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ENERGY - EFFECTIVENESS OF VARIED WINTER WHEAT CULTIVATION SYSTEMS UNDER VARIED SOIL CONDITIONS

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ABSTRACT

The present research was carried out over 1997-2000 on good rye (Agricultural Experiment Station Lipnik in the vicinity of Stargard Szczeciński) and good wheat (Agricultural Experiment Station Ostoja in the vicinity of Szczecin) soil suitability complexes in a static crop-rotation experiment, which compared the effect of soil cultivation systems: A - plough, B - ploughless, C – direct sowing (Lipnik Agricultural Experiment Station, only) on the growth, development and yielding of winter wheat in crop rotation: sugar beet – winter wheat – faba bean – winter barley + stubble intercrop (white mustard). The results presented cover winter wheat - 'Kobra'. Irrespective of the soil cultivation system applied, significantly higher grain yields were obtained on the soil of medium quality. The reaction of plants to simplified pre-sowing cultivation depended on the soil. The light soil was observed to coincide with a significantly lower ear density and stem length, while the medium quality soil – with the grain weight per ear. Limiting the intensity of cultivation irrespective of the soil type decreased the energy –effectiveness of the soil management for winter wheat.

Key words: soil management systems, grain yield, winter wheat, energy effectiveness

INTRODUCTION

In Poland the share of cereals in the total crop structure accounts for 69.1%, out of which wheat – for 20.5% [16]. The interest in wheat results from its relatively highly cost-effective cultivation. Introducing energy-saving plant production technologies leads to a rationalised energy management in agriculture. One of the methods of enhancing economic cereal production conditions is a search for soil management systems which would be

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energy-saving, environment-friendly and which would maintain the soil yielding potential [1,4,5,11]. The reaction of plants to cultivation simplifications considerably depends on the soil type, its grain size composition, structure and organic content [3,6,9,11]. The present research and those reported by other authors show a possibility of limiting the soil management intensity provided that higher index values of plant cultivation energy effectiveness are obtained. Giving up ploughing can limit the plant yield. Wheat cultivars showing a high production potential recorded significantly lower yields when exposed to extensive agronomic practices [17]. Yields can be lowered provided that the input savings obtained are higher than the yield energy losses [7].

The reaction of winter wheat to soil cultivation simplification, including direct sowing varies. A search for optimal energy-saving soil cultivation technologies in varied soil conditions aims at sourcing out the best solutions. Introducing soil cultivation systems alternative to ploughing, especially on large farms, can increase the cost-effectiveness of the cereal production.

The aim of the present research was to define the effect of three soil management systems applied under varied soil conditions on the energy effectiveness of winter wheat grain production.

MATERIAL AND METHODS

The static field experiment was set up in 1993 at the Lipnik Agricultural Experiment Station in the vicinity of Stargard Szczeciński on light soil of good rye complex, IV b soil quality classification class, and at the Ostoja Agricultural Experiment Station in the close vicinity of Szczecin on medium quality soil of good wheat complex, III b quality classification class in the Zachodniopomorskie Province. The results presented of 1997-2000 cover the winter wheat cultivated in crop rotation: sugar beet – winter wheat – faba bean – winter barley + stubble intercrop (white mustard).

The following soil management systems have been compared (Table 1):

A - traditional, with plough (Lipnik and Ostoja),
B - ploughless, with cultivator plus cage roller (Lipnik) and with rotary cultivator plus roller (Ostoja),
C – direct sowing (RSD Lipnik only).

Table 1. Agronomic practices in the soil cultivation systems applied

Soil	Soil cultivation	Agronomic practices
Light	Traditional ploughing	In autumn - ploughing (25 cm), light harrow, row drilling, light harrow
	Ploughless	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$), cultivation unit: cultivator + cage roller, row drilling, light harrow
	Direct sowing	In autumn - direct sowing
Medium	Traditional ploughing	In autumn - ploughing (25 cm), light harrow, row drilling, light harrow
	Ploughless	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$), cultivation unit: rotary cultivator + roller, row drilling, light harrow

'Kobra' winter wheat, 500 grains per 1 m^2, was sown in the first decade of October. The phosphorus and potassium fertiliser doses were defined with the soil richness in nutrients, nitrogenous for grain yield 6 $t \cdot ha^{-1}$, while nurturing practices over wheat vegetation period were carried out compliant with commonly applied agronomy guidelines. Weed infestation was reduced with Cougar 600 EC and spring harrowing. The grain yield energy and the cumulated energy resources of the soil cultivation systems tested were calculated based on equivalents and standard indices for agronomic practices, mineral fertilisers, pesticides and sowing material [18,19]. The results obtained were statistically verified for static model with variance analysis for respective research years and for the total 4-year research period for each soil type separately, while significance of the differences was verified with the Tukey test at the significance level of α=0.05.

