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VARIANTS OF CARROT PRODUCTION TECHNOLOGY AND COSTS OF MANUAL AND MECHANICAL WORKS

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ABSTRACT

Cost analysis of manual and machine works related to production of carrots was carried out in the context of supply of the fresh vegetables market for four technological variants of a varied level of works mechanization in a horticultural farm, where the surface of carrot crop was 3.67 ha. Technology based on the use of machines applied previously for agricultural production in small-area farms with a great participation of human labour was accepted as a basic carrot production technology. Based on the analysis of possibilities of using new solutions of machines in the previous production technology, variants were developed, the assumption of which was reduction of costs of manual and mechanical works. For the developed four variants of carrot production technology, incurred human labour costs and costs of machines and tools exploitation were determined. Minimal costs of human labour and machine exploitation were accepted as a criterion of selection of the best variant. 4th variant, which was characterized with the lowest costs of human labour and machines exploitation, which constituted 12,570 PLN·ha^{-1} was recognized as optimal, from among four developed and recommended for use in small area horticultural farms. Costs of human labour and machines exploitation in this variant were lower than the costs incurred in the 3rd variant by 5,100 PLN·ha^{-1}, in the 2nd variant by 9,995 PLN·ha^{-1}, and by 13,536 PLN·ha^{-1} than calculated in the 1st variant.

Introduction and the objective of the paper

Horticultural production requires high work inputs, which considerably increases its costs. In relation to the variety of cultivated plants, they are 10 to 20 times higher than for grains calculated into the area unit. Therefore, mechanization of the most labour consuming works related to field cultivation, plant protection and preparation for sale plays a significant role in the development of this production department (Hołownicki, 2006).

Production of vegetables in Polish conditions is carried out most frequently in small farms of the area not exceeding 10 hectares which prevents the use of more efficient machines and consequently a considerable part of works in this production is carried out man-

ually. Thus, in small horticultural farms which produce vegetables, labour costs, particularly of human work as well as costs of machines exploitation are a significant problem (Borcz and Kowalczyk, 1997; Kowalczuk and Leszczyński, 2006; Kowalczyk, 2003; Kowalczyk and Wnęk, 2007; Michałek and Kowalczyk, 2000).

In Poland recently, even in horticultural farms of a small acreage, a considerable progress in implementation of new, with regard to structure, machines and organizational solutions in the carrot production process is noticeable, which allows the increase of its yield from a hectare, to improve the quality of the product offered for sale, to decrease the incurred inputs and raise the efficiency of production (Adamicki et al., 2004; Kowalczuk, 2005; Kowalczuk and Leszczyński, 2005; Kokoszka and Tabor, 2006; Kurpaska and Tabor, 2006; Kaniszewski, 2007).

It justifies accepting the research assumption that in the standard technology used in the carrot production for supply of fresh vegetables market, particularly in small area garden farms, there is a possibility of reducing costs of human work and costs of exploitation of machines by organizational operations and introduction of new structure of machines.

Knowing differences in the size of costs of human and machine work in new variants of carrot production technology in comparison to recently used, may serve for assessment of usability of a given variant and recommendations to its wider use in garden production.

The objective of the research was to carry out comparative analysis of carrot production costs for supply of fresh vegetables market for four technological variants of a very diverse level of mechanization of works and determination of the optimal variant of technology of its production for use in small area garden farms.

The object and the research method

The research on costs in four technological variants of carrot production were carried out in a garden farm in 2006-2009, with total area of arable land of 9.62 ha and the area of carrot cultivation was 3.67 hectare, located in Opolskie voivodeship in the town Bobrów. Based on the analysis of the size of work inputs, occurring in the estimated technological variant starting with the basic one, subsequent variant performed in the following years were drawn up, the assumption of which was to reduce the costs of human work and exploitation of tools and machines. The characteristic of conditions for the research and methodology was presented in Molendowski et al.'s paper. (2010, 2012).

In order to determine the costs of human work and costs of machines exploitation for the prepared variants of carrot production a record of time inputs of manual and machine works for specific technological operations was maintained. Since, the farm functions within the producer's group, in which mutual availability of machines and tools for the group members occurs, accounting rate of costs for an hour of use of technical means and for human work were assumed. Based on the determined time of manual and machine works and hour rates for manual works and the use of technical means, cost of particular technological operations was determined.

From among the researched variants of carrot production technology a variant, in which costs of human work and machines exploitation reached the lowest values, should be recognized as optimal.

