DET – A METHOD WHICH INTEGRATES STATISTICAL ANALYSIS WITH ECONOMIC EVALUATION IN LARGE AREA OF TYPE 2^3 EXPERIMENTS.

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Abstract

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 (progress in plant breeding and mechanization of field work, new agrochemicals, effective microorganisms, etc) 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. (Nasalski i in. 2004). Farmer who has a definite resource of land and capital must determine the minimum level of performance of working hours or efficiency per hectare. Instability of a market enforce producers to either change or modify a production technology. The yield is conditional on a large number of factors whose effects are complex and inter-modifying. Testing a number of agronomic factors is possible by using advanced experimental systems methodically type k^n, which are tested at the same time n factors, each of k levels. However, to implement this, traditional plant cultivation technologies require a modification of agricultural factors or their *de novo* creation. The aim is to select agricultural engineering factors in the production technology which require relatively low inputs to obtain an optimal yield with accurate quality raw material parameters.

Keywords: field experiments, production experiment, technological efficiency,

Introduction

In agricultural research, a production experiment is a tool used to evaluate the economic efficacy of plant production technology. Based on such a production experiment it is possible to perform: 1) a comparative analysis of technologies in which one agricultural engineering factor is described (e.g. nitrogen doses), or 2) a comparative analysis of technologies in which numerous experimental factors are described (e.g. planting density and plant protection techniques). In the first case, precise information is obtained on a factor effect, although there is a lack of information on interactive effects with other factors. In the latter case, which may be assumed to be a conventional analysis, a research methodological problem in the evaluation of economic efficiency of technologies arises because the effects of a real factor resulting from a statistical analysis are assessed independently of an economical evaluation.

In relation to the analysis of results from a large area experiment set in the 2^3 configuration, a procedure for the evaluation of cultivation technology has been proposed and it integrates a statistical and economic approach used to assess the proportion of individual factors and their economic evaluation. The partial *ex post* cost account has been assumed as a basis for the economic analysis of a new production technology. In the DET analysis (the difference of technological efficiency), the additional costs associated with a modification of a cultivation technology, additional income, marginal income and marginal revenue are determined both in relation to a new technology and to modified production factors (Gołaszewski et al. 2008). The input and efficiency of individual factors and their interactions were assessed. The efficacy of factors was determined as a contrast between the means related to a change in the level of a factor: from 1 to +1 (Mead et al. 1993, Mason et al. 2003). The Farm Accountancy Data Network (FADN) has specified a standard procedure for calculating a direct surplus based on a calculative cost arrangement which divides the costs into direct and indirect groups and allows for an efficiency assessment of a given technology, although it does not permit the input of individual factors. The application of a functional cost arrangement for RET makes it possible to determine the costs of specific procedures (e.g. ploughing, sowing, fertilization). It allows not only for an evaluation of the difference of technological efficiency between a new and a traditional technology, but it also permits an identification of an individual input of tested factors and, consequently, it is possible to determine whether an increased input on a given factor by an additional 1.00 PLN is economically justified.

Methods

In regard to an analysis of the results of a field experiment, a procedure has been proposed for assessment of a technology of cultivation which integrates the statistical and economic approach in valuation of individual factors and their economic assessment. *Ex post* partial cost accounting has been taken as the basis for the economic analysis of the new production technology. The analysis includes determination of extra costs associated with modification of the cultivation technology, extra income, final income and final profit, both in regard to the new technology and to the modified means of production (Gołaszewski et al. 2008). The contribution of individual means of production and their interaction have been assessed. The effectiveness of factors has been determined as a contrast between the means associated with a change of the factor level from -1 to +1 (Mead et al. 1993, Mason et al. 2003) (Tab. 1)

Table1. The level of factors in technologies and the method of estimating the effects of a factor

	technologies								Wkład czynnika w technologie
	nnn	nnt	ntn	tnn	ttn	tnt	ntt	ttt	
A	+1	+1	+1	+1	-1	-1	-1	-1	¼[$(y_{222}+y_{221}+y_{211}+y_{221})-(y_{122}+y_{121}+y_{112}+y_{111})$]
B	+1	+1	-1	-1	+1	+1	-1	-1	¼[$(y_{222}+y_{221}+y_{122}+y_{121})-(y_{212}+y_{211}+y_{112}+y_{111})$]
C	+1	-1	+1	-1	+1	-1	+1	-1	¼[$(y_{222}+y_{212}+y_{122}+y_{112})-(y_{221}+y_{211}+y_{121}+y_{111})$]

Subsequently, the difference of technological effectiveness (DTE) was determined.

The extra income due to a factor remaining at the new technology level was determined as the ratio of the sale price and the additional yield. On the other hand, the final profit which results from the application of individual factors in the new technology was determined as the difference between the outlay for application of a factor and the income increase caused by the change of the factor.

