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PRACTICAL STATISTICAL AND ECONOMIC ASPECTS OF USING SURVEY STUDIES FOR IDENTIFICATION OF THE KEY PLANT CULTIVATION TECHNOLOGY FACTORS

1. Introduction

Survey studies are a research method that is widespread in social sciences but less common in agro-technical studies. Among the publications which have appeared in Poland, mainly concerned with the methodology of using surveys for evaluation of plant cultivation technologies and agro-technical factors, noteworthy are papers written by Krzymuski (1982), Krzymuski et al.(1995), Laudański et al. (2007a, 2007b) and Imiołek et al. (2010).

Plant production is governed by certain, well-defined cultivation recommendations, especially important when quality standards imposed by contract agreements are to be met. Due to technical and economic conditions, a farmer is not always able to adhere to such recommendations in practice, but at the same time changes on the farm produce market enforce producers to either change or modify a production technology. Selecting an adequate combination of agro-technical factors depends on the qualitative and quantitative parameters of a market product (yield), but the decision is also shaped by such organization of plant production which enables the farmer to minimize production costs and maximize the profit. The volume and quality of yield are a product of many factors, which comprise elements of plant agro-technology and random events. A general problem in all research methods is the identification of factors which can be named as the key ones in a given technology. In the present study, it has been assumed that creating a new cultivation technology or modifying an existing begin through the recognition of the technological foundations of

production. In respect of the methodology, a decision to use surveys has been made.

Because the research covered a large area, it was rather difficult to have the survey completed by all agricultural producers. Survey studies are significantly affected by the time which elapses from events which a survey investigates to the time when respondents are interviewed and the form of questions (Conrad et al. 2009). Winter crops cultivation is characterized by relatively long duration. For the respondents' replies to be reliable, a survey should be completed as soon as possible after the termination of a production process and before a new cycle begins. Another difficulty in survey-based studies is the general unwillingness of agricultural producers to reveal detailed information about the agro-technical factors of the production they conduct (except situations when monitoring production on a given farm is compulsory). Therefore, the results of surveys, even when applied to a representative sample, can be burdened with an error and although they are a valuable material for scientific research, they should not be used for making production recommendations. When planning this survey study, the authors presumed that it should generate a general view of the configuration of factors involved in rye cultivation technology and enable economic evaluation of the production as well as selection of factors for further examination in strict experiments.

This paper is therefore an attempt at using survey data for evaluation of a technology of rye cultivation, making an economic evaluation and selecting key agro-technical factors.

2. Methodology of survey studies

The present survey on the technology of growing winter rye covered the area of northeastern Poland, the provinces of Warmia and Mazury, Podlasie and Mazowsze. In order to reflect the current economic status of agricultural producers, our selection of respondents was intentional and the size of a winter rye plantation over 1 ha was the selection criterion. Most of the surveyed farms grew rye under contracts with rye processing plants (mainly mills). During direct interviews at farms, survey questionnaires were completed. The questionnaire was divided into four groups of questions, which were to determine the value of a plantation, pre-sowing treatments, quality of seed material, agro-technical aspects of grain sowing, plantation treatments and harvest.

Statistical analysis of the surveys. The preliminary stage of statistical analysis of the data provided by the questionnaires consisted of coding the data. The factors were divided into natural categories (e.g. forecrops) or class ranges (e.g. levels of nitrogen fertilization) according to the technological guidelines for rye cultivation given in the references.

The next step in our analysis consisted of creating a linear model and analyzing grain yields per ha for the whole sample population and divided into biological forms of cultivars, i.e. hybrid and population. For the particular types of cultivars, the model included only such agro-technical factors that were involved in a technology of growing those cultivars.

For assessment of the main effects of the factors and de-composition of the contribution of particular production factors into the variability of grain yield, type III sums of squares were used and the coefficient η^2 (eta-square) was determined, which reflected the relative contribution of an examined production factor to the volume of yield.

$$\eta^2 = SS_{Ef.} / SS_{Og.}$$

where: $SS_{Ef.}$ is the sum of squares of the variability of a given effect, and $SS_{Og.}$ is the sum of squares of the general variability of a model.

