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MINIMIZATION OF LABOUR INPUTS IN EARLY CABBAGE PRODUCTION TECHNOLOGY

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ABSTRACT

The objective of the paper was determination of the optimum variant of technology of production of early cabbage on supply of the fresh vegetables market from among developed four variants of technology suggested for use in small-area horticultural farms. The scope of the study covered horticultural farms, where the area of cabbage cultivation was in a four-year period from 1.5 to 2.3 hectare. A technology, based on manual work and machinery used earlier for agricultural production in small-area horticultural farms was assumed as a typical carrot production technology. Minimal inputs of human labour and machine labour were accepted as a criteria of optimisation. The 4th variant was an optimal variant from among the analysed. Total inputs of human labour and machine work in this variant were 788.9 h·ha^{-1} and were respectively lower by: 555.1, 568.9 and 659.1 h·ha^{-1} than the estimated for the 3rd, 2nd and 1st variant. Manual work inputs in this variant were lower in comparison to the inputs incurred in the 3rd variant by 533.4 man-hour·ha^{-1}, in the 2nd variant by 544.8 man-hour·ha^{-1} and in the 1st variant by 696.1 man-hour·ha^{-1}, and machines respectively lower by 21.7 mh·ha^{-1} for the 3rd and 24.1 mh·ha^{-1} for the 2nd variant and higher by 37 mh·ha^{-1} in comparison to the 1st variant.

Introduction and the objective of the paper

National production of cabbage, which was in 2011 approx. 1.1 million tonnes is carried out on the area of approximately 34 thousands of hectares. It places Poland at the first place in Europe, and at the eighth in the world (Rocznik Statystyczny, 2011). China is the biggest cabbage producer in the world, with production over 33 million tonnes (which constitutes half of the global production). In the country, the biggest areas of cultivation of cabbage are in Małopolskie voivodeship and Mazowieckie voivodeship and the lowest in Opolskie voivodeship. Average crop in Poland is 35 t·ha^{-1} and it should be recognized as relatively low because presently at the use of new technologies and technique with the use of hydration in highly specialized farms, the obtained crops are at the level of up to 70 t·ha^{-1} (Rocznik Statystyczny, 2011; Bardczak, 2007; Kierczyńska, 2006; Kaniszewski, 2007).

In the country, a trend to introduce new technological and organizational solutions in production of cabbage and other vegetables is visible, and it aims at lowering the inputs of human and machine work and to raise the efficiency of their production (Kowalczuk and Leszczyński, 2006; Kurpaska and Tabor, 2006).

Departing from direct sowing of seeds in soil and moving towards the seedling production and planting in the field of already well developed plants is a new direction in the technology of cabbage production. It allows obtaining considerable savings of seeds because at sowing directly to the soil, 30-40% more of them is sown than it is required. Producing cabbage from seedling may also accelerate harvesting (Adamicki et al., 2005). Simultaneously a shift from the cheapest and prevailing seedling with uncovered root system for the benefit of pot seedling is reported (Babik, 2006). Production of seedling is considerably mechanized, which facilitates the whole process of cabbage production and thus enables reduction of work inputs (Kunicki, 2005).

Planting seedling on a field is a work consuming process in cabbage production, for which various types of planters are used. In small-area farms, the simplest plate planters, which place seedling in a furrow, ploughed out with a drill opener, are used. Gripper planters, which may be used for planting seedlings with uncovered and covered root system in a muskeg cube are also used. Carousel planters, which are equipped with plates with seats may also be used. Seedlings are placed in the shield seats, which while rotating moves them over a leading funnel, through which seedlings get to the bottom of a furrow, made by a drill opener. Big-area farms use a new generation of automatic gripper planters, introduced into the market by Italian company Ferrari Costrzioni Meccaniche under the name Futura. One person shall suffice for its operation, whose task is to give plates. Seedlings are precisely gripped by a root nodule with grippers and placed on conveyors and then in soil. A computer controls the spacing of plants, in which few spacing of rows and planting various cultivars of plants may be set, which considerably facilitates the work. Also, a Swedish company BCC AB implements fully automatic planter. In this machine, plants are ejected by pushers and placed in tunnels, through which they are transported to soil (Podymniak, 2009).

