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PRODUCTIVITY OF TRANSPORT AGGREGATES IN HARVESTING CORN GRAINS

SUMMARY

Transport in plant production includes the entire transport of products and raw material from the place of production to the storehouse. Participation of transport in plant production relative to the total volume of mechanized works ranges from 35-50%, which significantly affects the total production costs. Determining the optimal organization of transport, the formation of transport aggregate and transport means can affect the increase in the economy of production. The paper presents the results of research of transport aggregate and transport means for harvesting corn grains at the distance of: 1km, 10km, 15km. Based on the data processed, the most efficient transport aggregate is determined.

The results of the research of transport aggregates (A, B, C) show that they have made significant differences in the quantity of transported corn grain at different operating speeds.

At a distance of 1km, the transport aggregate (A) transported 150.4 tonnes of corn grains, with an average operating speed of 11.2 km.h⁻¹, the transport aggregate (B) transported 104.58 tonnes of corn grains with an average operating speed from 7.41 km.h⁻¹ and transport aggregate (C) transported 103.65 tonnes of corn grains with an average speed of 14.69 km.h⁻¹.

At a distance of 10 km, the transport aggregate (A) transported 27.64 tonnes of corn grains, with an average operating speed of 12.78 km.h⁻¹, the transport aggregate (B) transported 72.50 tonnes with the average operating speed of 10.75 km.h⁻¹ and the transport aggregate (C) transported 187.50 tonnes of corn grains with an average operating speed of 23.25 km.h⁻¹.

At a distance of 15 km, the transport aggregate (A) transported 19.45 tonnes with an average operating speed of 17.00 km.h⁻¹, the transport aggregate (B) transported 56.68 tonnes with an average operating speed of 15 km.h⁻¹ and the transport aggregate (C) transported 143.5 tonnes of corn grain with an average operating speed of 30.50 km.h⁻¹.

Keywords: aggregate, corn, transport, effectiveness, efficiency.

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INTRODUCTION

Transport in agriculture is an integral part of the production process from which organization the economy of production depends. Modern, intensive agricultural production as well as transport of raw materials and finished products have caused application of modern transport aggregates and transport means. The organization of transport and the formation of a transport aggregate depends on : types of products, available transport means, road network, weather conditions, productivity of harvesting and harvesting machines and warehouses. (Novaković and Đević 1999).

The share of transport in plant production in relation to the total volume of mechanized works ranges from 35% -50% (Stanimirović *et al* 2008). For these reasons, transport in agriculture, with the complete organization and synchronization of transport means, significantly affects the productivity and cost-effectiveness of production. Planning and organization of transport is difficult due to the characteristics of agricultural production and the type of products and raw materials. According to research (Čuljt 1988) in agricultural production about 80% of product transport takes place (five months) from June to November.

The design of transport means for harvesting and proper selection depends on: the number of available combines, harvesting capacity, capacity of the bunker, and the distance of the production area to the warehouse. (Tatomirović and Velimirović 1977)

MATERIAL AND METHOD

Research on transport aggregates was carried out in 2014 in the area Dervente Republika Srpska.

The research methodology is based on the analysis of the influence of the transport aggregate structure and the transport medium depending on: the distance of the production parcel, the structure of the transport aggregate and the transport means, the transport efficiency, the volume and capacity of the vehicle, the aggregate movement speed, the loading time, the transport time, the unloading time, the duration of the transport cycle, the coefficient of time shift utilization (τ_{sm}) and the efficiency of the transport aggregate and the transport means depending on the distance of the production parcel to the warehouse.

The harvesting of hybrid corn in the grains, ripening group 600, with a humidity of 30-34%, is intended for storage of silage in grain. Grain corn harvest

Based on work programs and established methods of work, organization of the harvest was based on the number of combines and their productivity. Based on the mentioned characteristics, the number and capacity of transport means was determined.

