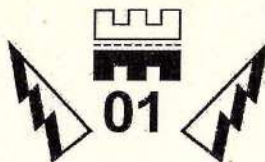


International Soil Tillage
Research Organization

ISTRO

BALTIC STATES BRANCH OF ISTRO



**1st INTERNATIONAL CONFERENCE
of BSB of ISTRO
&
Meeting of Working Group 3
of the
INCO-COPERNICUS Concerted Action on
Subsoil Compaction**

***MODERN WAYS OF SOIL TILLAGE
AND
ASSESSMENT OF SOIL COMPACTION
AND
SEEDBED QUALITY***

**21-24 AUGUST 2001
EAU, TARTU
ESTONIA**

Editor: E. Nugis

ISBN 9985-78-224-0

Current collection of papers was issued in the frame of 1st Conference of the Baltic States Branch of ISTRO and Meeting of Working Group 3 of the INCO-COPERNICUS Concerted Action on Subsoil Compaction. Issuing the collection was possible thanks to support provided by Ministry of Agriculture.

The camera ready manuscripts was printed in 200 copies by AS "REBELLIS"

Published by: SCA Ecofiller® & Estonian Branch of ISTRO
Teaduse 18-4
75501 Saku, Harjumaa
Estonia
Tel/Fax: +372-60-42-564

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THE ESTIMATION OF ENERGY EFFICIENCY OF SOIL TILLAGE TECHNOLOGY

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Abstract. Klochkov A., Duben I. 2001. *The Estimation of Energy Efficiency of Soil Tillage Technology. Proceedings of Baltic States Branch of ISTRO Conference & Meeting of WG 3 (INCO-COPERNICUS Project), Tartu, August 21-24, 2001.*

In this article an attempt has been made to introduce the new methods of soil cultivation, results of the research which are carried out for many years, the comparison of energy efficiency.

Keywords: *methods, soil cultivation, energy efficiency.*

1. INTRODUCTION

In most countries of the world the main soil-working implement is the share-moldboard plough. However, farming experience accumulated by the present time allows to use different techniques and complexes of machines for pre-sowing soil preparation. Now we increasingly use chisel implements, disk harrows, rotating tillers, combined aggregates, the "zero" tillage is applied. Choosing the right techniques one should take into account the actual virtues and drawbacks of different agricultural and technical methods, as well as concrete requirements of a field and of cultivated crops.

The application of new methods of soil cultivation is caused by the desire to minimize expenditures of work and fuel, by the necessity of guarding the soil against erosion and excessive soil compaction. It stipulates the tendency to minimize the effect of working parts and running systems of tractors on the soil. The comparative estimation of the efficiency of the machines and techniques being used now and the future ones suggests a comprehensive approach to the solution of these problems within the framework of the whole soil-working technique. The most objective and comprehensive indexes of performance are based on the machines efficiency estimation in terms of power consumption.

2. METHODS

The applied techniques are characterized by different power consumption of individual aggregates and by the number of their passes for reaching necessary quality of pre-sowing soil preparation. The index of the selected soil-working technique power consumption efficiency is expressed by the coefficient of energy efficiency [1]:

$$K_{\text{Э}} = \frac{E_{\text{Y}}}{\sum E_{\text{T}}},$$

where E_{Y} – energy value of the obtained crop from a unit area of a field;

$\sum E_{\text{T}}$ – aggregate energy used during crop cultivation

The most objective of the existing ways of agricultural methods and techniques energy analysis is the proposed [1] method of the analysis determining a dimensionless factor $K_{\text{Э}}$:

$$K_E = \frac{\sum E_N}{\sum E_B} \cdot \frac{U_B}{U_N},$$

where $\sum E_N$ and $\sum E_B$ – aggregate power consumption of execution of technological processes by new and serial machines taking into account the factors of the engineering, technological and economic character; U_N and U_B – crop yield of the cultivated crop based on using the new and the base techniques, accordingly. For the comparative evaluation of power consumption of machines and working parts of the same type we use the specific resistance in reference to the unit of operating width or to the unit of the cross-sectional area of the processed soil layer. In a number of cases a more effective index is mechanical energy consumption required for a unit of the processed area.