Harvesting is the most burdensome treatment in the cabbage production process. In small-area farms it is an activity fully performed manually. For facilitation of this operation, sometimes belt conveyors are used, which are mounted on a trailer or a tractor. Employees, manually cut cabbage and place it on a belt, therefrom is is transported on trailer, where it is loosely arranged or to box pallets.

A combine may be used in big-area farms for harvesting cabbage. Harvesting of cabbage with this type of machine causes considerable damage to its head and it is the most frequently harvested for food processing, but it allows harvesting cabbage during one day from approximately one hectare.

The presented pre-conditions of cabbage production indicate that in small-area farms in Poland, a competitive cabbage production in comparison to big-area farms is possible, but carried out for direct supply of market in fresh vegetables.

The objective of the paper was comparison of work inputs and indication of the optimal variant of early cabbage production from among the developed four technological variants of a different level of works mechanization suggested for use in small-area horticultural farms. Minimal inputs of human labour and machine labour were accepted as a criteria of optimisation.

Object and the research method

The research was carried out in 2006-2009 in a horticultural farm of cultivation area 7.1 ha located in the southern part of Poland in Baborów municipality. The cultivation area of cabbage in this farm in a four-year period was within 1.5 and 2.3 ha. Based on the analysis of the size of inputs of manual and machine work occurring in the estimated technological variants starting from the initial, subsequent variants were developed, which were carried out in the following years, the assumption of which was to reduce the human and machine work inputs. The characteristic of conditions for the research and methodology was presented in detail in Molendowski et al.'s paper. (2010, 2011). Work inputs on particular technological operations in the researched variants were determined based on the records kept in a current documentation of a farm and timing of human and machine work.

A technology, based on manual work and machinery used earlier for agricultural production in small-area horticultural farms was assumed as a typical carrot production technology. Technological operations within this technology and the manner of their performance were presented in table 1. In this technology after ploughing with a 4-furrow field plough aggregated with Ursus 1212 tractor, further treatments were carried out with the use of Ursus C330 tractor. After ploughing, treatment of soil with a soil miller and seedling planting was performed with the use of a plate five-section planter. The following treatments: herbicide and fungicide spraying with a sprayer with 300 litres container, manual weeding, fertilization by means of a suspended plate centrifugal distributor were carried out.

In the 2nd, 3rd and 4th variant (table 2, 3 and 4) for cultivation works a turning four-furrow plough and a subsoiler were used. In the 2nd variant for treatment of soil a cultivation aggregate aggregated with Ursus C330 tractor was used and in the 3rd variant the same cultivation aggregate but cooperating with Steyr 6660 tractor. In the 3rd and 4th variant for plant protection treatments a sprayer with a 400-litres container was used.

In the process of harvesting and transport in the 1st variant for transportation of boxes to a field a delivery truck, on to which boxes were loaded manually was used. In the process of harvesting of cabbage, crowns were placed in boxes, which were loaded on the transport mean. A delivery truck transported cabbage to the packing place, where boxes with cabbage were manually unloaded and prepared to shipment for consignees. In the 2nd variant a tractor with a trailer and box pallets were used for transport. Box pallets were loaded on a trailer with a fork lift truck and transported to a field. Cabbage after manual harvesting was loaded to box pallets, which were transported to the place of preparing for sale, where box pallets with cabbage were unloaded with a fork lift truck and subjected to further treatment carried out as in the 1st variant.

In the 4th variant (table 4) belt conveyors mounted on a trailer were used for loading cabbage. Employees manually cut out cabbage heads and placed on the conveyor's belt, which transported them to box pallets placed on a trailer.

Research results

Results of the research of work inputs in the researched variants of production technology of early cabbage were presented in table 1-4. In the 1st variant (table 1), which is based on a great participation of manual work and machines used so far in agricultural production and assumed as the basic one for small-area farms, the highest input of manual cultivation work, planting and treatment at planting (150 man-hour·ha^{-1}) and on double weeding (80 man-hour·ha^{-1}). The remaining technological operations have a relatively low participation in the total cultivation work input, planting and treatment, which was 254.2 man-hour·ha^{-1} (fig.1).