Corn grain transport was carried out by three transport aggregates, which were complemented in terms of manipulation of harvesters on the plot and during discharge. Based on the results of the research, the parameters as well as the mathematical data processing were summarized. In Table 1. the average results

of the corn grain transport from different distances, the total cycle time, the number of cycles, and the timing shift coefficient (τ_{sm}) for each transport unit are given.

The productivity of the transport aggregate depends on the proper aggregation of the tractor with the trailer and the organization of transport. The traction force of the tractor is greater than the overall resistance of the transport aggregate. (Mitrović *et al* 2014)

$$F_t > R_{or}$$

F_t – traction force of tractor,

R_{or} – overall resistance of the transport aggregate.

The total resistance of the transport aggregate on a flat terrain depends: the total weight of the aggregates, the characteristics of the tractor, the characteristics of the empty trailer, the load and the conditions of the road surface.

$$R_{or} = G_p \cdot f_t \cdot G_{ft} \cdot f_{tr}$$

G_t – tractor mass,

G_{ft} – mass of full trailer and cargo,

f_{tr} – trailer resistance coefficient,

f_t – coefficient of resistance of tractor movement.

The number of trailers that the tractor can pull can be determined based on the equation:

$$n = F_p / R_{or}$$

F_p – traction force of tractor

R_{or} – overall resistance of the transport aggregate

When assembling the tractor aggregate (tractor + trailer), the ratio of the total weight of the trailer and the weight of the tractor is important:

$$f_a = G_{ft} / G_t$$

f_a – aggregation coefficient

G_p – mass of full trailer and cargo

G_t – tractor mass

The productivity of the transport aggregate can be determined on the basis of the equation:

$$W_{ta} = G_{car} \cdot n_{cy}$$

W_{ta} – productivity of the transport aggregate

G_{car} – cargo mass

n_{cy} – number of cycles of transport aggregate.

$$n_{cy} = T_{gt} \cdot C_{ut} / t_{cy}$$

T_{gt} – total working time per day (gross time)

C_{ut} – coefficient of time use

t_{cy} – the duration of one cycle

The duration of one cycle of transport aggregate (t_{cy}) depends on: trailer load, trailer number, trailer loading time, transport time, type of substrate, unloading time and work organization, (Mitrović *et al.* 2014).

The duration of one cycle of the transport aggregate can be determined on the basis of the equation:

$$t_{cy} = t_{lo} + t_{dis} + t_{tft} + t_{tet} + t_{ch}$$

t_{lo} – loading time,

t_{dis} – discharge time (unloading),

t_{tet} – the time of empty trailer transport

t_{tft} – the time of transport full trailers

t_{ch} – checking time.

The required number of transport aggregates, in the transport of certain products and materials, depends primarily on the volume of transport and productivity (performance) of the machine transport unit, and it is determined on the basis of the equation:

$$n_{ta} = Q_{uk} / W_t$$

n_{ta} – number of transport aggregate

W_t – productivity of the transport aggregate

Q_{vt} – total volume of transport

$$n_{ta} = Q_{uk} / G_t \cdot n_{cy}$$

G_t – mass of tractor

n_{cy} – the duration of one cycle.

Coefficient of time shift utilization (τ_{sm}) for achieving technological useful work is determined based on the equation:

$$\tau_{sm} = t_{uk} / T_s$$

τ_{sm} – coefficient of time shift utilization

t_{cy} – total transport cycle duration

T_s – time of shift

Depending on the conditions and complexity of the technological process, the coefficient of time shift utilization is different. Under the test conditions, the minimum coefficient is 0.34 for the transport aggregate (C) at a distance of 1 km, while for the transport aggregate (C) the maximum is 1.0 at a distance of 10 km. At a distance of 1km, the resulting coefficient for the transport aggregate (A) was 0.72, for transport aggregate (B) was 0.44 and for transport aggregate (C) was 0.34.

At a distance of 10 km, the resulting coefficient for the transport aggregate (A) was 0.62, for transport aggregate (B) was 0.96 and for transport aggregate was (C) 1.0.

At a distance of 15 km, the resulting coefficient for the transport aggregate (A) was 0.54, for transport aggregate (B) was 0.87 and for transport aggregate (C) was 0.98.

