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IMPACT OF POST-HARVEST SOIL CULTIVATION AND NITROGEN FERTILISATION ON THE ENERGY- AND COST- EFFECTIVENESS IN SPRING BARLEY AND WINTER WHEAT PRODUCTION

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ABSTRACT

In a four-year static field trial, an impact of post-harvest soil cultivation method and an increased nitrogen fertilisation on energetic and economic effectiveness of spring barley and winter wheat cultivation were researched. A simplified calculation method was applied in the research. Differences in energy input, direct costs and yield market value between respective variants of soil cultivation and traditional stubble skimming were estimated. Similarly, an impact of an increased nitrogen dose as compared with a lower level fertilisation was defined. It was observed that stubble mulching with cut straw was the most energy - and cost-effective post-harvest soil cultivation variant for spring barley and winter wheat. Cereal fertilisation, increased from 50 or 60 to 100-120 kg N/ha, despite an increased cumulative energy input and direct costs, showed energy- and cost-effective.

Key words: spring barley, winter wheat, post-harvest soil cultivation, intercrops, mulch, nitrogen fertilisation, energy input, direct costs.

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INTRODUCTION

In market economy, yield maximisation is not the only criterion for technology selection for plant cultivation and assessment of the habitat exploitation and productive input effectiveness. Energy and economic calculation allows optimisation of a production intensity level.

A share of respective agronomic and technical treatments within the energy and input and cultivation costs structure varies, depending on the species, habitat conditions and the production technology applied. Generally, the value of material input is the most considerable, fertilisers in specific [2,6,12]. Soil cultivation is also high in energy consumption. However, the amount of energy consumed depends, to a great extent, on the depth and intensity of soil cultivation and the degree of consumption of other productive inputs [1,2,3,13]. Giving up post-harvest cultivation, only, may cause a decrease in energy input by as much as 40% [4]. An increase in funds for plant protection and fertilisation allows cutting down on, or even eliminating, some of the cultivation treatments, which means a smaller share of soil cultivation in the total energy-consumption of plant production.

The aim of the present research was to determine an impact of differentiated post-harvest soil cultivation, including various methods of straw turn-into soil and increased nitrogen fertilisation, on the cropping of spring barley and winter wheat. Also an attempt was made to define energy – and cost-effectiveness of the respective post-harvest cultivation variants and an increased nitrogen fertilisation as compared with the traditional stubble skimming and a lower nitrogen dose applied in cereal cultivation.

MATERIALS AND METHODS

In 1995-1998 a field trial was made to determine an impact of various soil cultivation methods and nitrogen fertilisation on energy- effectiveness in the production of spring barley and winter wheat with cereal rotation applied. The field trial was set as a two-factor in split-block design. The first factor consisted of six variants of the post-harvest soil cultivation: skimming which covered the cut straw, skimming which covered the straw + 30kg N/ha, stubble skimming, intercrop cultivation, stubble mulching with cut straw, stubble cultivating. The other factor was a differentiated nitrogen fertilisation, namely 50 and 100kg N/ha for spring barley or 60 and 120kg N/ha for winter wheat.

Field experiment, here a static test, was realised in the soil of light clay mechanical composition, in three replications. The test was set in the following sequence: winter wheat - spring barley - winter wheat. The post-harvest soil cultivation was made on the 8 x 50m plots. An URSUS C-360 tractor was used here. The straw was collected with a T-010/2 automatic collection trailer. An ORKAN 2 green mass cutter was used to cut the straw. Soil cultivation was conducted with a U 425 cultivator and a U 025/1 plough. A stubble after-crop sowing, following winter wheat harvest (white mustard - 20kg/ha), was made with a Poznaniak 2 universal planter. The post-harvest companion crop in the sequence of spring barley - winter wheat (multi-flower ryegrass) – 20 kg/ha) was sown along with spring barley.

