Some technical aspects of cut height in wheat harvest

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Abstract. In order to determine the most appropriate cut height of wheat harvest, it is necessary to take into consideration not only the agronomical aspects, but some technical factors as well. In this research, the influence of cut height of harvest on the accounted losses and the fuel consumption of a combine harvester has been considered. It has been shown that the increasing of cut height up to straw-level in the threshed wheat mass 0.24 does not lead the accounted losses of the combine "CLAAS DOMINATOR – 106" over the permissible limits, without a necessity to install additional equipment on the machine. With such a technical solution, a decrease of fuel consumption of up to 30% can be achieved.

Key words: cut height, harvest losses, cereal, fuel consumption

INTRODUCTION

It is known that already in ancient Egypt cereal was cut high (History of Economy…). Then cattle were let in the field to graze. Thus, the fields were prepared for growing there next crops. Nowadays, the optimum stubble height is determined by a practical rule: 2/3 of the total stem height (Nielsen, 2004, etc.). In the meantime, however, the straw is not used, which makes the growing of next crops more difficult.

Generally speaking, cut height in harvest determines the effectiveness of the crops grown in many aspects. The most important is its impact on humidity preservation, soil erosion, the opportunities for retention of snow on fields, the quality and terms for the accomplishment of the following technological procedures, mostly direct sowing, the quantity and type of weeds, the quantity of straw, the optimum terms for crop harvest and linked operations (History of Economy…; McMaster et al., 1999; Korucu et al.; Vezirov & Atanasov, 2002). Of course, basic requirements in cereal harvest are keeping the agronomical term, not exceeding the permissible losses, and good quality of the grain. In our previous researches (Kolev & Kehayov, 1987) it has been proved that by applying high cut harvest (cutting only wheat-ears and a very small part of the stems) it is possible to increase the working speed of the combine harvester twice.

The aim of the present research is to show how cut height affects fuel consumption and accounted grain losses in wheat harvest. For this purpose, the basic factors have to be determined, as well as their influence on:

- Fuel consumption;
- Grain losses.

The results from the research must be presented graphically, in mathematical models and optimum values of the factors researched, impacting combine harvester performance.

MATERIALS AND METHODS

For the accomplishment of the tasks set, the methods of planning the experiment, a regression analysis, multifactor optimisation and simulation have been used (Mitkov & Minkov, 1977). Independent variables have been chosen in determination of:

- **fuel consumption:** grain yield – D, kg/ha, the ratio of straw to the grain – Rsg, cut height – Hc, cm. The dependent variable is specific fuel consumption – Fug, kg/ton;

- **losses:** harvester speed Vp, m/s, threshing drum speed V_6, m/s, X_6 – clearance between the drum and the counter-drum at the entry of the threshing device, mm. The dependent variable, characterising the quality of the process, are the accounted losses Z in %, which include uncut wheat-ears, broken and free grain, cut wheat-ears, accounted by conventional methods (Dimitrov, 1988).

First, it was considered if it was possible to adjust the combine to achieve the permissible level of losses. For specific conditions (crops, ratio of straw to grain, humidity of straw and grain, stubble height), the clearance between the drum and the counter-drum has been changed X_6 from 13 to 21 mm, the peripheral drum speed X_6 from 27.08 to 35.02 m/s and the harvester speed Vp from 3.30 to 4.83 m/s. For determination of a mathematical model of the process, an experiment using a factorial design type B_3 has been carried out (Mitkov & Minkov, 1977). The combine harvester "CLAAS DOMINATOR – 106" has been used, with a width of the header 5.10 m, with no modernisation of the machine.

On condition that this is possible it can be accepted that the effectiveness of height cut in harvest can be evaluated by fuel consumption.

RESULTS AND DISCUSSION

For the conditions of the experiment, the harvester speed Vp does not greatly influence the grain losses Z (Fig. 1). This effect is a result of the suitable choice for X_6 and V_6.

After processing the results of the experiment, the following regressive model has been found:

$$Z = 0.97 \cdot X_6 + 0.87 \cdot V_6 + 0.049 \cdot X_6^2 - 0.04 \cdot X_6 \cdot V_6. \quad (1)$$

By Fisher's criterion, the model has been checked for validation on a level of significance $\alpha = 0,05$.