The coefficient of time shift utilization was significantly influenced by the distance of the production plot from the economic yard, which can be concluded that the transport aggregate (A) at the distance of the production area of 1km achieved the highest coefficient.

Considering the conditions and complexity of the technological process, as well as congestion due to technical, organizational and personal character, the value of the coefficient of time shift utilization in the transport aggregate (A) was 0.72, which was characterized by the mobility and the possibility of accessing combines on the plot.

The transport cycle consists of empty driving, loading, freight and unloading. The duration of each operation is required by the time dimension (Marković, D., 1997) and can be determined on the basis of the equation:

$$t_{uk} = t_o + t_u + t_p + t_i \quad (h)$$

RESULTS AND DISCUSSION

Observing the number of cycles performed for each transport aggregate, from different distances, the result was that the transport aggregate (A) at a distance of 1km, performed 20 cycles, the transport aggregate (B) 7 cycles and the transport aggregate (C) 5 cycles.

At a distance of 10 km the transport aggregate (A) has performed 4 cycles, transport aggregate (B) 5 cycles and transport aggregate (C) 9 cycles.

At a distance of 15 km, the transport aggregate (A) has performed 3 cycles, transport aggregate (B) 4 cycles and transport aggregate (C) 7 cycles. On smaller distances, the more mobile transport aggregate (A) performed several cycles more in contrast to the vehicle (C), and in the case of a larger distance, the situation is inverted.

The carrying capacity of the transport unit, the number and structure of transport means has been affected by the duration of the transport cycle. The loading time (t_u) can be achieved by applying a self - loading trailer with a bunker that can monitor the work of the harvester and harvested grain unloading in the means of transport at the end of the parcel

Driving with load (t_l), depends on transport speed with load, distance and road network status.

Time of unloading (t_{ul}) appears as inevitability in the duration of the transport cycle, and depends on the method of discharging the transport means.

Table 2. shows the quantities of transported corn grains, from which it can be concluded that transport aggregates A, B, C transported different quantities depending on the distance of the parcels.

The transport aggregate (A), at a distance of **1 km**, transported 150.4 tonnes or 42.0% of the total 358.6 tonnes of transported corn grains. The

transport aggregate (B) transported 104.58 tonnes or 29.2% of the total, and the transit aggregate (C) transported 103.65 t or 28.9%.

Table 1. Average results: duration of the cycle, number of cycles and coefficient of time shift utilization (τ_{sm})

Transport aggregate	Duration of the transport cycle (<i>min</i>)					τ_{sm}	Number of transport cycles
	t_o	t_u	t_p	t_i	t_{uk}		
distance 1 <i>km</i>							
A	4,40	8,36	5,40	3,41	21,57	0,72	20
B	5,10	18,12	8,10	6,10	37,42	0,44	7
C	3,45	28,14	4,08	4,48	40,16	0,34	5
distance 10 <i>km</i>							
A	33,44	8,36	47,00	3,07	91,87	0,62	4
B	35,00	18,12	56,00	6,06	115,18	0,96	5
C	15,34	28,10	26,00	4,10	73,54	1,11	9
distance 15 <i>km</i>							
A	44,00	8,38	52,00	3,03	107,41	0,54	3
B	47,33	18,13	60,00	6,07	131,53	0,87	4
C	22,00	28,13	30,00	4,10	84,23	0,98	7

Table 2. Amount of transported corn per transport means

Transport aggregate	Number of transport cycles	Amount of transported corn				Percentage of participation in transport (Pup)
		By cycle (<i>t</i>)	<i>t</i>	<i>tkm</i>	<i>tkm/h</i>	
distance 1 <i>km</i>						
A	20	7,52	150,40	150,40	15,04	42,00
B	7	14,94	104,58	104,58	10,46	29,20
C	5	20,73	103,65	103,65	10,37	28,90
in total			358,63			
distance 10 <i>km</i>						
A	4	6,91	27,64	276,40	27,64	9,62
B	5	14,50	72,50	725,00	72,50	25,20
C	9	20,83	187,50	1875,00	187,50	65,25
in total			287,34			
distance 15 <i>km</i>						
A	3	6,48	19,45	291,75	29,18	8,86
B	4	14,17	56,68	850,20	85,02	25,81
C	7	20,50	143,50	2152,50	215,25	65,34
in total			219,63			