To calculate energy consumption and cost-effectiveness for respective cultivation variances of spring barley and winter wheat, simplified calculation was applied. A stubble skimming and a lower level nitrogen fertilisation served as the control tests here. A difference in yield and resources for respective objects, as compared with the control test, expressed in energy units, zl (Polish currency unit) and euro/ha constituted a basis to estimate the effectiveness for the post-harvest soil cultivation methods and an increased nitrogen fertilisation. Energy consumption was calculated from the analysis of four cumulative energy streams, namely human labour (machinery and tool operation), energy carriers (fuel), materials (nitrogen fertiliser, aftercrop seeds) as well as machinery and equipment. Machinery efficiency was defined compliant with the brochure, Agroma-Informator [7]. To calculate fuel consumption and translate the resources into energy units, a set of meters and indicators was applied in agribusiness research [5]. Energy value for grain yield difference was calculated with an equivalent of 1 ton of cereal grain = 14235 MJ of energy. 1 man-hour to calculate human labour equivalent was translated into 40 MJ of energy and 0.8 euro (3.5 zl).

Cost-effectiveness for respective cereal cultivation variants, as compared with the control variants, was calculated similarly. Prices of grain, seeds, fertiliser and the value of resources for post-harvest soil cultivation, compliant with the price index for goods and services in the Bydgoszcz province for September 1998 [10]. To express the values calculated in euro, an equivalent value of 4.13 zl was applied.

RESULTS

An effect of an increased nitrogen fertilisation on yielding of cereals was seen in both species, although the level of statistic significance was exceeded in spring barley, only (Table 1). The highest grain yields, independently of a fertilisation level, were observed in mulched objects and after ploughing the cut straw with nitrogen added. Also stubble after-crop cultivation caused, as compared with a skimmed object, an increase in spring barley yield by 0.47t/ha. However multi-flower ryegrass sown between spring barley did not have a considerable impact on winter wheat cropping. The worst variant of the post-harvest soil cultivation, both for spring barley and winter wheat, was its simplification to stubble cultivating.

Table 1. Spring barley grain yields (mean of 1995 and 1997) and winter wheat (mean of 1996 and 1998), t/ha

Post-harvest cultivation method	Grain yield (t/ha)					
	Spring barley			Winter wheat		
	N_1	N_2	mean	N_1	N_2	mean
Skimming + straw	3,63	4,13	3,88	4,62	5,27	4,95
Skimming + N + straw	4,24	4,74	4,49	4,79	5,34	5,07
Skimming	3,62	4,04	3,83	4,59	5,22	4,91
Intercrop cultivation	4,08	4,52	4,30	4,58	5,20	4,89
Mulching	4,15	4,53	4,34	4,78	5,39	5,09
Cultivating	2,78	3,44	3,11	4,24	4,97	4,61
Stubble	3,75	4,23		4,60	5,23	
$LSD_{p=0,05}$ for:						
cultivation method (I)			0,72			0,18
nitrogen fertilisation (II)			0,04			ns
interaction I x II			ns			ns

The treatment at a decreased nitrogen fertilisation caused a decrease in energy value in the spring barley grain yield by about 12, 000 MJ/ha and winter wheat grain yield by almost 5,000MJ/ha. However with a doubled nitrogen dose, the decrease amounted to, respectively 8,500 MJ and 3,500MJ/ha (Table 2). Similarly, economising on energy input which amounted to 257 MJ/ha as compared with stubble skimming did not compensate for worse yielding. A simplified economic calculation shows a higher decrease in the value of cereal cropping than the value of the decrease in costs. The best energy- and cost-effectiveness due to a simplified post-harvest soil cultivation was achieved due to stubble mulching with cut straw. Here the surplus value of the spring barley yield obtained as compared with the skimmed object yield value amounted to 76.3 euro/ha (315 zl/ha) at a decreased nitrogen dose and 73.4 euro/ha (303zl/ha) with an increased nitrogen fertilisation. Respective values for winter wheat yield amounted to 58.6 euro/ha (242 zl/ha) and 56.4 euro/ha (233 zl/ha) (Table 2). Ploughing the cut wheat straw with mineral nitrogen added, as well as stubble intercrop cultivation, was favourable for the amount of the energy cumulated in the spring barley grain yield. The variants required, however, additional resources, which caused a decrease in energy- and cost-effectiveness of the yield surplus, as compared with the yield value in the skimmed object.