For the determination of the values of the considerable factors, in which the accounted losses Z are minimum, an optimisation has been carried out by a program to search a global extreme (Nielsen, 2004). The extreme of the function is $Z^*=2.5\%$ in the following values of the considerable factors:

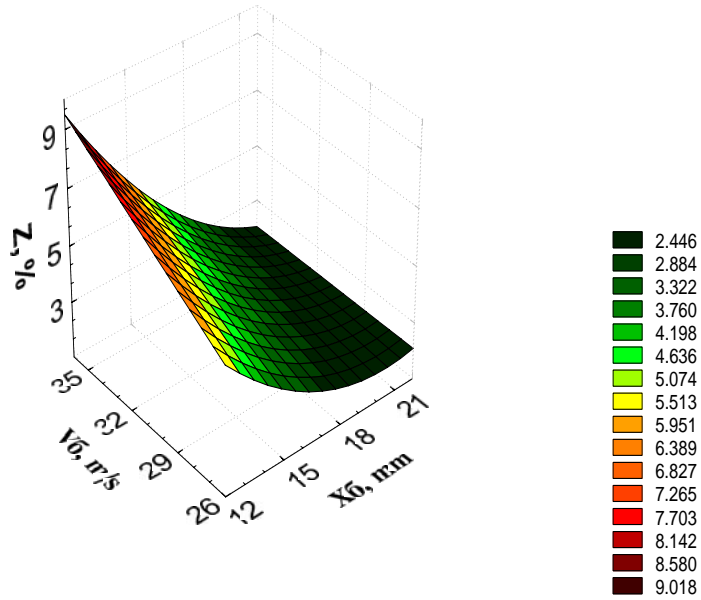X_6=20.1 mm, V_6=28.6 m/s, V_p = 4.31 m/s.

Fig. 1. Relations between accounted losses Z, drum speed V_6 and clearance X_6.

The result mentioned above allows us to use, in this case, the fuel consumption as a basic criterion for the technical effectiveness in the choice of cut height levels.

Based on the results of the experiment and harvester performance simulation, the relations shown on Fig. 2 and Fig. 3 have been determined.
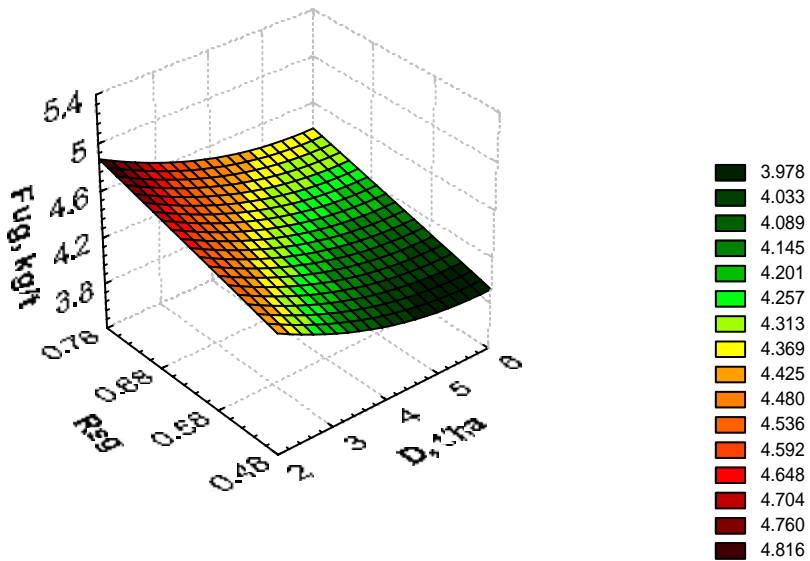

Fig. 2. Relation between fuel consumption Fug, kg/t grain, grain yield D, kg/ha and straw to grain ratio Rsg.

It can be seen that the yield and straw to grain ratio have a considerable impact on fuel consumption (Fig. 2). The energy applied in the process of threshing the cereal, can be regarded as consisting of two components – constant and variable in size. The constant component constitutes the energy necessary for the direct influence on wheat-ear and extraction of the grain from it. The variable component shows the energy necessary for overcoming the buffer action of straw in threshing process. With the growth of the straw-level, the quantity of straw, passing through the threshing device, in the general mass increases. Because of this, the energy necessary for overcoming the buffer properties of straw increases, too. The growth of the necessary energy leads to increased fuel consumption. With the growing of the harvest, the relative impact of the straw-level decreases.

economy of fuel can be achieved if the cut height is close to the wheat-ear – cut height to straw height ratio to 0.7 (Fig. 3). In this case, the fuel consumption can be decreased by up to 30%. This is an essential opportunity for reducing the cost of grain harvest.

These conclusions do not account for the necessity of additional expenses on clearing the fields from the higher crop remains. This also regards the influence of the other factors, listed at the beginning of this article.