In the later part of statistical analysis, a hierarchy of the cultivation technology factors was established (evaluation of the importance of factors) via an application of classification trees – analyses were made for the whole population and divided into cultivar forms. The classification trees were constructed from a learning set, which consisted of the upper and lower quartile of the population, corresponding, respectively, to low and high yields. The C&RT (Classification and Regression Trees) method was applied to constructing a tree that exhausted the search for one-dimensional divisions. This method verifies all possible divisions for each predictive variable in order to find out a division for which the best improvement of the goodness of fit (or else the highest reduction in the lack of fit) appears. The goodness of fit was determined with the Gini coefficient, which reaches the value 0 when only one class appears in a given node. For stopping the division, the option 'cut at an error of wrong classification' was chosen, so that a tree was divided until the moment when all the nodes were clear (containing objects from only one class) or having no more than a specified maximum number of objects. This number was set as 5. The size of a tree was set according to V-fold cross-validation. All statistical analyses were performed with the aid of the computer software STATISTICA ® 9.0.

The economic analysis of the results. The inventory of treatments and applied equipment was used for determination of labour, tractive power and technological devices as well as material outlays used for cultivation of rye. The costs of exploitation of technical means were computed with the method suggested by the Institute of Economics and Agricultural machinery Exploitation, the Institute of Civil Engineering and Agricultural Machinery in Warsaw (Muzalewski 2010). The material costs (e.g. mineral fertilizers, plant

protection chemicals) were determined as a product of their use and price per unit. For the calculations, the market prices as of June 2010 were taken. The parity rate per 1 hour of labour was computed according to the average pay in the whole Polish economy (www.stat.gov.pl.), assuming that – as the EUROSTAT claims – 1 person can work no more than 1 annual work unit (AWU), even if they actually work longer. The annual work unit (AWU) is an equivalent of the time taken to perform the work done by 1 person employed on a full-time basis at a farm. In Poland, it is assumed that 2,120 hours of work per year are an equivalent of a full-time job in agriculture (www.stat.gov.pl.). The value of outlays originating from own production (seed material) was estimated with the own costs method. The cost of mineral fertilizers was assessed by the comparative method, transferring the average market value of the fertilizer's mineral components onto the analogous components found in FYM, taking into consideration the amount of nitrogen applicable in a given year. The direct costs also include the surcharge of indirect costs. The production profitability index, understood as a ratio of the value of production which is a potential commodity to the total costs of the production outlays, was applied as a synthetic economic measure which regarded the effectiveness of the outlays (Nasalski et al. 2004).

The costs have been presented in a functional pattern, distinguishing particular outlays related with a given treatment, i.e. pre-sowing soil tillage, sowing, fertilization, application of plant protection chemicals. The costs of the treatments include the outlays on exploitation of machines, labour outlays and expenditures on material production means.

3. The results

The survey study encompassed 73 villages in ten administrative districts lying in three province: Warmia and Mazury, Podlasie and Mazowsze. During face-to-face interviews, 201 questionnaires were filled in; they covered environmentally different variants of rye production on 153 farms, which had at least 1 ha of winter rye grown for grain in their structure of crops sown in 2007/2008.

When the data from all the plantations were collected, the analysis of variance of the rye grain yields demonstrated the significance of all the main effects, except pre-sowing tillage and pre-sowing fertilization. In turn, the analysis of the production technology applied to hybrid cultivars proved that the pre-sowing tillage, seed dressing and weed and fungus control treatments were non-significant, but when population rye was grown, the non-significant factors included pre-sowing tillage, seed certification grade, sowing technique, row spacing, fungal control and application of a retardant.