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RESULTS AND DISCUSSION

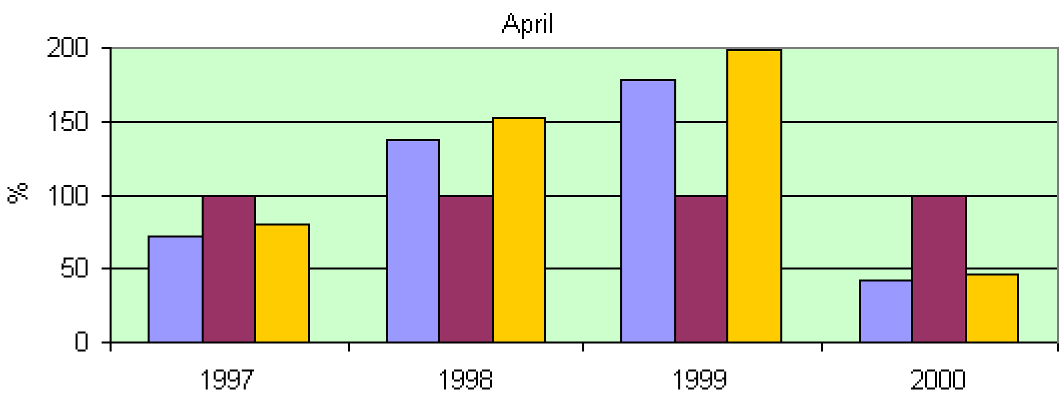
The data given in Table 2 show considerable seasonal changes in winter wheat yielding depending on the soil type and precipitation and its distribution over 1997-2000. The good wheat complex soil showed an interaction between years and the cultivation system. The reaction of winter wheat cultivated on good wheat complex soil to simplified cultivation varied over respective years and depended on precipitation distribution over the vegetation period, especially over spring (April–July, Fig. 1). Irrespective of the cultivation system, the highest grain yield, on good wheat complex soil was recorded in 2000 – 6.79 t·ha^{-1}, and on good rye complex soil in 1998 – 5.90 t·ha^{-1}. The excessive amount of precipitation in 1999, in April and May, by respectively 79% and 54% on light soil and 99% and 71% on medium quality soil, as compared with water requirements, resulted in a lushness of the wheat plant vegetative growth. The water deficit recorded in June and July which coincided with high water requirement over the period led to low grain yields. The lowest grain yields on both soils were obtained in 1999, respectively by 35% and 34% lower than over the years of the most favourable precipitation distribution. The variability of winter wheat yielding observed in the present research irrespective of the cultivation system is confirmed by many other authors [1,5,6,12].

Table 2. Impact of soil cultivation systems on winter wheat grain yield, t·ha^{-1}

Cultivation system	Year				Mean
	1997	1998	1999	2000	
Good rye complex					
A	5.11	5.93	4.28	5.06	5.09
B	4.83	5.69	3.88	4.18	4.65
C	4.74	6.07	3.55	4.51	4.72
Mean	4.89	5.90	3.90	4.58	4.82
$LSD_{0.05}$	ns	ns	0.465	0.608	0.332
$LSD_{0.05}$ for cultivation system x year					ns
Good wheat complex					
A	6.44	5.85	4.79	6.25	5.83
B	5.24	3.81	3.52	6.59	4.79
Mean	5.84	4.83	4.15	6.42	5.31
$LSD_{0.05}$	0.462	0.203	0.703	0.176	ns
$LSD_{0.05}$ for cultivation system x year					0.280

A,B,C – soil cyultivation systems
ns – non-significant difference

Fig. 1. Monthly shortage and excessive precipitation on light and medium soil (winter wheat precipitation requirements = 100)