The relation between fuel consumption per kilogramme of harvested grain G, grain yield D, straw-grain ratio Rsg and cut height H can be shown by the following equation:

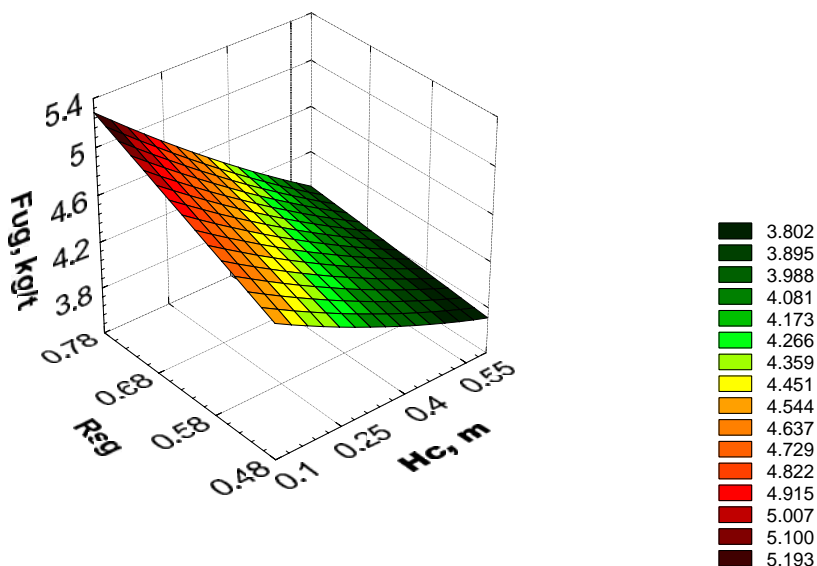$$G = A_1 + A_2.D + A_3.Rsg + A_4.H + A_5.D^2 + A_6.Hc^2 + A_7.Rsg.Hc \quad (2)$$

Fig. 3. Relation between fuel consumption Fug, kg/t grain, Hc cut height and Rsg straw to grain ratio.

A_1 to A_7 are coefficients in the equation, determined by a multiple step regressive analysis. They have been checked for significance with the **t** criterion. The model is adequate. The equation can be used for forecasting, as the value of the **F** criterion is high enough. The analysis of the residuals confirms the statement: there are no anomalous values and trends; the prerequisite for homogeneousness of dispersions is performed. The numerical values at the allowable level 0.05 for specific conditions are shown in Table 1.

Table 1. Numerical values of the coefficients, standard error and the **t** criterion of the regressive model for relation between fuel consumption Fug, yield D, straw to grain ratio Rsg, cut height Hc.

	Coefficients	Standard error	t criterion
A_1	4.415	0.028	158
A_2	-0.395	0.009	43.0
A_3	2.834	0.032	86.9
A_4	-0.483	0.069	6.94
A_5	0.033	0.001	29.5
A_6	0.859	0.061	13.9
A_7	-3.736	0.085	44.1

The equation can be used for forecasting fuel consumption in specific conditions. The equations received make the general estimation of an optimum harvest cereal cut height easier. It is an objective base for appropriate economic selection of cut height.

CONCLUSIONS

- In increasing cut height up to straw-level in the threshed wheat mass 0.24, the accounted losses of the combine "CLAAS DOMINATOR – 106" for the tests carried out are in the permissible limits, without any necessity to install additional equipment on the machine.
- The increase of cut height in wheat harvest can lead to up to 30% of fuel decrease, without exceeding the limit of grain losses.

REFERENCES

Dimitrov, D., etc. 1988. *Decrease of Losses in Grain Crop Harvest.* Zemizdat, Sofia (in Bulgarian).

History of Economy (Экономическая история). http://egypt.icenut.ru/egypt11201.html (in Russian)

Kolev, K. & Kehayov, D. 1987.Opportunities of Change of Technology in the Wheat Harvest. *Agricultural Machinery* **5** (in Bulgarian).

Korucu, T., Kirişci, V. & Görücü Keskin, S. Residue Management for Successful Direct Seeding. http://www.cu.edu.tr/insanlar/vahitkr/artik.htm

McMaster, G.S. Aiken, R.M. & Nielsen, D.C. 1999. Optimizing Wheat Harvest Cutting Height, Soil Erosion and Water Conservation. *Great Plains Systems Research Units Publications.*

Mitkov, A. & Minkov, D. 1977. *Statistical Methods in Agricultural Machinery*. Zemizdat, Sofia (in Bulgarian).

Nielsen, D.C. Optimum Wheat Stubble Height to Reduce Erosion and Evaporation. http://www.akron.ars.usda.gov/fs_optimum%20height.html

Vezirov, Ch. & Atanasov, At. 2002. Duration of Transport Processes in Agriculture. In *Proceedings of the International Scientific Conference EE&AE*, Rousse, Bulgaria, vol. I, p.171.