The energy and economic calculation allowed defining a considerable increase in the yield value due to an increased nitrogen fertilisation. An increase in dose from 60 to 120 kg N/ha for winter wheat and from 50 to 100 kg N/ha for spring barley gave an increase in cumulative energy in cereal grain yield from about 5,500 to 10,000 MJ/ha (Table 3). An increased nitrogen fertilisation, despite the increase in resources, had a favourable impact on the final energy- and cost-effectiveness. The value of the yield surplus of the spring barley, having factored in the extra costs was, depending on the post-harvest soil cultivation method, by 13,0-33,3 euro/ha (53.5-137.5 zl/ha) higher as compared with the value at a lower nitrogen dose. Similarly, the respective indicator for winter wheat grain yield was still higher and it amounted to from 42.3 to 62.0 euro/ha, namely from 174.9 to 255.9 zl/ha.

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Table 2. Economic and energy values of grain yield difference for spring barley and winter wheat in respective objects, as compared with the skimmed plot, when exposed to different doses of N fertiliser

Post-harvest cultivation method	N_1						N_2					
	Energy and economic value of yield difference per ha, in:		Difference in direct input expressed in:		Profit or loss Energy savings		Energy and economic value of yield difference per ha, in:		Difference in direct input expressed in:		Profit or loss Energy savings	
	MJ	euro	MJ	euro	MJ	euro	MJ	euro	MJ	euro	MJ	euro
SPRING BARLEY												
Skimming + straw	142	0,7	-262	-14,5	404	15,3	1281	6,5	-262	-14,5	1543	21,1
Skimming + N + straw	8826	45,0	2048	-5,8	6778	50,8	9965	50,8	2048	-5,8	7917	56,7
Skimming	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Intercrop cultivation	6548	33,4	489	16,9	6059	16,5	6833	34,9	489	16,9	6344	17,9
Mulching	7545	38,5	-796	-37,8	8341	76,3	6975	35,6	-796	-37,8	7771	73,4
Cultivating	-11957	-61,0	-257	-13,1	-11700	-47,9	-8541	-43,6	-257	-13,1	-8284	-30,5
WINTER WHEAT												
Skimming + straw	427	3,4	-262	-14,5	689	17,9	712	5,6	-262	-14,5	974	20,1
Skimming +N + straw	2847	21,8	2048	-5,8	799	27,6	1708	13,1	2048	-5,8	-340	18,9
Skimming	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Intercrop cultivation	-142	-1,2	67	-8,7	-209	7,5	-285	-2,2	67	-8,7	-352	6,5
Mulching	2705	20,8	-796	-37,8	3501	58,6	2420	18,6	-796	-37,8	3216	56,4
Cultivating	-4982	-38,3	-257	-13,5	-4725	-25,2	-3559	-27,4	-257	-13,1	-3302	-14,3

*** 1 euro = 4,13 zl**

Table 3. Economic and energy values of grain yield difference for spring barley and winter wheat due to increased N fertilisation

Post-harvest cultivation method	Energy and economic value of yield difference per ha, in:		Difference in direct input expressed in:		Profit or loss Energy savings	
	MJ	euro	MJ	euro	MJ	euro
SPRING BARLEY						
Skimming + straw	7118	36,3	**3850**	**14,6**	3268	21,7
Skimming + N + straw	7118	36,3			3268	21,7
Skimming	5979	30,5			2129	15,9
Intercrop cultivation	6263	32,0			2413	17,3
Mulching	5409	27,6			1559	13,0
Cultivating	9395	47,9			5545	33,3
WINTER WHEAT						
Skimming + straw	9253	70,8	**4620**	**17,6**	4633	53,2
Skimming + N + straw	7829	59,9			3209	42,3
Skimming	8968	68,6			4348	51,1
Intercrop cultivation	8826	67,6			4206	50,0
Mulching	8683	66,5			4063	48,9
Cultivating	10392	79,5			5772	62,0