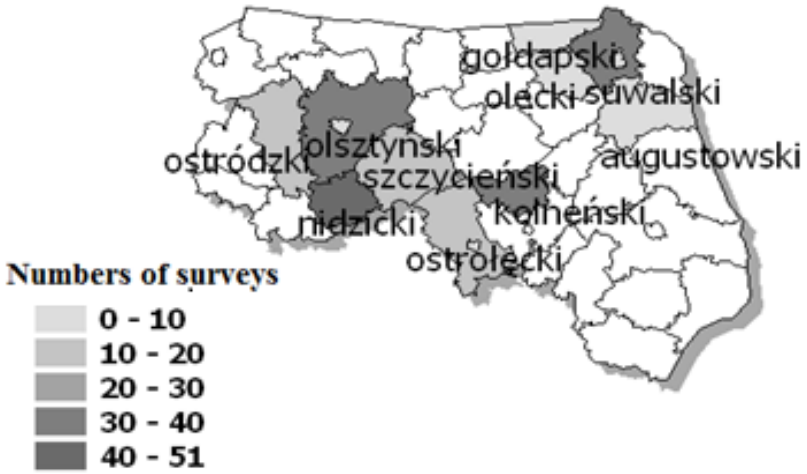

Fig. 1. The area covered by the surveys and number of surveys in the administrative districts of northeastern Poland

Table 1

Analysis of variance of grain yield of rye

Specification	Hybrid cultivars			Population cultivars		
	df	SS III	p	df	SS III	p
Organic fertilization	1	17.09	0.00	1	4.56	0.00
Pre-sowing cultivation	1	0.01	0.70	1	0.61	0.22
Pre-sowing fertilization	1	1.55	0.00	2	21.39	0.00
Cultivars	3[a]	20.28	0.00	5[a]	64.21	0.00
Seed certification	2	0.94	0.00	3	2.55	0.10
Seed dressing	1	0.08	0.30	1	7.83	0.00
Sowing technique	1	0.34	0.03	1	0.00	0.95
Date of sowing	2	0.54	0.02	2	3.73	0.01
Sowing rate	2	9.03	0.00	1	17.83	0.00
Row spacing	1	0.87	0.00	1	0.13	0.57
Depth of sowing	2	30.01	0.00	4	12.57	0.00

Top dressing	1	0.67	0.00	2	49.77	0.00
Mechanical cultivation[b]				1	6.28	0.00
Fungicide application	1	0.24	0.07	1	0.41	0.31
Herbicide application	1	0.09	0.73	1	14.18	0.00
Retardant application	1	2.41	0.00	1	0.26	0.42
Date of harvest	2	10.04	0.00	3	10.18	0.00
Error	832	60.11		951	384.08	
In total	855	482.96		982	711.79	

[a] when analyzed cultivars were a factor tested by the analysis covering types of cultivars

[b] the factor was absent from the technology

The de-composition of contribution of particular production factors to the total variability demonstrated that the random factors made up the largest contribution to the variability of rye grain yields, especially in the case of hybrid rye (61%) (fig. 2). The major factors determining the yield of rye grains were the date and parameters of sowing. In respect of the type of cultivars, large differentiation was discovered. When growing population cultivars, the factors related to seed quality and plant cultivation treatments were found to dominate, whereas in the cultivation of hybrid varieties, where the seed material is exchanged on 66% of the analyzed plantations, the dominant effect was produced by the agro-technical factors connected with seed sowing.