Table 1
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 1st variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor 1212+4-furrow field plough	3.5	3.5
	Soil treatment	Tractor C330 + plough	8	8
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 300 l	1.7	1.7
	Double weeding	Manually	80	0
	Spraying with fungicide	Tractor C 330 + sprayer 300 l	6	6
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of boxes	Manually	40	0
	Transport of boxes to a field	Delivery truck	40	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Delivery truck	40	13.3
	Unloading and packing	Manually	200	0
Total in technology			1374.2	73.8

Total inputs of manual work in harvesting and transport of early cabbage are approximately 5.4 times higher than in works related to cultivation, planting, treatment and are 1120 man-hour·ha^{-1} (fig.1). The highest work consumption is characterised by activities related to harvesting (400 man-hour·ha^{-1}) and loading (400 man-hour·ha^{-1}) and unloading and packing (200 man-hour·ha^{-1}). It results from the fact that cabbage is arranged in a row close to the place of the transport mean crossing and then it is transferred to a transport mean. After transporting cabbage is unloaded, packed and prepared for transport to a consignee.

Total manual work inputs in the 1st technological variant, which was 1374.2 man-hour·ha^{-1} shall be recognized as very high. Whereas, inputs of mechanized work incurred are relatively low because in this variant these are inputs for field cultivation, planting and

treatment – 47.2 mh·ha^{-1}, harvesting and transport 26.6 mh·ha^{-1}, which in total gives 73.8 mh·ha^{-1}.

Based on the determined work inputs in the 1st variant activities for their reduction were undertaken. In the 2nd variant (table 2) for cultivation works, tractors of a higher power were used, which allowed reduction of work inputs.

Table 2

The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 2nd variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor C330 + cultivation aggregate	4	4
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 300 l	1.7	1.7
	Double weeding	Manually	80	0
	Spraying with fungicide	Tractor C 330 + sprayer 300 l	6	6
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			1221.9	134.9

The use of cultivation aggregate in this variant for treatment of soil reduced the work inputs by 4 man-hour·ha^{-1}. The use of a forklift truck for loading of box pallets onto a farm trailer allowed the reduction of work inputs by 26.7 man-hour·ha^{-1}. The use of C330 tractor and a farm trailer for transport into a field and box pallets from a field instead if a delivery truck allowed reduction of work consumption of this operation in total by 53.4 man-hour·ha^{-1}. The use of a forklift truck for unloading of box pallets in the packing object allowed the reduction of work inputs by 93.4 man-hour·ha^{-1}.

Inputs of manual work in the 2nd variant achieved: for field cultivation, planting and treatment 248.7 man-hour·ha^{-1} (fig.1), harvesting and transport 973.2 man-hour·ha^{-1} (fig.1), i.e. in total 1221.9 man-hour·ha^{-1} and were lower by 152.3 man-hour·ha^{-1} than the one incurred in the 1st variant. As a result of the introduced changes, used technical means of mechanized work input in cultivation, planting and treatment in the 2nd variant were

41.7 mh·ha^{-1} (fig.1) and decreased by 5.5 mh·ha^{-1} in comparison to the 1st variant, whereas in the harvesting and transport processes they were 93.2 mh·ha^{-1} (fig.1) and increased by 66.6 mh·ha^{-1}. Total inputs of human work and mechanized per a hectare in the 2nd variant were 1,356.8 hours and were lower by 91.2 hours in comparison to the 1st variant.

