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PRECONDITIONS FOR MODELLING PLANT PRODUCTION TECHNOLOGY IN VEGETABLE ORGANIC FARMS[1]

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ABSTRACT

Preconditions for modelling technological processes in organic farms, which are oriented to vegetable field production, were presented. Based on empirical data, a rotation model and technical equipment models for farms of the agricultural land area of 10, 20 and 40 ha were developed. In relation to services, they enable full mechanization of production processes. Empirical data, which constitute batch data to models were collected in organic farms, which were included in the research as a part of the project NCBiR [National Centre for Research and Development] NR12-0165-10, titled "Innovative influence of technology and information management supporting system on production efficiency in organic farms." The project was carried out within 2011-2014.

Introduction

Selection of the production system in agriculture is preconditioned by restrictions of physical nature in the farm resources field. Financial means of a farmer play an important role in these resources, out of which a considerable part enables the use of farm mechanization means (Szeląg-Sikora and Kowalski, 2012). However, one should remember that only rational mechanization enables harmonization of production, social and ecological purposes, which are essential for sustained farming including organic farming (Muzalewski, 2008; Pawlak, 2008; Wójcicki, 2010; 2013). Economic work efficiency is a measurable effect of rational selection of mechanization means. It is usually measured as a ratio of the gross final production value per a unit of work inputs (Tabor, 2007). Thus, it reflects work productivity, which in small farms constitutes a basic production resource. However, due to the fact that mechanization on one side influences decrease of human work inputs and on the other hand generates costs related to its exploitation, assessment of efficiency as a part of agricultural incomes is significant. It is generated as a difference between final gross

[1] *The paper was carried out as a part of the project of the National Centre for Research and Development NCBiR NR 12-0165-10, titled „Innovative influence of technology and information management supporting system on production efficiency in organic farms".*

production and incurred production costs, in the structure of which, all basic components of mechanization costs are included (beside contractual remuneration for own work)

Objective of the paper and method

The basic objective of the paper was development of models of technical equipment for organic farms oriented to vegetable field production. Organic production is defined as a system of farm and food production management, which combines the most favourable practices for the environment. It constitutes a collection of technological processes and auxiliary processes which are carried out according to soil, plants and animals requirements, which lead to production of food products of high quality. Thus, in an organic farm, production should be carried out pursuant to the rule of the sustained development, which favours development of agriculture (Krasowicz, 2009). Activation of environmental mechanisms of agricultural production takes place as a result of using natural production means, which ensure long-lasting soil fertility, high wholesomeness of plants and animals and high biological value of agricultural products (Kondratowicz-Pozorska, 2006). What is significant, organic farming is characterized with the rotation cycle of organic substance: soil - plant – animal. In this cycle, soil constitutes a base for cultivation of plants, indispensable for ensuring fodder for livestock. On the other hand, animals supply manure indispensable for renewal of organic substance in soil and supplementation of nutritious elements necessary for plants growth. Thus, the quality of soil and animal production trend determine a proper selection of plants and rotation and it enforces specific plant production technologies (Jończyk, 2005; Krysztoforski and Stachowicz 2008). Such conditions may be modified in case of vegetable field production, which usually is carried out with no animal production or at a very low livestock. Then, after-crops cultivated for green manure and even plants cultivated in the main crop are, except for straw, the source of organic substance – table 1.

Table 1
Characteristic of plant production

Plant or type of crop	Crop		Price of the main product,	Coefficient of renewability of organic substance *		Balance of organic substance	Gross final production
	main	side					
	($t \cdot ha^{-1}$)	($t \cdot ha^{-1}$)	($PLN \cdot t^{-1}$)	($t \cdot ha^{-1}$)	($1 \cdot t^{-1}$)	($t \cdot ha^{-1}$)	(thousand $PLN \cdot ha^{-1}$)
Edible potatoes	17.5	0.0	620.0	-1.40	-	-0.280	11.58
Winter wheat + after-crop	3.6	3.8	540.0	-0.53	0.18	0.031	3.54
Onion + after-crop	17.6	-	940.0	-1.40	-	-0.280	18.58
Spring barley + companion crop	3.1	2.7	510.0	-0.53	0.18	-0.009	3.23
White clover with grass	32.0	-	-	1.96	-	0.392	1.73
Companion crops	12.0	-	-	0.35	0.06	0.214	-
Fertilizing after-crop	16.5	-	-	0.35	0.06	0.536	-
Agricultural land	x	x	x	x	x	0.604	7.73