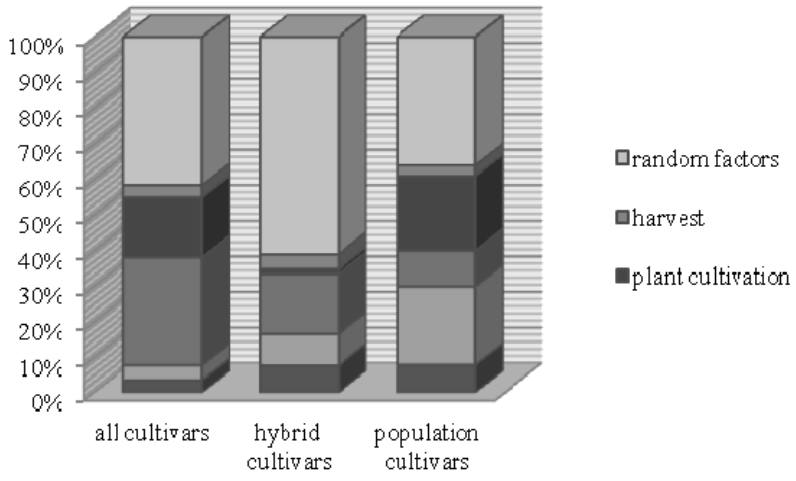

Fig. 2. Decomposition of variability of factors in winter rye production

Depending on the form of rye, the volume of average grain yields varied by 1.05 t. Three classification trees were constructed for the total rye population and for the two rye forms: population and hybrid varieties. On each occasion, the learning set consisted of the upper and lower quartile of yields. The major factor discriminating rye production (based on the results from all the rye plantations) was the sowing rate. High yields classified initially as low ones were discriminated by the soil class and soil complex, as well as nitrogen dressing. For the population cultivars, the moment the cultivation technology factors had been included, the major determinant was the application of seed dressing (fig. 3). High yields initially classified as low ones were determined by nitrogen top dressing, followed by the date of sowing, row spacing and plant protection measures such as the application of a herbicide.

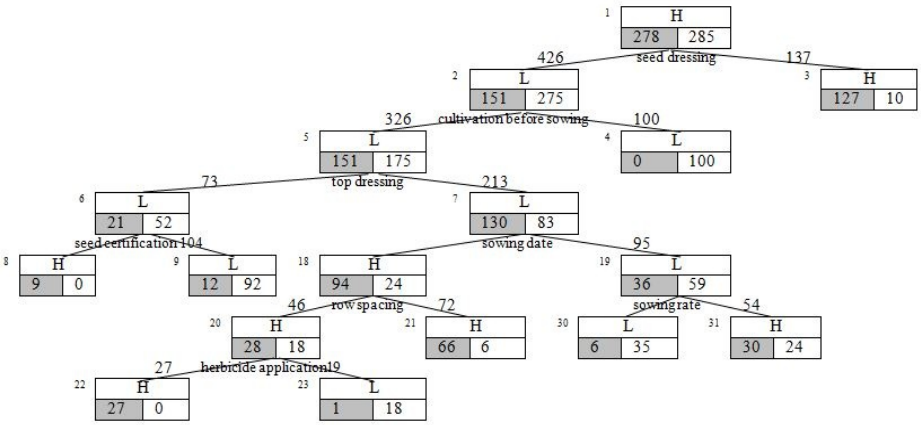

Fig. 3. Classification tree of low and high yields of winter rye population cultivars

In respect of hybrid forms, high yields were obtainable at a low sowing rate (in accord with the cultivation recommendations prepared for hybrid rye) and application of a herbicide (fig. 4). High yields initially classified as low ones were determined by the parameters defining the quality of sowing seeds and the date of sowing.

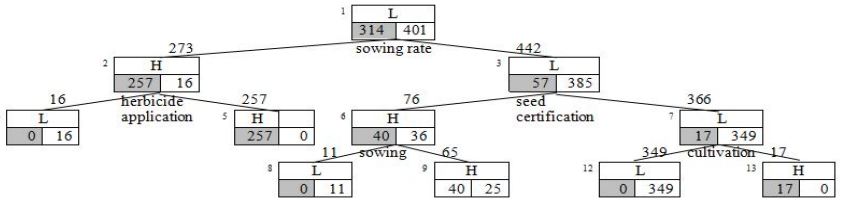

Fig. 4. Classification tree of low and high yields of winter rye hybrid cultivars

Among the analyzed production factors, ranks achieved for hybrid varieties were much different from the ones for population forms (fig. 5). The highest ranks were achieved by the parameters related to sowing, row spacing 79% for pre-sowing tillage and 76% for the sowing rate. In contrast, for population cultivars the highest rank was scored by weed control measures, followed by parameters connected with the quality of seed material, cultivars and nitrogen top dressing.