Characteristic of the researched technological variants of carrot production was presented in table 1. Technology based on the manual work and machines used earlier for agricultural production in small area agricultural farms was assumed as the basic carrot production technology (1st variant). Technological operations within this technology and the manner of its execution were presented in table 1. In this technology after ploughing with a 4-furrow field plough aggregated with Ursus 1212 tractor and harrowing, further treatments (fertilization, sowing, spraying) were carried out with the use of Ursus C330 tractor. Then, fertilization was carried out with the use of a suspended shield distributor and for formation of ridges a potato seeders S204. On the performed ridges, sowing of seeds was carried out with the use of a brush 2- row seeder. For chemical protection in the first variant, the sprayer Pilmet 312 of the volume of the container of 300 dm^3 was used and in the remaining variants Pilmet 400LM with a container of 400 litres.

In the 2nd, 3rd and 4th variant for field works, tractor Fendt 110 was used, with which a 4-furrow field plough was aggregated and a subsoiler, for formation of ridges – an active harrow Struik 4RF320 and for sowing seeds – a point seeder by Monosem MS company equipped with shields for sowing two rows of carrot at one ridge.

In the processes of harvesting and transport in the 1st variant, roots were ploughed and leaves were manually removed and loaded to boxes, which also were manually loaded on the supply truck of the admissible load of 1.5 tonne. Carrot was transported to a farm, where it was washed in a drum washer and then packed to 10 kilo bags. In the 2nd variant, carrot after manual collection of ploughed roots was loaded to box pallets, which were loaded to a tractor trailer with a forklift truck and then transported to further treatment performed in the 1st variant. In the 3rd variant a one-row combine Dewulf P3C purchased at the secondary market was used to wash a washing line. In the 4th variant, a new combine Dewulf P3K was used for harvesting and a washing line was equipped with a vegetable bagging unit.

Results of the research

Results of the cost research in the estimated variants of carrot production technology were presented in table 1. In the 1st technological variant, which was assumed as the first one for the small-area farms, the highest cost of human work in the process of field cultivation, sowing and treatment, is incurred on double weeding (440 PLN·ha^{-1}), operation of tools for ridges formation (143 PLN·ha^{-1}) and sowing of seeds (132 PLN·ha^{-1}). The remaining technological operations of the field cultivation, sowing and treatment, had a proportionally low participation in the total cost of human work amounting to 1006 PLN·ha^{-1} (fig. 1).

Total costs of human work in operations related to harvesting and transport of carrot are over fifteen times higher than in cultivation works, sowing and treatment and amount to 15,730 PLN·ha^{-1} (fig.1). Collecting affected so high costs of human work (6,600 PLN·ha^{-1}) and washing and packing (5,500 PLN·ha^{-1}) (tab. 1). Also costs of exploitation of machines in this variant, amounting to 8,970 PLN·ha^{-1} should be considered as high and they result from costs incurred in the field cultivation and treatment 3,670 PLN·ha^{-1} and harvesting and transport 5,300 PLN·ha^{-1} (fig. 1). Total cost of human work and exploitation of machines in the 1st technological variant amounting to 25,706 PLN·ha^{-1} (fig. 1) should be considered very high.

Table 1
The list of technological operations and costs of manual and mechanical work in the researched technologies of carrot production

Technology		Technological operation	Manner of performance	Costs of human work (PLN·ha^{-1})	Costs of machines exploitation (PLN·ha^{-1})
1	2	3	4	5	6
Technological variant – I	Cultivation, sowing and treatment	Ploughing	Tractor C1212+4-furrow field plough	38	420
		Harrowing	Tractor C1212+light harrow	44	480
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor C330+ potato planter	143	910
		Sowing of seeds	Tractor C330+2-row brush seeder	132	840
		Spraying with herbicide	Tractor C 330 + sprayer 3001	66	360
		Spraying with fungicide Double weeding	Tractor C 330 + sprayer 3001	99	540
			Manually	440	0
	Harvesting and transport	Loading of boxes	Manually	825	0
		Transport to a field	Delivery truck	440	650
		Roots ploughing	Tractor C330 + plough	275	2 000
		Harvesting and cleaning Transport from a field	Manually	6 600	0
		Unloading of boxes	Delivery truck	440	650
		Washing and packing	Manually	1 650	0
			Drum washer, manual packing	5 500	2 000
Total in technology				16 736	8 970

Technology		Technological operation	Manner of performance	Costs of human work (PLN·ha^{-1})	Costs of machines exploitation (PLN·ha^{-1})
1	2	3	4	5	6
2nd technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + subsoiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+distributor	22	120
		Formation of ridges	Tractor Fendt 110 + harrow Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+2-row brush seeder	132	840
		Spraying with herbicide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungicide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and transport	Loading of box pallets			
		Transport to a field	Forklift truck	110	400
		Roots ploughing	Tractor C330 + trailer	110	550
		Harvesting and cleaning	Tractor C330 + plough	275	2 000
		Transport from a field	Manually	6 600	0
		Unloading			
		Washing and packing	Tractor C330 + trailer	110	550
			Forklift truck	165	600
			Drum washer, manual packing	5 500	2 000
Total in technology				13 697	8 468