In the 3rd variant (table 3) in soil cultivation, tractor C330 was replaced with a tractor of a greater power of Steyr 660 type and the 300 l sprayer was replaced with a sprayer of a newer structure and with a bigger 400 litres container. These changes allowed reduction of work inputs on soil cultivation by 5 man-hour·ha^{-1} and 5 mh·ha^{-1},

Table 3
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 3rd variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor Steyr 6660 + cultivation aggregate	3	3
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 400 l	1.3	1.3
	Double weeding	Manually	72	0
	Spraying with fungicide	Tractor C 330 + sprayer 400 l	5	5
	Operation of fertilizing	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			1211.5	132.5

The use of a more modern sprayer caused that spraying with herbicide was more careful and as a result work inputs on weeding were lower by 8 man-hour·ha^{-1}. Human work inputs in the 3rd variant achieved for: cultivation, planting and treatment 238.3 man-hour·ha^{-1} (fig.1), harvesting and transport 973.2 man-hour·ha^{-1} (fig.1), and in total 1211.5 man-hour·ha^{-1} and were lower by 10.4 man-hour·ha^{-1} than the incurred in the 2nd variant and by 162.7 man-hour·ha^{-1} than those in the 1st variant. Total human work and machine inputs per hectare in the 3rd variant were 1344 hours and were lower by 104 and 12.9 hours in comparison to the 1st and 2nd variant.

The increase of the acreage of cultivated cabbage in the 4th variant (table 4), forced out the need for further improvement of the production process of this vegetable through a replacement of the plate planter used for planting seedlings, a carousel and bucket planter as well as a belt conveyor mounted on a trailer for transport of cut off cabbage. During a crossing with a trailer, where such conveyor was mounted, an employee cut off cabbage

and placed it on a conveyor's belt and transported it directly to box pallets. It eliminated a burdensome activity related to loading (manual throwing) of cabbage heads onto a trailer.

Table 4
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 4th variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor Steyr 6660 + cultivation aggregate	3	3
	Planting	Tractor C330+ carousel planter	16.6	3.3
	Spraying with herbicide	Tractor C 330 + sprayer 400 l	1.3	1.3
	Double weeding	Manually	72	0
	Spraying with fungicide	Tractor C 330 + sprayer 400 l	5	5
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage and loading	Manually + belt conveyor	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			678. 1	110.8

The introduced innovations allow reduction of planting work consumption in this variant by 133.4 man-hour·ha^{-1},and cutting out cabbage crowns and their loading to box pallets by 400 man-hour·ha^{-1}. Inputs of manual work in the 4th variant at cultivation, planting and treatment 104.9 man-hour·ha^{-1} (fig.1), harvesting and transport 573.2 man-hour·ha^{-1} (fig.1). This figure also presents the set of results of research on manual and machine work inputs for remaining variants.

Total inputs of human work in the 4th technology were 678.1 man-hour·ha^{-1} and were lower by 696.1 man-hour·ha^{-1}, 543.8 man-hour·ha^{-1} and 533.4 man-hour·ha^{-1} than those in the 1st, 2nd and 3rd variant. Total inputs of machinery work in the 4th technology are 110.8 mh·ha^{-1}. They were lower than inputs for the 3rd variant by 22 mh·ha^{-1}, for the 2nd variant by 24.1 mh·ha^{-1} and were higher than the determined for the 1st variant – by 37 mh·ha^{-1}.

To sum up, one may state that the 4th variant is the most optimal variant of early cabbage production on account of the assumed criterion, the lowest inputs of human and machine work, for supply of fresh vegetables market from among the analysed. Total inputs of human and machine work in this variant were 788.9 h·ha^{-1} and were lower respectively by 555.1, 568.9 and 659.1 hours than the determined for the 3rd, 2nd and 1st variant.