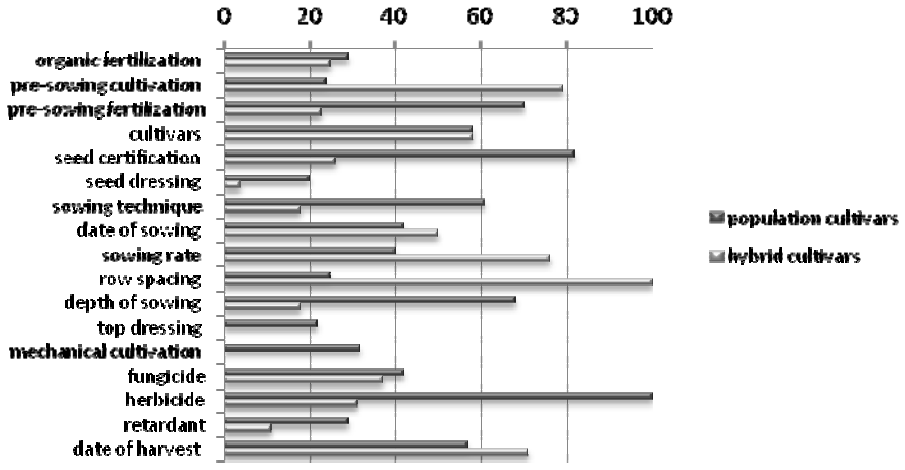

Fig. 5. Ranking of the importance of some variables for population and hybrid cultivars [%]

The costs calculation in agricultural practice should be used as a source of information useful when making strategic decisions as well as operational ones. Economic analysis enables farmers to optimize the production structure and to make a more rational use of particular techniques. When cereal prices are unstable, one of the very few chances to improve the economic output on farms which grow cereals as a commodity is the verification of outlays and costs (Nasalski et al. 2004).

The volume and quality of rye grain yield were significantly shaped by fertilization. As demonstrated by the conducted survey, 40% of the total direct costs were incurred by fertilization operations alongside the expenditure on the purchase of fertilizers (table 2). The costs related to chemical protection of rye plants were extremely varied, depending on the size of a farm. On farms which had up to 7 ha of arable land, they hardly reached 1%, but went up to 12% on farms which had over 100 ha of acreage. The outlays on soil tillage before sowing were lower in larger farms, which possess more efficient machines and can aggregate the performed operations.

Table 2

Structure of direct costs [€·ha^{-1}]

Size of a farm [ha]	<4	4-7	7-10	10-15	15-20	20-30	30-50	50-100	>100	In total
Soil cultivation	101.27	83.39	76.95	78.93	73.92	66.87	71.94	62.65	56.62	74.05
Sowing	53.99	45.41	51.51	49.61	49.19	46.10	43.97	47.64	52.26	48.62
Fertilization	157.54	176.00	138.73	116.58	128.53	115.05	118.81	126.35	166.29	134.44
Plant protection	3.59	2.05	6.56	4.73	6.27	7.14	11.56	14.68	45.10	10.37
Harvest	43.01	42.15	41.70	40.97	41.96	41.99	43.31	42.93	39.56	41.93

In the costs structure of all the surveyed farms, the costs connected with the agro-technical operations made up on average 61.1%, including 23.9% of the outlays on pre-sowing treatments (fig. 6). The outlays on such production means as seed material, plant protection chemicals and fertilizers constituted 38.9% of all the direct costs. The highest expenditure was incurred by the purchase of fertilizers (28%).

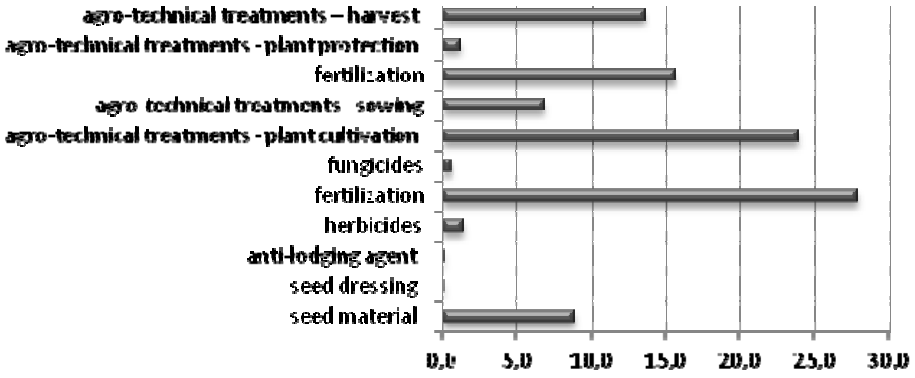

Fig. 6. Structure of direct costs of winter rye cultivation on farms in northeastern Poland [%]