3rd Technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + sub-soiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor Fendt 110 + har-row Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+4-row seed-er Monosem MS	22	260
		Spraying with herbicide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungicide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and trans-	Loading of box pallets	Forklift truck	110	400
		Transport to a field	Tractor C330 + trailer	110	550
		Collection of roots	Combine Dewulf P3C	1 320	3 600
		Repeated collection of roots	Manually	550	0
		Transport from a field	Tractor C330 + trailer	110	550
		Unloading	Forklift truck	165	600
		Washing and packing	Washing line, manual packing	2 200	4 500
Total in technology				5 282	11 988
4th technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + sub-soiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor Fendt 110 + har-row Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+4-row seed-er Monosem MS	22	260
		Spraying with herbi-cide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungi-cide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and transport	Loading of box pallets			
		Transport to a field	Forklift truck	110	400
		Collection of roots	Tractor C330 + trailer	82.5	412.5
		Repeated collection of roots	Combine Dewulf P3K	330	3 200
		Transport from a field	Manually	55	0
		Unloading	Tractor C330 + trailer	82.5	412.5
		Washing and packing			
			Forklift truck	220	400
			Wash Line and bagging unit	660	3,300
Total in technology				2 257	9 913

Costs of human work in the 2nd variant achieved for field cultivation, sowing and treatment 827 PLN·ha^{-1}, harvesting and transport 12 870 PLN·ha^{-1}, and in total 13,697 PLN·ha^{-1} and were lower respectively by 179 PLN·ha^{-1}, 2 860 PLN·ha^{-1} and 3039 PLN·ha^{-1} than estimated in the 1st variant. Reduction of costs of human work in this variant were obtained inter alia as a result of the change of manual loading and unloading of boxes onto a transport mean and the use of box pallets and a forklift truck for this purpose (715 PLN·ha^{-1} and 1 485 PLN·ha^{-1}).

The use of a tractor and a low-suspension trailer for transport instead of a delivery truck proved to be advantageous since it allowed reduction of the cost of this operation from 1 090 PLN·ha^{-1} to 660 PLN·ha^{-1}.

Costs of exploitation of machines and tools in the 2nd variant for field cultivation, sowing and treatment reached 2 368 PLN·ha^{-1}, for harvesting and transport 6 100 PLN·ha^{-1} (fig.1) and in total 8 468 PLN·ha^{-1} and were respectively lower by 1 302 PLN·ha^{-1} and higher by 800 PLN·ha^{-1} and 502 PLN·ha^{-1} than the estimated in the 1st variant. Reduction of costs of exploitation of field cultivation, sowing and treatment machines, resulted inter alia from using a tractor Fendt 110 for ploughing with a 4-furrow field plough in the 2nd variant, which allowed shortening the exploitation time and as a consequence the cost of exploitation of tools during ploughing was lower by 180 PLN·ha^{-1} than in the 1st variant performed with a tractor Ursus 1212 aggregated with a 4-furrow non-field plough. Similar relations occurred at the use in the 2nd variant of a tractor with a greater power, Fendt 110 and harrow Striuk 4RF320 – a tool of higher performance for formation of ridges instead of a tractor Ursus C330 and a potato seeder as in the 1st variant, as a result of which the time of exploitation was shorter and the costs were lower by 690 PLN·ha^{-1}. At the same time a better quality of the performed treatment was obtained. A higher cost of exploitation of machines for collection and transport and total costs in the 2nd variant than in the first one, results from the cost of exploitation of a forklift truck used in this variant for unloading and loading of box pallets. As a result of the changes which were carried out in the carrot production technology in the 2nd variant a total cost of human work and machines and tools exploitation was lower than the costs incurred in the 1st variant by 3 541 PLN·ha^{-1} and was 22,165 PLN·ha^{-1}.