)* – Source: Kodeks Dobrej Praktyki Rolniczej. 2004. Fundacja Programów Pomocy dla Rolnictwa. Warszawa. ISBN 83-88010-58-1

In a classic five-field rotation, vegetables and edible potatoes are cultivated on two fields (40% of crops), grains on two fields (40% of crops) and forage crops on one field (20% of crops). Crops obtained from empirical research confirm that in ecological farms they are 20-30% lower in comparison to the crops obtained in conventional farms. Despite intensive use of land resources, the use of side products and after-crops and two windrows of white clover with grass for fertilization enables full reproduction of organic substance ($0.6\ t \cdot ha^{-1}$).

Main crops of grains and vegetables and root crops mainly constitute commodity production. A small part of grain seeds (7%) and potatoes (12%) is left as sowing material and seed potatoes. Value of commodity production and the obtained funds (acc. to rates of 2013) constitute the gross final production value. For the example of the analysed rotation, the gross final production value of edible potatoes and vegetables constitutes 78% of total value.

Results of modelling

Farm tractors are the basic element of machinery park equipment of each agricultural farm. In the analysed models, three types of farm tractors of low and average classes of towing power of the respective rated power were selected: 34.6 kW; 52.2 and 68.0 kW. In models for 10 and 20 ha there are 2 items of tractors for each and in the model for 40 ha, beside 1 tractor of 68.0 kW power there are 2 items of tractors of power 52.2 kW – table 2. Consequently, indexes of power installed are respectively: $8.7\ kW \cdot ha^{-1}$; $6.0\ kW \cdot ha^{-1}$ and $4.3\ kW \cdot ha^{-1}$.

Table 2
Characteristic of equipment and use of farm tractors

Specification	Type	Parameter	Number (items)			Use (h)		
			10 ha	20 ha	40 ha	10 ha	20 ha	40 ha
URSUS tractor	U914	68.0 kW	-	1	1	-	243.5	430.0
URSUS tractor	U5312	52.2 kW	1	1	2	133.5	430.5	784.0
URSUS tractor	U3512	34.6 kW	1	-	-	312.0	430.5	784.0
Average use per 1 ha of agricultural land						44.6	33.7	30.3

The use of farm tractors increases along with the area of agricultural land. However, per 1 ha of these lands, tendency is decreasing and is respectively: $44.6\ cgh \cdot ha^{-1}$; $33.7\ cgh \cdot ha^{-1}$ and $30.3\ cgh \cdot ha^{-1}$. However, one should state that as long as in models of 20 and 40 ha, the use of tractors as a part of services was not predicted, in the model of 10 ha, each 1 ha of agricultural land is burdened with 4.2 cgh of hired labour.

Table 3
Characteristic of equipment and the use of basic agricultural tools and machines

Specification	Type	Parameter	Number (items)			Use (h)		
			10 ha	20 ha	40 ha	10 ha	20 ha	40 ha
Field plough	U151/1	3-furrow	1	-	-	38.0	49.0	-
Field plough	U151/2	4-furrow	-	1	-	-	49.0	-
Rotating plough	KM 180	3-furrow	-	-	1	-	-	79.5
Cultivator	U478/1	18 tines	1	-	-	18.0	-	-
Cultivating aggregate	Tiger 25	2.5 m	-	1	1	-	39.0	72.5
Grain seeder	S078u	3.0 m	-	1	1		12.0	22.0
Bucket seeder	S222	2-row	1	1	1	10.5	18.5	34.5
Spring onion seeder	SD 4u	4-row	-	1	1	-	14.0	26.0
Tractor chaff cutter	Z364	-	-	1	1	-	61.0	114.0
Elevator-digger	Bulwa 2	-	1	1	1	25.0	22.5	41.5
Potatoes combine	Pyra 1500	-	-	1	1	-	74.0	138.5