In the production process, the total sum of the incurred costs only weakly corresponded to the evaluated profitability of a given technology. It is not until we compare the costs with the volume of produced yield that the effectiveness of a technology in question can be seen. The unit production cost (UPC) is a product of the total costs and the volume of production. Figure 7 shows the average unit production cost for 1 deciton [dt] of rye depending on the size of a farm. The average UPC ranged from € 9.70 to € 16.20 for deciton. In the group

of small farms, i.e. up to 7 ha of acreage, it highly varied: from € 6.42 to € 9.49 for deciton; a similarly high deviation was recorded for the farms between 30-50 ha of acreage (6.55 €/dt). On the remaining farms, the AUPC differed by 3.53--4.53 €/dt.

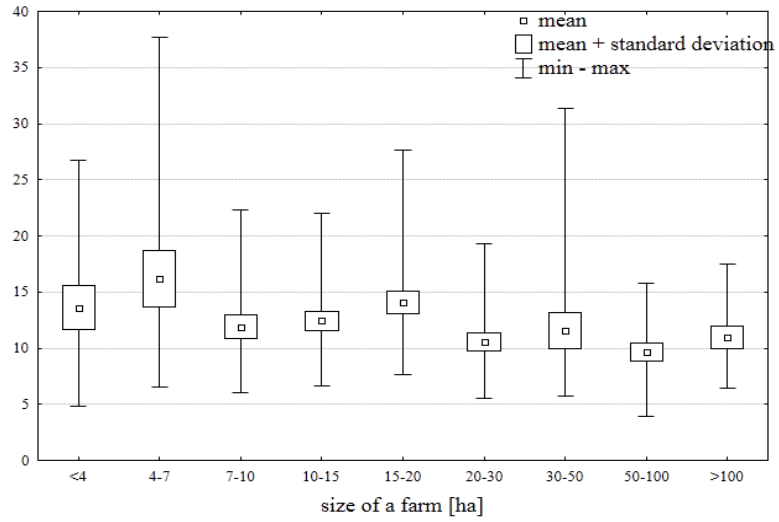

Fig. 7. Unit production cost of growing winter rye on farms in northeastern Poland [€·ha^{-1}]

The field operations, as already mentioned, constituted 60% of the direct costs. Aggregating such operations improved the quality of a field prepared for rye plantation and, consequently, the volume of yield. It also reduced the use of fuel, which meant lower direct costs of rye production. Attaining higher yields and decreasing the outlays resulted in lower unit production costs (fig. 8).

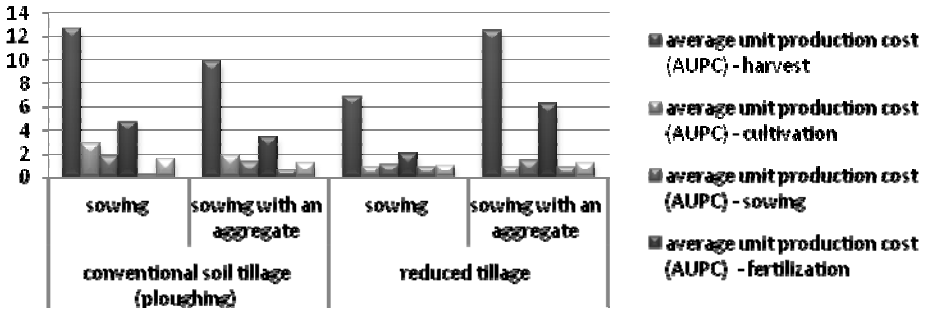

Fig. 8. Value of unit costs depending on soil tillage reduction [€·dt].