3. RESULTS AND DISCUSSION

The general tendency to reduce soil tillage results in wider application of boardless implements, as well as the reduction of tillage depth, the use of combined aggregates performing a number of operations in one pass. At present considerable experience of use of different soil-working techniques is accumulated in many countries. According to the data of the National Institute of Agricultural Engineering in the UK [2], the largest energy consumption corresponds to the traditional tillage technique on the basis of moldboard plowing (Tab. 1). The application of a chisel plough does not allow to reduce power consumption considerably; it can even increase by 7.8 % if the number of field passes of an aggregate is to be increased. Among the given tillage variants fine plowing is the most suitable, as the basic tillage power consumption is minimal and is by 37... 40 % lower than the moldboard plowing power consumption. The tillage combined with sowing and the application of herbicides allows to reduce power consumption considerably. However, at the expense of expenditures on herbicides the general power consumption is only by 15... 44 % less than the traditional technique power consumption. It is also necessary to take into account the ecological damage which considerable chemical preparations doses application may cause.

On Belarussian soils the chisel or subsurface basic tillage can somewhat increase the crop yield of winter rye (Tab. 2). However, this requires effective destruction of weeds by chemical or mechanical means. The tillage power consumption decrease by 52 % at direct sowing is accompanied by a simultaneous decrease of productivity by 10 % in comparison with the traditional technique, therefore the power consumption efficiency coefficient in this case is the greatest. However, the data of Table 2 do not take into account extra power consumption, stipulated by the application of herbicides and by different metal consumption of the applied machines.

Table 1. Results of comparative examination of different soil-working techniques for grain crops cultivation

Technique	Power consumption, MJ/ha		Cost of tillage, pound / ha
	for the basic tillage	general	
Traditional on the basis of moldboard plowing	118...307	180...324	20.2...32.0
Fine plowing and pre-sowing tillage combined with sowing	68...133	108...203	12.5...16.5
Double chiseling (0.125 m) and pre-sowing tillage combined with sowing	147...213	194...308	16.5...26.5
Rotary tillage and pre-sowing tillage combined with sowing	88...156	144...201	13.5...17.0
Immediate sowing with the application of herbicides	–	38...54	17.0...18.0

Based on the results of the research carried out for many years, the comparison of energy efficiency of the traditional, boardless (chisel and subsurface), contracted and combined tillage techniques (Tab. 3) was carried out taking into account extra power consumption with fertilizers and plant protection means, as well as material consumption of machines and equipment. The contracted tillage represented disc tillage by a heavy disk harrow and tillage; the combined tillage – tillage and sowing at the same time. The power consumption of extra expenditures is considered to be constant for all the given techniques, the energy equivalent of agricultural machines is considered to be equal to 75 MJ on a kilogram of their mass.

Table 2. Comparative power consumption estimation for winter rye cultivation under different techniques

Tillage	Fuel consumption, kg / ha	Power consumption, MJ/ha	Crop yield, centner/ha	Energy value of the crop yield, MJ/ha	Power consumption efficiency coefficient, K_G
Plowing, tillage with harrowing (twice), sowing	27.9	1190.9	22.1	33696	28.3
Chiseling, tillage (twice), sowing	23.3	996.2	22.8	34763	34.9
Subsoil tillage, tillage (twice), sowing	28.7	1225.1	24.5	37355	30.5
Direct sowing by a stubble seeder	13.3	567.9	19.9	30342	53.4

Table 3. Results of the energy analysis of tillage techniques for grain crops cultivation

Indexes	Base variants			Perspective variants	
	Traditional	Chisel	Subsurface	Contracted	Combined
Productivity, μ /ha	22.1...25.2	22.8...25.7	24.5...24.7	26.6...30.5	22.4...26.6
Labour consumption, persons per hour/ha	2,686	1,884	1,718	1,580	1,648
Basic operations fuel consumption, kg / ha	38.81	27.35	31.10	24.19	20.20
Basic operations power consumption, MJ/ha	1657.2	1167.8	1328.0	1032.9	862.5
The total power consumption, MJ/ha	13698.1	13272.5	13519.7	13106.1	12520.2
Coefficient K_E	–	0.94...0.95	0.9...0.97	0.79...0.80	0.87...0.90

For labour consumption and fuel consumption the contracted and combined tillage are more preferable ensuring a decrease of basic operations power consumption up to 37... 48 %. The variants with the use of chisel and

subsurface tillage also ensure better performance in comparison with the traditional technique. However, extra expenditures on herbicides for boardless tillage methods, taking into account the energy equivalent of the applied machines, reduce the techniques efficiency considerably.

