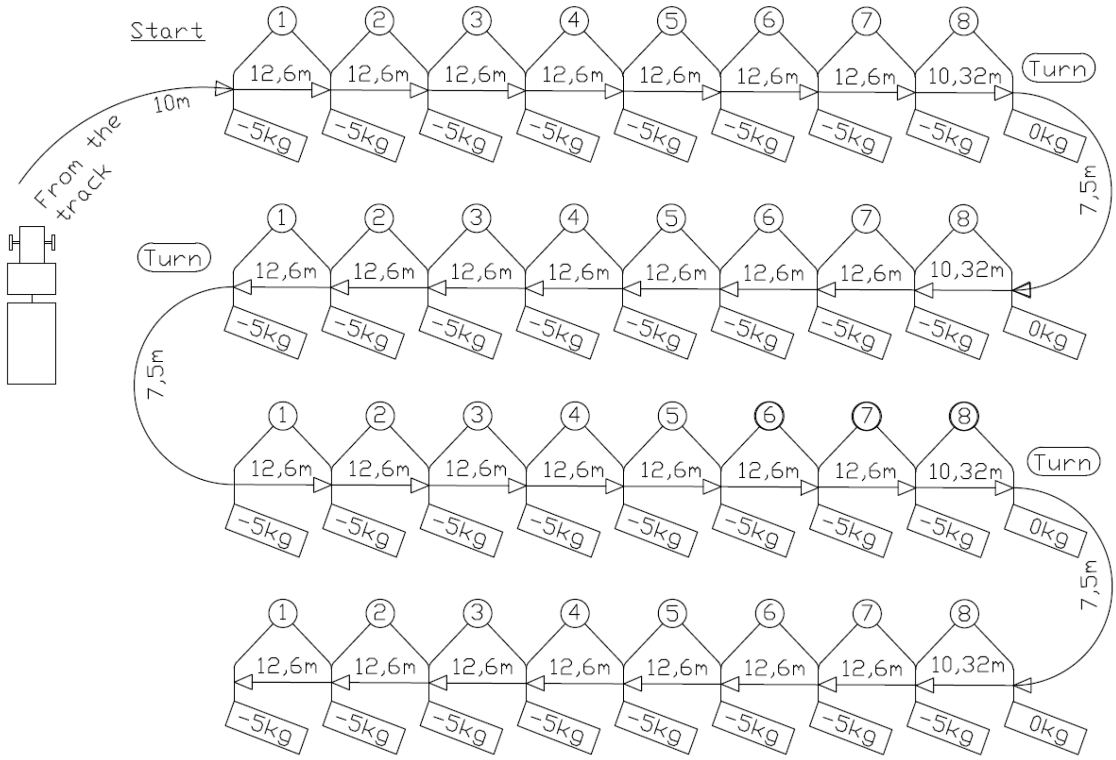

Figure 5: Scheme of movement of a tractor with a trailer when unloading empty crates in the interrows

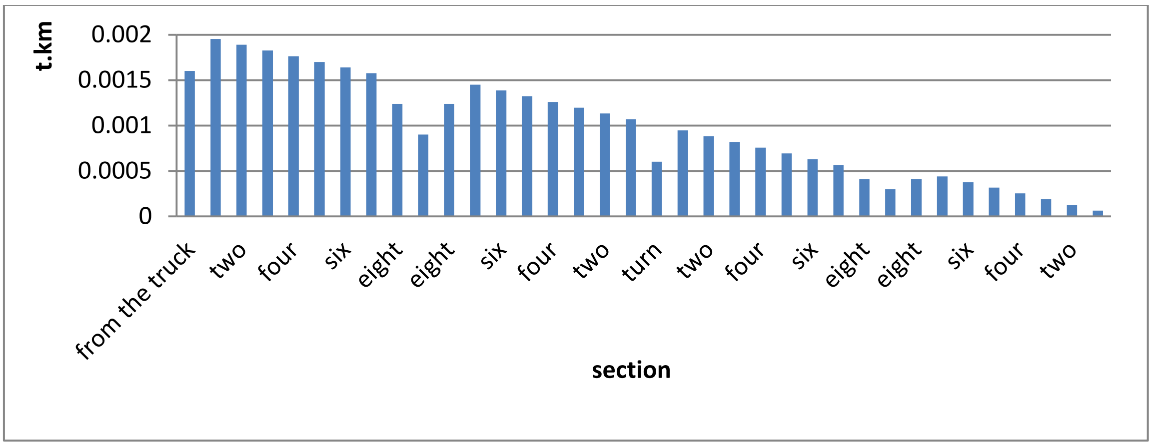

Figure 6: Change in the volume of transport operations when empty crates are unloaded in the aisles

The volume of transport work when unloading the empty crates in 4 working shifts is 0.03493 t.km.

With 26 rows, the unloading of empty and the loading of full crates is repeated 3 times as described above plus a final work move.

During the last working move, the tractor with the trailer-platform passes in the space between the two rows and unloads empty crates. He exits the aisle at the other end and waits for the tills to fill. Makes a U-turn and enters the aisle to collect the full crates. Takes them to the transshipment truck.

Table 3: Determining the volume of transport operations when unloading empty crates from the last work shift

Last work move - sections.	from the truck	1	2	3	4	5	6	7	8
transport distance, km	0.01	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01032
load unloaded, t	0	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
load in the trailer, t	0.0400	0.0350	0.0300	0.0250	0.0200	0.0150	0.0100	0.0050	0
volume of transport, t.km	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0

The volume of transport work when unloading the empty crates from the last work move is 0.002200 t.km.

Table 4: Determining the volume of transport operations when loading full crates from the last work shift

Last work move - sections.	8 start	7	6	5	4	3	2	1	to the truck
transport distance, km	0.01032	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.01260	0.010
cargo loaded, t	0.0360	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0.0428	0
load in the trailer, t	0.0360	0.0788	0.1216	0.1644	0.2072	0.2500	0.2928	0.3356	0.3356
volume of transport, t.km	0.000372	0.0010	0.0015	0.0021	0.0026	0.0032	0.0037	0.0042	0.003356

The volume of transport work when loading full crates from the last work shift is 0.022002 t.km.

- The total volume of transport work in the vineyard with:
  - full crates: 3 x 0.29303 + 0.022002 = 0.901092 t.km
  - empty boxes is 3 x 0.03493 + 0.002200 + 1.332 = 1.43899 t.km
- Volume of transport activities for the bicycle:
  The cyclist has a mass of 82 kg (0.082 t).
  2 x 0.082 t x 3.6 km = 0.5904 t.km.
- Volume of transport activities for bus 8+1 seats:
  We have 9 people in the bus - 1 driver and 8 passengers. Their ratio is 4 women and 5 men. Due to the fact that buses will be autonomous in the near future, it is correct to add the driver's mass.
  2 x (4 women x 0.066 t + 5 men x 0.079 t) x 3,6 km = 4.7448 t.km.
- The full volume of transport work when picking the vineyard is:
  0.901092 + 1.43899 + 0.5904 + 4.7448 = 7.675282 t.km.

IV. CONCLUSION

Based on the above, the following conclusions can be formulated:

1. The volume of transport operations when harvesting wine varieties of grapes from small family areas was determined.
2. From the calculations made for the considered example, it is clear that the vineyard is harvested by 8 pickers, 1 tractor driver and 2 loaders.
3. The intended two containers with a volume of 5.5 m^3 (2 x 5.5 = 11 m^3) are correctly selected.

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