Fertilization is one of the most important factors which affect the volume of yields. For hybrid cultivars, the lowest production costs per unit were obtained when 2 rates providing 60-90 kg/ha of fertilizers were applied. Dividing this dose of fertilization is not effective, as it rises the outlays. The highest yield was obtained when the fertilization rate was over 90 kg/ha, divided into two doses, which was the most effective fertilization variant (the lowest unit costs) (fig. 9). For population cultivars, division of fertilization rates increased the yields. Nonetheless, fertilization with a single rate of up to 60 kg/ha was the only economically viable fertilization variant.

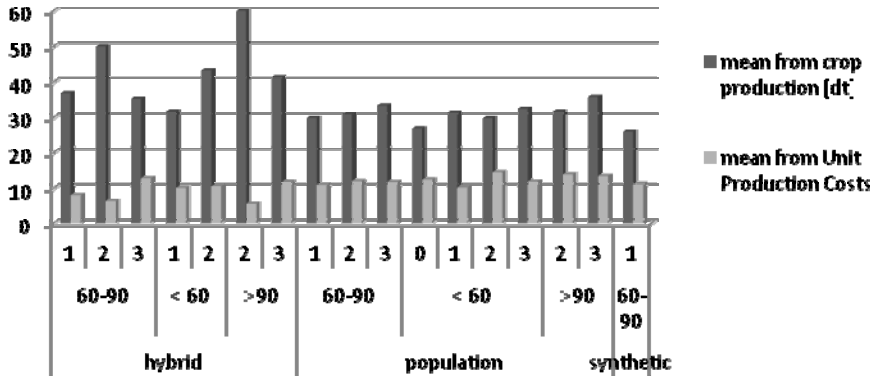

Fig. 9. Unit production costs and yield volume depending on fertilization rates for the forms of winter rye [€·dt]

A synthetic economic measure which takes into account the effectiveness of the outlays is the direct margin effectiveness index, which is a ratio, expressed in per cent, of the direct margin to the gross commodity production. A negative value of this index was found for a population cultivar grown on small farms with poor farming practice (fig. 10). As the volume of yields increased, the margin rate continued to rise, reaching the value of 70% for hybrid forms.

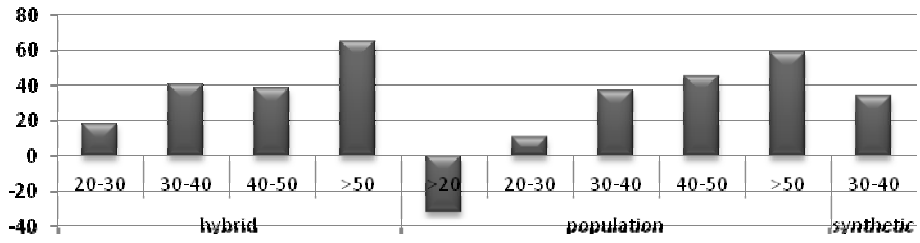

Fig. 10. Direct margin rate [%] depending on the form of rye and yield volume

Production operations are under the influence of some endogenous factors: the production potential of each farm, i.e. land, labour and capital resources, their quality and usability, and exogenous ones, produced by some external influence produced on agriculture (Skarżyńska 2010). Market prices for rye are highly unstable, varying from year to year between 80.5 and 20.12 euro per dt^{-1} (www.minrol.gov.pl/pol/Rynki-rolne). Beside the indirect income obtained from selling grain, farmers also receive subsidies, which largely affect the profit obtained from this type of production, especially on small, low--productivity farms, which would generate loss was it not for the subsidies they are paid (fig. 11). Low yields obtained on organic farms are compensated for only by higher subsidies.