In the 3rd variant the use of a combine for harvesting of carrot influenced the reduction of costs of human work by 5,280 PLN·ha^{-1} and increase of costs of exploitation of machines by 3,600 PLN·ha^{-1} in comparison to the 2nd variant. However, total costs of human work and exploitation of machines for harvesting of carrots were lower by 1,680 PLN·ha^{-1} than in the 2nd variant. Similar relations occurred in case of using in the 3rd variant a washing line (comprising the brush washer and dosing devices and conveyors for loading and unloading of carrot (2nd variant). As a result of using a washing line in the 3rd variant, costs of human work were reduced by 3 300 PLN·ha^{-1} and increased the costs of machines exploitation by 2 500 PLN·ha^{-1} and total costs of human work and machines exploitation were lower by 800 PLN·ha^{-1} than in the 2nd variant. Costs of exploitation of machines in the 3rd variant were 11,988 and due to the above presented reasons were higher than the ones occurring in the 1st variant by 3 018 PLN·ha^{-1} and by 3 520 PLN·ha^{-1} in the 2nd variant.

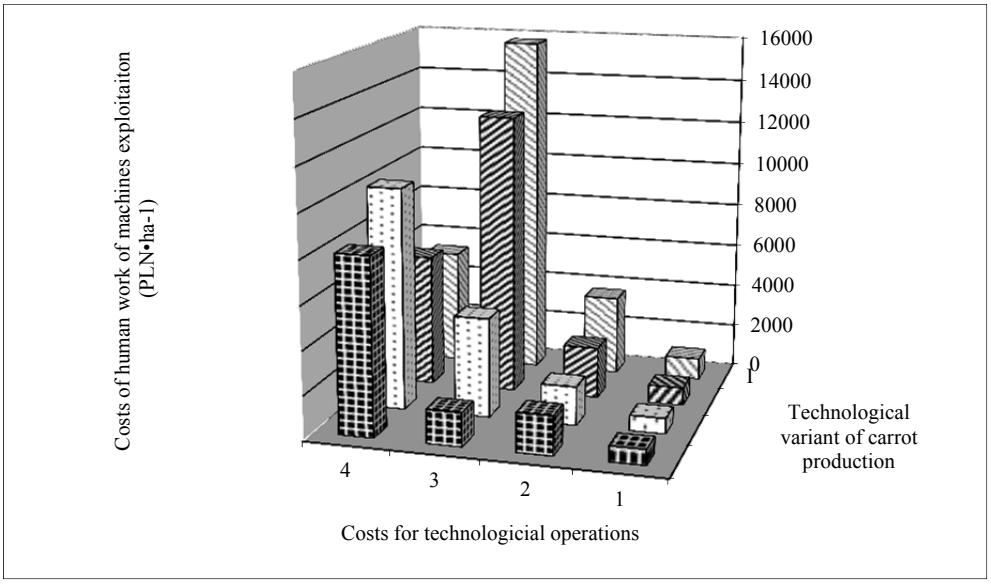

Figure 1. The list of results of studies on costs of field cultivation, sowing and treatment, crop and transport and packaging of carrot: 1 – human work inputs in the cropping, sowing and treatment (PLN·ha^{-1}), 2 – costs of machines and tools exploitation in the processes of cropping, sowing and treatment (PLN·ha^{-1}), 3 – costs of human labour in the harvesting, transport and packing processes (PLN·ha^{-1}), 4 – machinery work inputs in the cropping and transport processes (PLN·ha^{-1}).

In this variant costs of exploitation of machines and tools for field cultivation, sowing and treatment amounted to 1 788 PLN·ha^{-1} and were lower than those in the 1st variant by 1 882 PLN·ha^{-1} and in the 2nd variant by 580 PLN·ha^{-1} and total amounted to 2 505 PLN·ha^{-1} and which were lower than the incurred in the 2nd variant. In the 3rd variant costs of human work incurred during harvesting, transport, washing and packing were 4 565 PLN·ha^{-1} and as a result of the introduced changes of the machinery park, they were considerably lower than the calculated in the 1st variant by 11 165 PLN·ha^{-1} and by 8 305 PLN·ha^{-1} in the 1st variant. Also total costs of human work, which were 5,282 PLN·ha^{-1} were lower than in the 1st variant by 11 454 PLN·ha^{-1} and in the 2nd variant by 8 415 PLN·ha^{-1}. Total costs of human work and exploitation of machines and tools in this technology were 17,270 PLN·ha^{-1} and were lower as a result of the used machines by 8,414 PLN·ha^{-1} than the one determined in the 1st variant and by 4 895 man hour·ha^{-1} in the 2nd variant.