The analysis of different systems of minimum tillage on Belarussian soils shows, that cultivation of many crops allows the substitution of the usual moldboard plowing by heavy disk harrows tillage to the depth of 0.10...0.12 m or moldboard primary tillage to half the depth of the arable soil layer. And then the crop yield depends not on the depth of tillage, but on its quality, timeliness and on the amount of the destroyed weed vegetation. However, because of extra passes the danger of excessive soil compaction of subsurface soil layer increases.

The substitution of moldboard plowing by fine tillage is possible only if the fields are not weeded by perennial weeds. The research confirms, that the substitution of plowing by moldboard primary tillage and disc tillage does not result in the crop yield decrease, but reduces tillage power consumption by 19.8...26.6 %.

On sward-podzolic soils the rational system of tillage in crop rotation can be based on the principle of combination of plowing and surface tillage. With high culture of farming on sward-podzolic soils it is possible to plow in a year, and on light cultivated soils – in 2...3 years in alternation with surface tillage methods to the depth of 0.10...0.2 m or with boardless breaking of the soil to the depth of 0.20...0.25 m.

At the same time one cannot exclude moldboard plowing completely, it is irreplaceable in sufficient and superfluous moisture content conditions, as well as for effective struggle with perennial weeds. The task is to decrease plowing power consumption, saving and developing the agro-technical advantages of plowing, which can be achieved by improving the structure of the share-moldboard-plow bottoms.

The new structure of plate plow bottom with curved plates has relative simplicity and high performance (Fig. 1). Its application ensures soil crumbling quality increase up to 12...17 % with covering up to 98.3 % of plant remains, the specific traction resistance thus is reduced by 10...25 % [4]. Under favorable soil conditions the application of the plate bottom with cylindrical plates allows to reduce the number of passes which the machines make on the field for pre-sowing soil tillage.

To increase the quality of tillage with more rational tractor loading we use additional ploughs attachments intended for additional breaking and leveling of the soil simultaneously with plowing. Its teeth make a crumbling effect on the bed immediately after coming off the moldboard. According to the results of the tests, the coefficient of soil crumbling made up 86.5...91.1 % with covering of 95...97 % of the plant remains, the average height of the crests on the seedbed surface did not exceed 24.3 mm. The application of the attachments ensures elimination of one extra tillage with harrowing, that allows to decrease power consumption for tillage and to reduce soil compaction by tractor wheels.

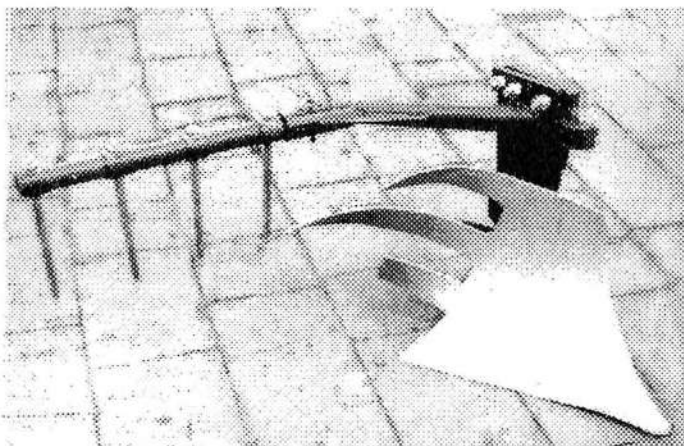


Fig. 1. Plate plow bottom with cylindrical plates and an additional teeth attachment.

4. CONCLUSIONS

The expediency of application of a particular tillage technique should take into account the factors of the energy and ecological character. With high culture of farming the alternation of plowing with boardless and surface tillage methods is possible, that allows to reduce the plowing material and power consumption. However, we cannot avoid plowing completely as it leads to the necessity of application of chemical plant protection means, that is connected with extra expenditures and the negative effect on the environment.

The improvement of agro-technical characteristics of plowing promotes a decrease of intensity of additional soil tillage. The use of the structure of the plate plow bottom with cylindrical plates and teeth attachments ensures substitution of one tillage with harrowing.

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