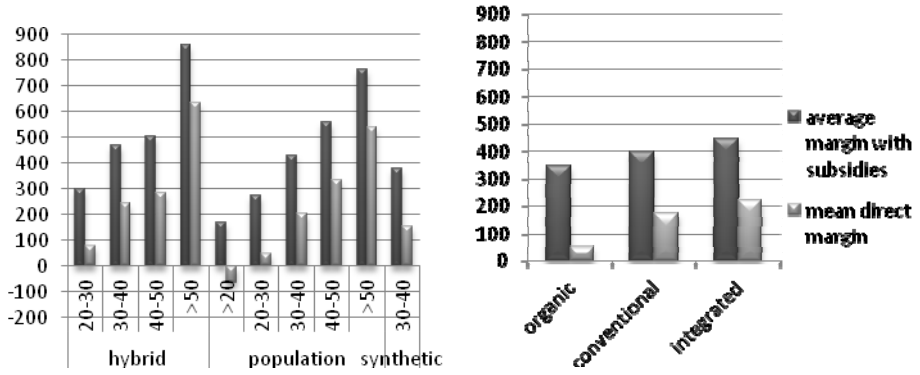

Fig. 11. Profit obtained from rye production depending on a) rye form and yield volume [€·ha^{-1}], b) type of farm management

4. Conclusions

A survey study, carried out in the form of face-to-face interviews, can be a source of valuable data on the currently applied plant production technologies over an area covered by that research, and the ANOVA methods, including type III sums of squares and classification trees, can properly discriminate among the analyzed factors, allowing researchers to identify the key factors necessary to obtain high yields.

When different types of agricultural cultivars are grown, the results of surveys and of the subsequent analyses will enable us to capture these production factors which are universal in character and the ones which are specific for a given type of crops.

In rye cultivation, 39% of the grain yield variability is attributable to the quality of a cultivation field. The production techniques significantly differentiate

between the types of rye – hybrid and population varieties. Better yielding hybrid cultivars are highly variable in terms of the factors connected with the quality of seed material and plant cultivation treatments, whereas the group of most significant agro-technical factors in cultivation of population cultivars comprises the seed sowing techniques. It is among these groups of rye grain production factors that we should identify the ones for testing in strict and production experiments.

The economic analysis of the results of our survey shows what costs rye cultivation incurs, which can change due to growing prices of different raw materials but which are also dependent on the applied technology, cultivation acreage, labour potential or the available machines and tools.

The economic costs calculation, which was completed in a year when grain selling prices were high, showed that all the analyzed rye plantations generated profits. However, those farmers who relied on extensive technologies or organic farming obtained low yields and then the profitability of production was ensured exclusively by the received subsidies.

It was economically viable to use cultivation aggregates or aggregated cultivation and sowing machines, because then the number of runs was lower (saving on fuel and labour) and good soil conditions were maintained, affecting the volume of yields.

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PRAKTYCZNE ASPEKTY STATYSTYCZNO-EKONOMICZNE WYKORZYSTANIA BADAŃ ANKIETOWYCH W TYPOWANIU KLUCZOWYCH CZYNNIKÓW TECHNOLOGII UPRAWY ROŚLIN

Streszczenie

Badania ankietowe przeprowadzone w 2008 roku miały na celu określenie kluczowych elementów technologii produkcji oraz kalkulację kosztów jednostkowych produkcji żyta ozimego (*Secale cereale* L.) uprawianego na ziarno. Ankietyzacją objęto producentów ziarna żyta w północno-wschodniej Polsce prowadzących uprawę na areale większym niż 1 ha. Kwestionariusz ankietowy zawierał pytania połączone w grupy dotyczące: 1) charakterystyki ogólnej gospodarstwa, 2) czynników technologicznych produkcji, 3) oceny energochłonności (agrotechnicznej) oraz 4) struktury nakładów. Dane o czynnikach produkcji stanowiły predyktory w ogólnym modelu liniowym, a zmienną zależną był plon ziarna. W analizie wariancji plonu ziarna wykorzystano sumy kwadratów typu III oraz oszacowano efekty główne czynników. Analizę ekonomiczną wykonano na podstawie nakładów bezpośrednich poniesionych na produkcję, obliczono jednostkowe koszty oraz nadwyżkę bezpośrednią, określono strukturę kosztów oraz zyskowność produkcji żyta ozimego.