The use in the 4th variant of a more efficient and modern combine Dewulf P3K instead of Dewulf P3C (3rd variant), with which the harvested carrot was loaded to box pallets placed on a trailer affected reduction of the work time during harvesting and as a consequence of human work costs by 990 PLN·ha^{-1} and costs of machines exploitation by

400 PLN·ha^{-1}, although the cost of an hour of exploitation of a new combine was approximately two times higher than the combine used in the 3rd variant. Introduction of the washing and packing line in the 4th variant allowed reduction of the cost of human work by 1 540 PLN·ha^{-1} and exploitation of machines by 1 200 PLN·ha^{-1} in comparison to the 3rd variant. Costs of human work of harvesting and packing in the 4th variant were 1 540 PLN·ha^{-1} and were lower in comparison to the ones from the 1st, 2nd and 3rd variant by respectively: 14 190 PLN·ha^{-1}, 11 330 PLN·ha^{-1} and 3 025 PLN·ha^{-1} Whereas, a total cost of exploitation of a harvesting machine, transport and packing in this variant was 8 125 PLN·ha^{-1} and were higher respectively by: 2 825 PLN·ha^{-1}, 2 025 PLN·ha^{-1} and lower by 2,075 PLN·ha^{-1} than the ones occurring in the 1st, 2nd and 3rd variant. The cost of human work in this technology was 2,257 and was lower than the determined in the 1st, 2nd and 3rd variant by respectively: 14 479 PLN·ha^{-1}, 11 440 PLN·ha^{-1} and 3,025 PLN·ha^{-1}. The cost of exploitation of a machine in this technology was 9 913 and was higher respectively by: 943 PLN·ha^{-1}, 1 145 PLN·ha^{-1} and lower by 2 075 PLN·ha^{-1} than the one occurring in the 1st, 2nd and 3rd variant.

Concluding, one may say that the 4th variant of carrot production technology from among the researched ones is optimal and it characterizes with the lowest cost of human work and machines exploitation. Total cost of human work and exploitation of machines and tools in this variant was 12 570 PLN·ha^{-1} and was lower respectively by: 13 536 PLN·ha^{-1}, 9 995 PLN·ha^{-1} and lower by 5 100 PLN·ha^{-1} than the ones occurring in the 1st, 2nd and 3rd variant.

Conclusions

1. From among the assessed technologies of carrot production for supply of fresh vegetable market, the most optimal is variant 4th with the lowest total costs of human work and machines exploitation of 12,170 PLN·ha^{-1} and were lower respectively: by 13 536 PLN·ha^{-1}, 9 995 PLN·ha^{-1} and 5 100 PLN·ha^{-1} from the determined in the 1st, 2nd and 3rd variant.
2. As a result of the innovative changes of carrot production technology, reduction of the cost of human work in technology 4th in comparison to the following variants, was obtained: 3rd by 3 025 PLN·ha^{-1}, 2nd by 11 440 PLN·ha^{-1} and by 14 479 PLN·ha^{-1}, and the costs of exploitation of machines by 2 075 PLN·ha^{-1}, and by increase by PLN·ha^{-1} and 943 PLN·ha^{-1}.

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WARIANTY TECHNOLOGII PRODUKCJI MARCHWI A KOSZTY PRAC RĘCZNYCH I MECHANICZNYCH

Streszczenie. Przeprowadzono analizę kosztów prac ręcznych i maszynowych produkcji marchwi na zaopatrzenie rynku warzyw świeżych dla czterech wariantów technologicznych o zróżnicowanym poziomie zmechanizowania prac w gospodarstwie ogrodniczym, w którym powierzchnia uprawy marchwi wynosiła 3,67 ha. Za podstawową technologię produkcji marchwi przyjęto technologię opartą na wykorzystaniu maszyn stosowanych wcześniej do produkcji rolniczej w gospodarstwach małoobszarowych z dużym udziałem pracy ludzkiej. Na podstawie analizy możliwości zastosowania w dotychczasowej technologii produkcji nowych rozwiązań maszyn, opracowano warianty, których założeniem było zmniejszenie kosztów prac ręcznych i mechanicznych. Dla opracowanych czterech wariantów technologii produkcji marchwi określono poniesione koszty pracy ludzkiej i koszty eksploatacji maszyn i narzędzi. Za kryterium wyboru najlepszego wariantu przyjęto minimalne koszty pracy ludzkiej i eksploatacji maszyn. Za optymalny, spośród czterech opracowanych i zalecanych do stosowania w małoobszarowych gospodarstwach ogrodniczych, uznano wariant IV, charakteryzujący się najniższymi kosztami pracy ludzkiej i eksploatacji maszyn wynoszącymi 12 570 zł·ha^{-1}. Koszty pracy ludzkiej i eksploatacji maszyn w tym wariancie były niższe od ponoszonych w wariancie III o 5 100 zł·ha^{-1}, w II o 9 995 zł·ha^{-1}, i o 13 536 zł·ha^{-1} od wyliczonych w wariancie I.

Słowa kluczowe: koszty pracy ludzkiej i mechanicznej, produkcja marchwi, warianty technologii