The cost of production is presented in the functional arrangement, listing individual outlays associated with a procedure, i.e. pre-sowing tillage, sowing, fertilisation, pest control. The cost of procedures included the outlay for machine operation, labour and for material means of production.

Results

Winter rye (*Secale cereale* L.) was used as a test crop in this study. Rye is, and will continue to be, one of the major cereals, both in Poland and elsewhere, not only because of its nutritional value, with rye products being known for their high content of nutritional fibre, beneficial fatty acids and protein profiles and a high content bioactive compounds (Heinio et al. 2008), but also owing to the potential for its use as a renewable energy source, both as feedstock in production of biofuels and in direct combustion in processes of generation of electricity and heat (Franceschina et al. 2011).

Due to disadvantageous soil and climate conditions during the plant vegetation period in Bałdy, the effects of the factors and the rye grain yield for the Palazzo cultivar differed from the effects of the factors and the grain yield for the cultivar in the production experiment in Tomaszkowo (Tab. 2).

Table 2. The principal and interactive effects in the yield of winter rye grain in production experiments with hybrid rye (Bałdy, Tomaszkowo) and population rye (Tomaszkowo)

Source of variation	Palazzo, Bałdy	Palazzo, Tomaszkowo
Sowing rate (A)	-1,51 *	7,83 **
Depth of sowing (B)	0,52	-0,64
Top dressing N (C)	4,77 **	0,61
AB	-3,23 **	5,49 **
AC	-0,03	3,78 **
BC	0,59	1,09

* significance p<0,1
** significance p<0,05

An analysis of variance of the yield of grain of Palazzo rye grown in Bałdy revealed significant principal effects of the amount of grain sown (A) and top-dressing (C) and interactive effects of: *amount of grain sown x sowing depth* (AB). In an experiment conducted with the same cultivar grown in Tomaszkowo, significant effects were observed in the amount of grain sown (A) and interaction of the *amount of grain sown x sowing depth* (AB) and *the amount of grain sown x top-dressing with nitrogen* (AC).

The direction of reaction in terms of yield varied from one location to another, both in regard to the factor level and to the scale of effects. The principal effect of the amount of grain sown in Bałdy was negative -1.51 $dt \cdot ha^{-1}$, whereas in Tomaszkowo it was positive +7.83 $dt \cdot ha^{-1}$. The difference in mean yield for the interaction *the amount of grain sown x sowing depth* in Bałdy +3.75 $dt \cdot ha^{-1}$, in Tomaszkowo -6.13 $dt \cdot ha^{-1}$. Only for the interactive effect of *the amount of grain sown x top-dressing* was the mean effect the same in both locations: +4.73 in Bałdy and +4.39 in Tomaszkowo (Tab.3).

Table 3. Differences in mean yield of winter rye grain in production experiments with hybrid rye (Bałdy, Tomaszkowo)

Source of variation	Palazzo, Bałdy	Palazzo, Tomaszkowo
AB (nn-nt)	-2,70	4,85
AB (tn-tt)	3,75	-6,13
AC(nn-nt)	4,73	4,39
AC (tn-tt)	4,80	-3,17
BC(nn-nt)	5,36	1,70
BC (tn-tt)	4,18	-0,48

The highest yield in Bałdy of 35,2 dt·ha^{-1} was achieved in the tnn technology, in which a larger amount of grain was used: 300 grains·m^{-2} (t), more shallow sowing at 2 cm (n) and extra top-dressing with nitrogen 30+30 (n) (Fig. 14a). The other technologies with top-dressing with nitrogen gave a lower yield by about 5 dt·ha^{-1}, and at sites with a single dose of nitrogen - it did not exceed 30 dt·ha^{-1}. Therefore, it can be assumed that top-dressing with nitrogen in the production experiment conducted at Bałdy was the main discriminating factor between the technologies which offered a possibility of achieving a higher yield and those in which a lower yield could be achieved.