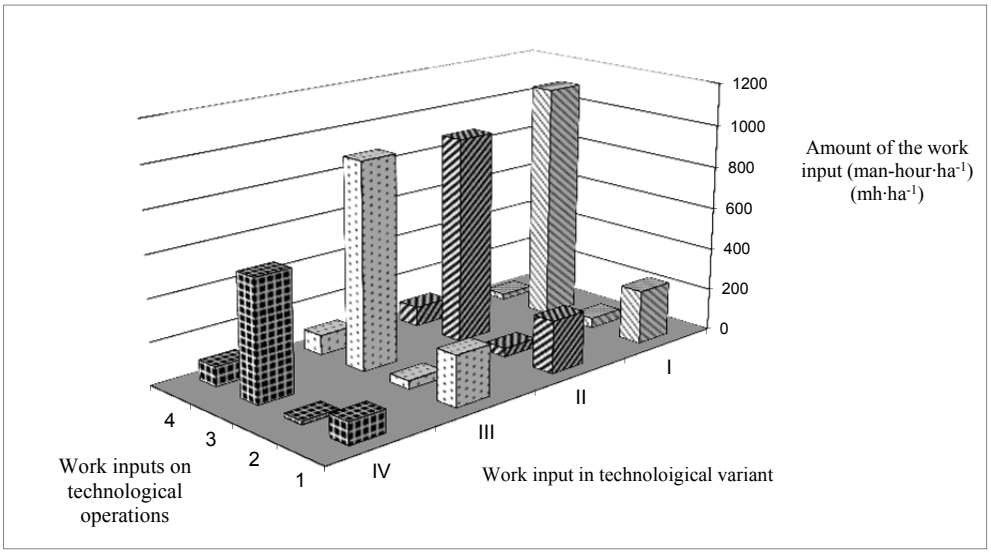

Figure 1. The list of test results on work inputs related to field cultivation, treatment and transport of early cabbage: 1 – manual work inputs in the cropping, sowing and treatment (man-hour·ha^{-1}), 2 – machinery operation inputs in the cropping, sowing and treatment (mh·ha^{-1}), 3 – manual work inputs in the harvesting and transport processes (man-hour·ha^{-1}), 4 – machinery work inputs in the cropping and transport processes (mh·ha^{-1}).

Conclusions

1. 4th technological variant, where the lowest human and machine work inputs occurred amounting to 788.9 h·ha^{-1} was an optimal technology of early cabbage production, where minimization of work inputs was reported.
2. As a result of the innovative changes of early cabbage production technology, reduction of the cost of human work inputs in technology in the optimal technology was obtained (4th variant). In comparison to the 3rd variant by 533.4 man-hour·ha^{-1}, to the 2nd by 544 man-hour·ha^{-1} and to the 1st by 696.1 man-hour·ha^{-1}, and machines respectively by 22 mh·ha^{-1} and 24.1 mh·ha^{-1}. To the 1st variant increase by 37 mh·ha^{-1}was reported.

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MINIMALIZACJA NAKŁADÓW PRACY W TECHNOLOGII PRODUKCJI KAPUSTY WCZESNEJ

Streszczenie. Celem pracy było wyznaczenie optymalnego wariantu technologii produkcji kapusty wczesnej na zaopatrzenie rynku warzyw świeżych spośród opracowanych czterech wariantów technologii proponowanych do stosowania w małoobszarowych gospodarstwach ogrodniczych. Zakresem badań objęto gospodarstwo ogrodnicze, w którym powierzchnia uprawy kapusty wynosiła w okresie czteroletnim od 1,5 do 2,3 ha. Za typową (wyjściową) technologię produkcji kapusty przyjęto technologię opartą na dużym udziale pracy ręcznej i maszynach stosowanych wcześniej do produkcji rolniczej w gospodarstwach małoobszarowych. Za kryterium optymalizacji przyjęto minimalne nakłady pracy ludzkiej i maszynowej. Optymalnym wariantem spośród analizowanych uznano wariant IV. Łączne nakłady pracy ludzkiej i maszyn w tym wariancie wyniosły 788,9 $h \cdot ha^{-1}$ i były niższe odpowiednio: o 555,1, 568,9 i 659,1 $h \cdot ha^{-1}$ od oszacowanych dla wariantów III, II i I. Nakłady pracy ręcznej w tym wariancie były niższe w stosunku do ponoszonych w wariancie III o 533,4 $rbh \cdot ha^{-1}$, w II o 544,8 $rbh \cdot ha^{-1}$ i w I o 696,1 $rbh \cdot ha^{-1}$, a maszyn odpowiednio mniejsze o – 21,7 $mh \cdot ha^{-1}$ dla III i 24,1 $mh \cdot ha^{-1}$ dla II oraz większe o 37 $mh \cdot ha^{-1}$ w porównaniu do wariantu I.

Słowa kluczowe: produkcja kapusty wczesnej, nakłady pracy, technologia optymalna