In the accepted models of equipment in the basic set of farm tools and machines, respectively small differences occur between objects of 20 and 40 ha. They concern only the type of a plough – a rotating plough occurs only in the model of the biggest facility. Whereas in the smallest facility, own machinery park is reduced to a field plough, cultivator, bucket seeder and an elevator-digger. Certainly, in all models equipment with the set of tools and machines for treatment and in trailers and sorting machines was accepted. In case of the biggest facility, a sorting machine was replaced with a sorting - cleaning machine. Whereas, an own combine harvester was not designed for any model. It was used only as a part of services.

Replacement value of the machinery park was respectively:

– model of 10 ha – 267.50 thousand PLN, i.e. 26.75 thousand PLN·ha^{-1};
– model of 20 ha – 473.63 thousand PLN, i.e. 23.68 thousand PLN·ha^{-1};
– model of 10 ha – 615.53 thousand PLN, i.e. 15.39 thousand PLN·ha^{-1};

Due to estimation of amortization, VAT tax was not included in the replacement value.

Total costs of mechanization show a clear decreasing tendency and they decrease from 2.64 thousand PLN·ha^{-1} in the model of the surface area of 10 ha to 1.65 thousand PLN·ha^{-1} in the model of 40 ha area – table 4. In the smallest facility, the participation of services costs in the structure of mechanization costs is 21.6%. While in the remaining facilities it is respectively: 20 ha – 7.6% and 40 ha – 9.1%. It should be mentioned that in these models, purchases of services concern only combine harvesting of grains. Their higher participation in the biggest facilities results from a considerable decrease of the costs of own machines exploitation including fixed costs.

Table 4
Mechanization costs (thousand PLN·ha^{-1})

Specification	Exploitation costs						Servi-ces	Total costs of mechanization
	Amortization	Charges	Garages and carports	Fuel and energy	Repairs and services	Total		
Model of 10 ha	1.05	0.12	0.23	0.49	0.18	2.07	0.57	2.64
Model of 20 ha	0.98	0.06	0.14	0.51	0.26	1.95	0.16	2.11
Model of 40 ha	0.68	0.03	0.08	0.46	0.25	1.50	0.15	1.65

Table 5
Production costs (thousand PLN·ha^{-1})

Item	Specification	Model		
		10 ha	20 ha	40 ha
1	Purchase of sowing material	0.64	0.64	0.64
2	Purchase of means for plant production	1.08	1.08	1.08
3	Purchase of other direct	0.01	0.01	0.01
I	Purchase of direct production means	1.73	1.73	1.73
1	Materials for repairs and renovations	0.21	0.28	0.27
2	Exploitation materials	1.67	1.68	1.68
3	Fuel and energy	0.50	0.54	0.55
II	Purchase of raw materials and exploitation materials	2.38	2.50	2.50
1	Amortization of buildings and infrastructure	0.51	0.41	0.36
2	Amortization of machines	1.05	0.98	0.68
III	Amortization of fixed assets	1.56	1.39	1.04
1	Veterinary and counselling services	0.02	0.02	0.01
2	Mechanization and craftsman ship services	0.57	0.16	0.15
IV	Services	0.59	0.18	0.16
1	Land tax	0.14	0.14	0.13
2	Property charges and insurance	0.02	0.01	0.01
3	Farmer's Social Security Fund	0.29	0.15	0.11
4	Other financial charges	0.06	0.06	0.06
V	Charges and other financial	0.51	0.36	0.31
VI	Total costs	6.77	6.16	5.74

Analogically to mechanization costs, also total production costs show a clear decreasing tendency – table 5. While in the 10 ha model they were 6.77 thousand PLN·ha^{-1} in the model, in the 40 ha model they were as much as 5.74 thousand PLN·ha^{-1}. In the type system, costs of raw material and exploitation materials have the highest participation. They constitute from 35.2% in the 10 ha facility to 43.6% in the 40 ha facility. The opposite relation of the participation concerns amortization of fixed assets. In this case its participation decreases from 23.0% in the 10 ha model to 18.1 % in 40 ha model. Whereas, mechanization costs in the structure of total production costs are from 28.7% in the biggest facility to 39.0% in the smallest facility. Thus, their participation has a clear increasing tendency and increases along with the surface area of agricultural lands.