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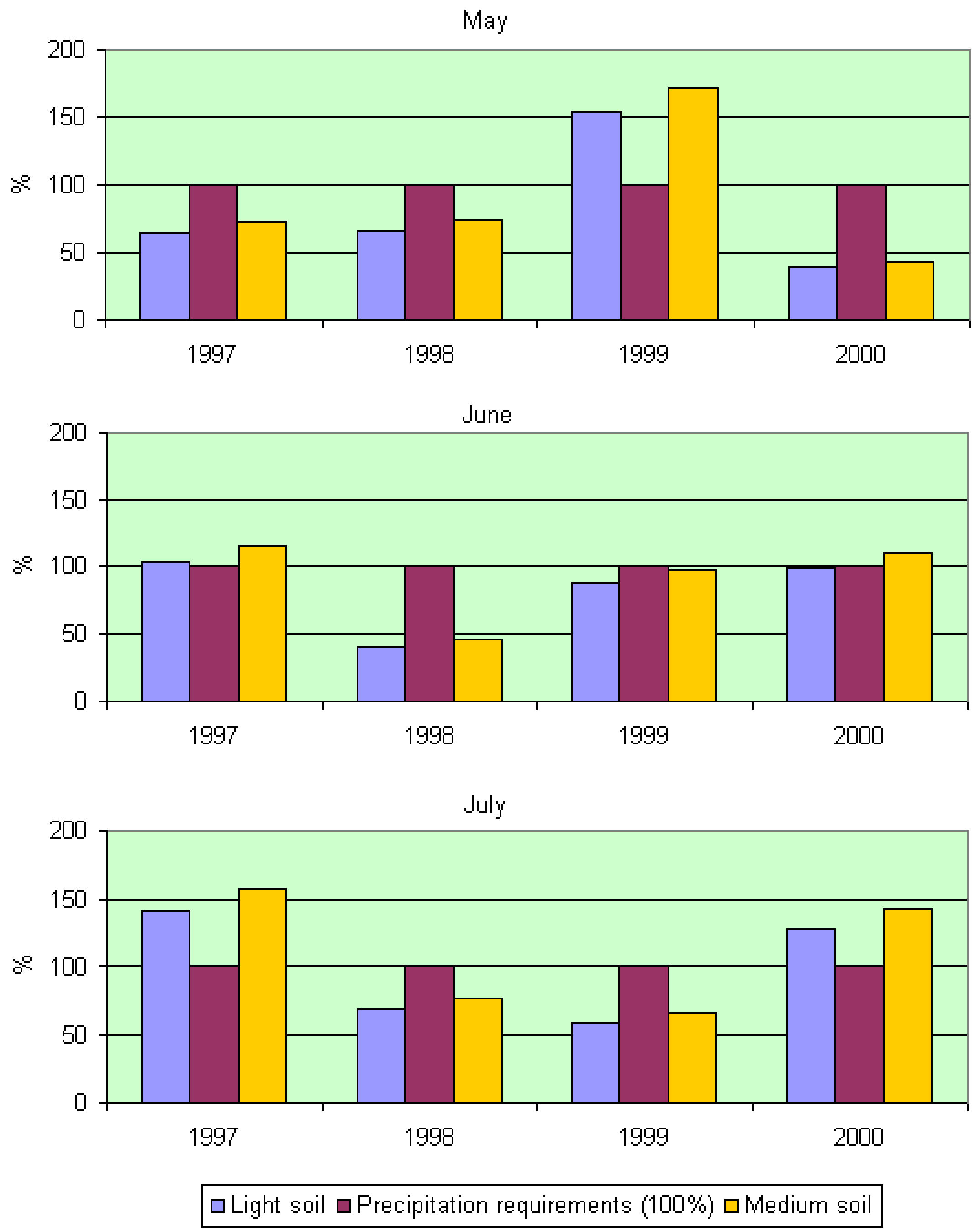

On good wheat complex soil mean 4-year grain yields obtained following the application cultivation sowing unit with rotary cultivator plus roller were lower by 18 % as compared with the traditional cultivation (5.83 $t \cdot ha^{-1}$), however the differences were insignificant. Similar trends were observed wherever plough was replaced by cultivator plus cage roller in post-harvest and pre-sowing soil cultivation. Biskupski and Sienkiewicz [3] obtained lower (by 15%) wheat grain yields (4.12 $t \cdot ha^{-1}$) due to the application of cultivator plus cage roller as compared with the objects which were post-harvest ploughed, and pre-sowing Campbell rolled. A similar reaction of winter wheat, namely a lower yielding, to simplified soil cultivation, is confirmed by the reports from Scandinavia [15] and Ireland [6].

A limited intensity of soil cultivation on good rye complex soil (B, C) led to decreased grain yields by 8 and 7% as compared with ploughing cultivation. Simplified soil cultivation on lighter soils decreased the yields in many experiments [2,9,20], which could have resulted from a smaller use of soil nutrients, especially nitrogen, as well as higher crop weed-infestation, which can suggest a need for an extra nitrogen dose, especially in direct sowing [2].