*** 1 euro = 4,13 zl**

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DISCUSSION

Respective agricultural and technological factors give varied yielding results. According to Niewiadomski, quoted after Nowicki and Marks [11], mineral fertilisation determines yielding in 40 – 50% and soil cultivation in 3 – 8%, only. Cultivation treatments, ploughing in specific, consume large amounts of energy, even up to 40%. A decrease in the amount, depth reduction or ploughing elimination seems to be considerable in economising on costs and energy inputs [1,3,8,13]. The analysis of the present results showed that post-harvest cultivation had a considerable impact on the energy-consumption of cereal cultivation technology. Replacing skimming with cultivating or its elimination and stubble mulching with straw allowed saving from about 250-800 MJ of the energy/ha. However, the level of energy input for the post-harvest soil cultivation influenced cereal yield, especially spring barley. Here, a possibility to use straw for soil mulching and giving up post-harvest soil cultivation seemed specially promising.

The treatment, despite economising on energy and being more cost-effective had a favourable impact on spring barley and winter wheat cropping. Straw turned into the soil, generally having a positive effect on nitrogen immobilisation [9] under the research conditions did not cause a decrease in cereal yield as compared with the yield obtained after stubble skimming. The addition of mineral nitrogen to skimmed straw had a favourable effect on cereal yielding, however its effectiveness varied. An energy unit introduced in nitrogen fertiliser, together with straw, caused an increase in spring barley yield by 3.76 energy units. Such effectiveness, which, according to Wielicki [14], may be considered high, was considerably lower for wheat and it amounted to 0.5 - 1.0. Energy value for straw, which according to Harasim [5] amounts to 800 MJ/ha, was omitted in the present discussion. It is difficult to define the relationship between straw energy amount introduced and a proportional increase or decrease in successive plant yielding. Straw application seems more important, which is related to its further decomposition and changes in the soil. A higher dose of straw, organic material with a wide C: N ratio, with a small amount of nitrogen accessible in the soil, may cause an immobilisation of this element, its shortage and worse cropping. However, with sufficient nitrogen content in the soil or nitrogen fertilising, straw becomes a precious organic fertiliser.

The dynamics of straw mineralising and its impact on the position value differ when leaving straw on the surface of the soil as mulch. Depending on the winter wheat production technology applied, mineral fertilisation may account for over 50% of the energy input and 20 - 40% of the direct costs [2,6,12]. Therefore an increased fertilisation, especially nitrogen fertilisation, should cause an increase in yielding cost-effectively; hence, higher nitrogen doses in spring barley and winter wheat cultivation, introduced in the present research, were justified as energy- and cost-effective.

CONCLUSIONS

1. An increased nitrogen fertilisation of spring barley and winter wheat, despite an increase in energy input and direct costs, showed to be justified as energy- and cost-effective. Depending on the method of the post-harvest soil cultivation, 1 MJ of the energy input in an increased nitrogen dose, caused an increased spring barley yield by 1.40 - 2.44 MJ, respectively, and an increase in winter wheat grain yield which amounted to 1.69 - 2.25 MJ.
2. Both with lower and high nitrogen fertilisation in spring barley, stubble mulching with straw, straw with mineral nitrogen added as well as stubble intercrop cultivation was energy- effective. A profit of cumulative energy, as compared with stubble skimming amounted to 6059 to 8341 MJ/ha.
3. Among post-harvest soil cultivation methods in winter wheat cultivation researched, only stubble mulching gave a considerable, as compared with stubble skimming, energy profit. Depending on the amount of nitrogen fertiliser applied, the profit amounted to 3200-3500 MJ/ha.
4. Cultivating as a substitute for skimming, caused a decrease in energy-consumption and in direct costs of cereal cultivation. However, it limited the yields and had a negative effect on the final production, spring barley in specific. A negative reaction of the cereals fertilised with a lower nitrogen dose was greater, as compared with spring barley reaction and winter wheat where, respectively 100 and 120 kg N/ha were applied.
5. Most cost-effective modification method of post-harvest soil cultivation, namely stubble skimming in spring barley and winter wheat was mulching with straw. The treatment, depending on the cereal and the amount of nitrogen applied, gave a profit from 56.4 to 76.3 euro/ha (233-315 zl/ha).

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