At a distance of 10 km, the transport aggregate (A) transported 27.64 tonnes or 9.62% of the total 287.34 tonnes of transported corn grains, transport aggregate (B) transported 72.5 tonnes or 25.2% of the total transported corn grains and the transport aggregate (C) transported 187.5 tonnes or 65.25% of total transported corn grains.

At a distance of 15 km, the transport aggregate (A) transported 19.45 tonnes or 8.86% of the total 219.63 tonnes of transported corn grains, the transport aggregate (B) transported 56.68 tonnes or 25.81% of total, and the transport aggregate (C) transported 143.50 tonnes or 65.34% of total transported corn grains.

The research results show that the transport aggregate (A) is more mobile than other two aggregates and at a smaller distance, transport aggregate (A) transported a larger amount of corn grains than the transport aggregate (C).

Comparing the results (Table 2) the transport aggregates efficiency is directly proportional to the increase of aggregates capacity and distance plots of the economic yard. If the productivity is expressed in (tkm/h), it is reversely proportional if the productivity is expressed in (t/h).

CONCLUSION

Presented data show that the problem of transport in agriculture is very complex and that in the current conditions of agricultural production with higher yields it becomes a brake on its further development, if it is not equipped with modern means of transportation.

At greater distances, transport with the truck in relation to the transport with tractor (tractor + trailer) has a greater advantage. At a distance of 15 km, the truck transported 65.34% while the tractor (tractor + trailer) transported 8.86% of the total quantity, which is 7.36 times more.

At smaller distances, productivity (t/h) is important because it is growing, while at larger distances it is decreasing.

The structure of the transport aggregate has shown that the transport aggregate (A) at a distance of 1km has priority over other transport aggregates for easier manipulation on the plot.

Transport means such as a container or a specialized trailer represent a better conceptual, technical and technological solution that affects transport efficiency and cost-effectiveness.

Solving the rationalization of transport, especially internal in agricultural production, is not enough to solve in the field, but it should be addressed in the warehouse and later in the production, packaging and transport to consumers.

Since transport in agriculture is specific, it is necessary to abide by the directive of the European Parliament and the Council of Europe on transport in agriculture. The influential transport factors are: the structure of the transport aggregate, the road network, the transport distances, the volume and load capacity of the transport means, the movement speed, the time of loading and unloading of the product or repro materials.

REFERENCES

- Čuljt, M. Suvremeno ubiranje žitarica i drugih ratarskih kultura. Agrotehničar, Zagreb, 1988.
- Marković, D. Transport u poljoprivredi Mašinski fakultet, Beograd, 1997.
- Mitrović, D., Railić, B., Maličević, Z., Jugović, M.(2014).: Knjiga, Mehanizacija i oprema u stočarstvu, Poljoprivredni fakultet Banja luka.
- Mitrović, D., Railić, B., Maličević, Z., Jugović, M.(2014).: Knjiga, Eksploatacija i održavanje poljoprivrednih mašina, Poljoprivredni fakultet Banja luka.
- Novaković, D., Đević, M.(1999). : Knjiga, Transport u poljoprivredi. Poljoprivredni fakultet Beograd.
- Stanimirović, N., Koprivica, R., Stevović, V., Veljković, B. (2008): Gubici pri transportu iseckane silomase kukuruza od parcele do silo objekta, Savremena poljoprivredna tehnika godina 34. broj 3-4 strana 158-162. Beograd.
- Tatomirović, M., Velimirović, S. (1977).: Knjiga, Transport u proizvodnji poglavlje V Transport, skladištenje proizvoda i rukovanje proizvodima u oblasti poljoprivredne proizvodnje. Beograd.