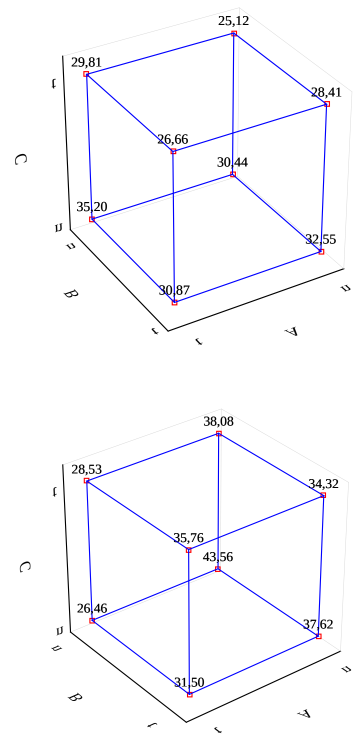

Fig. 1. Crop of rye grain in the configuration of three a) Bałdy, b) Tomaszkowo

Greater disproportions between grain yields as a result of application of different cultivation technologies were observed in Tomaszkowo (Fig. 1b). The largest yield of 43.56 dt·ha^{-1} was achieved by applying the new technology (nnn), in which a smaller amount of grain was sown: 200 grains·m^{-2} (n), more shallow sowing at 2 cm (n), and extra top-dressing with nitrogen 30+30 (n). On the other hand, the smaller yield was generated by the tnn technology: 26.46 dt·ha^{-1}, in which a larger amount of grain sown limited rye tillering, which probably made utilisation of the extra dose of nitrogen poorer. In this experiment, the yield was mainly differentiated by the amount of grain sown; in technologies with larger amounts of grain sown, the yield was lower by 7.8 dt·ha^{-1} (ttt) and by 17.1 dt·ha^{-1} (tnn) than in the new technology (nnn).

Table 4 shows the difference of technological effectiveness in terms of grain yield between the new technology and the traditional one (DTE=nnn-ttt), additional cost which results from applying factor A, B and C at the new technology level (n) and the additional income in the new technology.

Applying the new technology in cultivation of the hybrid cultivar, where the factors under study A, B and C were at the "n" level, i.e., a smaller amount of grain sown, more shallow sowing and an extra dose of N compared to the traditional technology, in which factors A, B and C were at the "t" level, larger amount of grain sown, deeper sowing and one dose of N, brought additional income of 703.61 PLN in Tomaszkowo and 290.79 PLN in Bałdy.

Table 4. Economic effects of agrotechnical factors of a new technology vs. the traditional technology in cultivation of hybrid rye, Palazzo cultivar (Tomaszkowo and Bałdy, 2010)

The economic analysis ratios	Tomaszkowo		
	Sowing rate (A)	Depth of sowing (B)	Top dressing N (C)
Difference of Technological Effectiveness (DTE), $dt \cdot ha^{-1}$		10,36	
Price, PLN 1 dt^{-1}		67,90	
Extra income – DTE, zł		703,61	
Additional cost, $zł \cdot ha^{-1}$	-69,14	-1,29	112,90
Sum of additional cost, $zł \cdot ha^{-1}$		42,47	
The main effect of factor, dt·ha-1	7,832	-0,640	0,611
Extra income, zł·ha-1	706,18	-57,69	55,12
Marginal income, $zł \cdot ha^{-1}$	815,15	-57,18	-96,83
Marginal profi, zł·1 $zł^{-1}$	-4,85	21,18	0,23
	Bałdy		
Difference of Technological Effectiveness (DTE), $dt \cdot ha^{-1}$		4,28	
Price, PLN 1 dt^{-1}		67,90	
Extra income – DTE, zł		290,79	
Additional cost, $zł \cdot ha^{-1}$	-69,14	-1,29	112,90
Sum of additional cost, $zł \cdot ha^{-1}$		42,47	
The main effect of factor, dt·ha-1	-1,51	0,522	4,77
Extra income, zł·ha-1	-115,94	40,12	366,60
Marginal income, $zł \cdot ha^{-1}$	-38,51	42,55	244,28
Marginal profi, zł·1 $zł^{-1}$	-0,43	8,13	-0,85

Extra income which resulted from the contribution of individual factors varied, both in regard to the factors under study and to the plantation locations. A positive income at both locations was generated only by extra nitrogen fertilisation: 55.12 PLN in Tomaszkowo and 366.60 PLN in Bałdy. The economic effects of the contribution of the other factors in extra income varied. Under the advantageous conditions of rye cultivation in Tomaszkowo, the reduced amount of grain sown generated large extra income of 706.18 PLN, whereas more shallow sowing generated a loss (negative income) -57.69 PLN. Furthermore, in Bałdy, where the conditions of rye cultivation were disadvantageous, a smaller amount of grain sown generated a loss: -115.94 PLN, whereas more shallow sowing generated an extra income of 40.12 $PLN \cdot ha^{-1}$. In line with the rule of decreasing final productivity with increasing a variable factor, production output increments per an additional unit of the factor decreased until they became negative (Kisiel 1999). At the same time, according to the Cobb-Dauglas production curve, smaller expenditures on production associated with a specific production factor do not necessarily result in a smaller production output, because the effect of a particular factor may be offset by other factors (Wiszniewska-Matyszkiel 2011). In the study conducted by these authors in Tomaszkowo, with a high final income of 815,15 PLN, resulting from decreased amount of grain sown, spending another 1 PLN on grain for sowing would result in a loss of 4.85 $PLN \cdot ha^{-1}$, whereas higher expenditure on fertilisation would result in a final income of 0.23 $PLN \cdot ha^{-1}$.

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