In comparison to production and mechanization costs, also inputs of farmer's own and family work show clear decreasing tendency. They were respectively:
- 10 ha model – 1 195 man-hour, i.e. 119.5 man-hour·ha^{-1};
- 20 ha model – 1 195 man-hour, i.e. 89.0 man-hour·ha^{-1};
- 10 ha model – 3 010 man-hour, i.e. 75.2 man-hour·ha^{-1}.

Table 6
Production effectiveness

Specification	Model		
	10 ha	20 ha	40 ha
Agricultural income in thousand PLN per 1 ha of agricultural land	0.96	1.57	1.99
Agricultural income in PLN per 1 man-hour	8.00	17.70	26.50

Consequently, work efficiency which results from the generated agricultural income amounts to: in a 10 ha model – 8.00 PLN·man-hour^{-1}, in the 20 ha model – 17.70 PLN·man-hour^{-1}, whereas in the 40 ha model – 26.50 PLN·man-hour^{-1}. Thus, an increasing tendency is visible, which was significantly influenced by rationally selected machinery park.

Conslusion

In organic farms, at a respectively fixed level of purchases and considerably low participation of direct materials and raw materials, a rationally selected machinery park has a significant impact on the production efficiency. On one hand, it influences decrease of human work inputs and on the other hand it generates costs related to its exploitation. Thus, smaller farms usually have tractors of lower power and transport means and a basic set of machines indispensable to carry out technological processes in the determined agrotechnical time limits. Expensive machines and specialistic devices are used as a part of mechanization services. Along with the increase of the surface area of agricultural lands the power of the possessed farm tractors and technical and exploitation parameters cooperating machines increases. Consequently, the possessed machinery park is more numerous and more complex and in its structure there are more expensive specialistic machines. Also usually, tools and simple machines are replaced with multi-functional machines. As a result, purchase of mechanization services, the use of which is burdened with the risk of failure to keep agrotechnical time limits, is limited. The above preconditions constitute basic assumptions for designing mechanization of technological processes. It seems that the proper measure of assessing their efficiency is a ratio of economic efficiency of labour, which is a ratio of the farm income to inputs of farmer's work. In the model solutions it is respectively: 10 ha model – 8.00 PLN·man-hour^{-1}, 20 ha model – 17.70 PLN·man-hour^{-1} and 40 ha model – 26.50 PLN·man-hour^{-1}. An increasing tendency is visible, which was significantly influenced by rationally selected machinery park. A decreasing unit replacement value is inter alia a measure of this rationality of selection.

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UWARUNKOWANIA MODELOWANIA TECHNOLOGII PRODUKCJI ROŚLINNEJ W EKOLOGICZNYCH GOSPODARSTWACH WARZYWNICZYCH

Streszczenie. Przedstawiono uwarunkowania modelowania procesów technologicznych w gospodarstwach ekologicznych, ukierunkowanych na produkcję polową warzyw. W oparciu o dane empiryczne opracowano model zmianowania i modele wyposażenia technicznego dla gospodarstw o powierzchni użytków rolnych wynoszącej 10, 20 i 40 ha. W powiązaniu z usługami umożliwiają pełną mechanizację procesów produkcyjnych. Dane empiryczne, stanowiące dane wejściowe do modeli, zebrano w gospodarstwach ekologicznych objętych badaniami w ramach projektu NCBiR nr NR12-0165-10, pt. „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych". Projekt realizowano w latach 2011-2014.

Słowa kluczowe: rolnictwo ekologiczne, warzywa, technologia, wydajność