On light soil the number of ears per sq. meter and grains per ear depended on soil cultivation system significantly (Table 3.). The simplified cultivation (B and C) significantly decreased the number of ears per sq. meter by 8.5 and 12%, respectively, as compared with plough cultivation. Simplified soil cultivation led in a stem shortening, even though the changes recorded over respective years differed. Having applied direct sowing, the plants were lower by an average of 9% and the number of grains per ear was lowest (31.4).

Table 3. Impact of soil cultivation system on selected stand biometrics and yield

Cultivation system	Number of ears per sq. m	Shoot length cm	Ear length cm	Number of grains per ear	Grain weight per ear g
Good rye complex					
A B C	519 441 403	70.3 67.6 64.4	6.46 6.60 6.29	33.2 36.1 31.4	1.32 1.38 1.23
Mean	455	67.4	6.45	33.5	1.31
LSD $_{0.05}$ LSD $_{0.05}$ cultivation system x year	33.2 ns	ns 3.41	ns ns	3.32 ns	ns ns
Good wheat complex					
A B	523 509	74.7 71.1	7.39 7.33	33.9 34.9	1.55 1.43
Mean	516	72.9	7.36	34.4	1.49
LSD $_{0.05}$ LSD $_{0.05}$ cultivation system x year	ns 11.8	ns 3.22	ns ns	ns ns	0.05 ns

ns – non-significant difference

Winter wheat direct sowing after varied forecrops reported by Blecharczyk et al. [2] enhanced the number of grains per ear, which was 12% higher as compared with skimming and pre-sowing ploughing [2]. The highest number of grains per ear was recorded following the ploughless soil cultivation (B), i.e. by 8% higher than following traditional plough. Similar changes in stand and grain yield components were recorded in IUNG Puławy research [10]. However, on medium soil, simplified cultivation did not show any similar responses. The weight of grain per ear as an effect of ploughless cultivation (B) was the only one which was significantly lower, by 8%, as compared with plough cultivation.

The energy potential effectiveness for the soil cultivation systems was calculated based on accumulated grain production energy potential. Irrespective of the soil type, the energy potential depended on the extent to which the soil cultivation was simplified (Table 4). The greatest accumulated energy potential was involved in traditional soil cultivation on light soil, and slightly lower – on medium quality soil.

Table 4. Impact of soil cultivation system on the value of winter wheat cultivation energy effectiveness index

Soil cultivation system	Accumulated energy potential Ne, $MJ \cdot ha^{-1}$	Grain yield energy P, $MJ \cdot ha^{-1}$	Energy effectiveness index E=P/Ne
Good rye complex			
A B C	18899 18278 18045	38175 35025 35400	2.02 1.92 1.96
Good wheat complex			
A B	17852 17222	43725 35925	2.45 2.09

Simplified soil cultivation in wheat growing (B and C) on light soil decreased the energy potential by, respectively, 3% and 5% and on medium soil by 4% (B). The highest value of energy effectiveness index (2.45) was recorded on medium quality soil following plough cultivation. Similar index values, 2.02 and 2.09 were obtained after plough cultivation on the light soil and after simplified cultivation on the medium soil. A slightly lower (1.96) energy effectiveness index was observed for winter wheat direct sowing while the lowest one (1.92) – following ploughless cultivation (B), both on light soil.

Lower grain yields obtained on ploughless objects in winter wheat pre-sowing soil cultivation decreased the index of energy effectiveness by 15% on medium quality soil. Accumulated energy potential on light soil (B and C) showed more effective; a slight decrease was recorded here, by 5 and 3%. Other authors record [14] on similar effects of accumulated energy in winter wheat growing on the index values.

Energy effectiveness of respective cultivation systems depends on soil and plant; the value for winter wheat was higher after direct sowing than after plough cultivation [8,11]. The present results confirm those recorded by Suwara et al. [14] and differ considerably from those by, i.e. Kordas [8] and Kuś and Kamińska 10], which calls for an adequate evaluation of soil condition prior to selecting a soil cultivation system for winter wheat under given weather conditions.

CONCLUSIONS

1. Simplified soil cultivation for winter wheat over favourable weather conditions differentiated the grain yield significantly on none of the soils tested. A greater response to simplified soil cultivation was shown by winter wheat grown on medium quality soil.
2. Ploughless soil cultivation or direct sowing limited accumulated energy yet they did not decrease winter wheat grain yield significantly.
3. A limited cultivation intensity showed no increase in the value of energy effectiveness index, while a slightly higher value was obtained on good wheat complex soil.
4. Direct sowing of winter wheat on light soil and ploughless system - on medium quality can be applied without any significant decrease in grain yield.

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