Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 52 (2012) 11397-11401

ISSN: 2229-712X

Minimizing combine harvester rear losses by intelligent modeling of MOG[1] passing concave

Asghar Mahmoudi*, Ali Mirzazadeh and Shamsollah Abdollahpor

Department of Agricultural Machinery Engineering, Faculty of Agriculture, University of Tabriz, Tabriz, Iran.

ARTICLE INFO

Article history:

Received: 17 July 2012;

Received in revised form: 2 November 2012;

Accepted: 9 November 2012;

Keywords

Combine harvester,
Loss,
MOG,
Neural Network.

ABSTRACT

Although the mean of combine losses is about 4-5% in advanced countries, unfortunately in Iran is about 20% and higher. In order to obtain little loss it is necessary that product process such as cutting, convayting, threshing, separating, etc., would be optimized. Threshing is one of these processes which has more effect on combine performance. Reduction of MOG passing concave could reduce the load on shoes that would increase cleaning system efficiency and decrease foreign materials in the bin. In order to evaluate effecting parameters on MOG passing concave, experiments were conducted in 4×3×3 factorial pattern with Randomized Blocks design. Independent variables in this experiment were, stem height, feed rate, threshing clearance ratio and rotational speed of threshing cylinder. To offer an intelligent model to forecasting of MOG passing concave and evaluating of these parameters' effects on MOG passing, Neurosolution was used. Multilayer Perceptron (MLP) network with four inputs and one output was used to analysise. Results showed that the amount of MOG passing concave had dependent to rotational velocity of threshing cylinder, stem height, feed rate and threshing clearance ratio, respectively. The amount of MOG passing has increased with reduction in stem height, feed rate, threshing clearance ratio and speed up of threshing cylinder.

Introduction

Introduce the Problem

Increasing world population makes clear the importance of nutrition and cereals for human life, as most of the food, is essential. Cereal production in world is 2.5 billion tons, which the maximum amount (approximately 690 million tons) is allocated to wheat, and it is the first in importance in the annual production and cultivation (Food and Agricultural Organization [FAO], 2008). One of the most important steps in the production of cereals, especially wheat, is harvesting, which requires a significant amount of energy and is associated the loss. Although the mean of combine losses is about 4-5% in advanced countries, unfortunately in Iran is about 20% and higher (Moghaddam, 2008). The loss of combine harvester is divided to natural loss (pre harvest loss), platform cutting loss (head loss), threshing loss, cleaning loss and the loss of body (Srivastava, Goering, & Rohrbach, 2006). One way to reduce the loss, since the process of harvesting by machine is a combination of several processes, breakdown of processes and provides the appropriate mathematical model for each process. Threshing is one of these processes which has important effect on combine performance. Threshing unit is the heart of combine harvester and materials are threshed in it. In effect of this operation, some free grains are passed through the concave wire rake and other grains, as free grains or semi threshing cluster, are transported to separation unit. During the threshing operation, some of MOG is passing from concave wire rake, too and then are dumped through the grain pan into upper sieve. threshing unit produces a perfect thresh of a maximum throughput, with optimum grain separation, while it preserves crop quality, minimizes grain loss and fragmentation and separation (Miu, 1999). Threshing is done by: 1) Beat a fast moving object on the material 2) Friction 3) Press the pod and the combination of two or more operations (Kepner, Bainer, & Barjer, 1978). Performance of threshing mechanism is measured by threshing efficiency, separation efficiency, the amount of grain damage and the amount of straw breakup (Srivastava et al., 2006). Excessive straw breakup during threshing results in an increased load on the cleaning shoe, which causes additional cleaning losses, Increase straw breakup also increases power requirements of the threshing cylinder. Research in this field (evaluation of MOG passing from concave) is not too much. In this section will be referred some of this research. Extensive laboratory evaluation by the National Institute of Agricultural Engineering in England [NIAE] about the effects of different design factors and operating parameters on rasp-bar thresher performance with tangential feeding was performed. The evaluation showed that increase of concave length causes an increase of straw breakup and grain damage. The study with no opening concave or concave covered, also showed no significant effect on the threshing loss or amount of fragmentation straw. The results of laboratory tests conducted by Reed et al. on wheat showed that amount of fragmentation straw affected by the type of product being maturity. Generally reduce of the space between concave and threshing cylinder no effect on the fragmentation straw. The test results also showed that the increase of cylinder speed causes increase of MOG passing from concave too and with increase of feeding rate, the percentage of MOG passing decreases. In this test, with ratio increase of grain to no grain from 0.7 to 1.0 and same feeding rate, the percentage of MOG passing from concave wire increased significantly (Kepner et al., 1978). Saij Paul et al. (1977) did series of tests on

Tele:
E-mail addresses: A_Mahmoudi@Tabrizu.ac.ir

an axial threshing unit to estimate the air pressure requirement to prevent the MOG and long stem passing from a rotor cage. Experiments were performed on a complex mechanism that consists an inner auger, cylindrical lipped screen and boundary of a pressurized chamber. Miu (1999) offered the following stochastic mathematical model for simulation of the material other-than-grain (MOG) in threshing units (tangential, axial), over the length of threshing space(x):

$$pp_n(x) = 1 - \int_0^x ae^{-bs}ds = 1 - \frac{a}{b}\left(1 - e^{-bx}\right) \quad (1)$$

$$pp_s(x) = \frac{a}{b(b-a)}\left[b\left(1 - e^{-ax}\right) - a\left(1 - e^{-bx}\right)\right] \quad (2)$$

$$pp_f = \frac{a}{b-a}\left(e^{-ax} - e^{-bx}\right) \quad (3)$$

Where $PP_n(x)$ is the percentage of unfragmented MOG, PP_s is the cumulated percentage of separated MOG, PP_f is the percentage of separable fragmented MOG, a is linear rate of MOG separation and b is linear rate of MOG fragmentation. Equation 2showes that the cumulated percentage of separated MOG over the length of the threshing space is PP(l) for a tangential threshing unit. In the other words:

$$pp_s(l) = \frac{a}{b(b-a)}\left[b\left(1 - e^{-al}\right) - a\left(1 - e^{-bl}\right)\right] \quad (4)$$

Figure 1 illustrates, with an example, the experimental data and curves of PP_n, PP_s and PP_f percentage in tangential thresher.

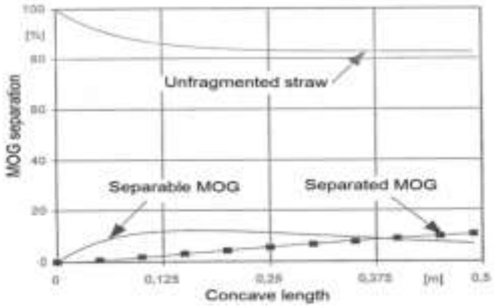

Figure 1. MOG separation in wheat

As it was mentioned earlier, research findings and carried out research in this field (evaluation of MOG passing from concave) is not too much and in very few cases, artificial neural networks are used for data analysis. The surveys of data are sometimes cases that the relationship between variables is a very complex issue. This makes that difficult to be analyzed and processed of data. So that often a certain relationship between variables cannot be obtained. In this case instead of purely theoretical research the applied research acts. Artificial Neural Networks (ANN) is one of the solutions that with processing of experimental data, discovers knowledge or law behind the data and transmits to the network structure. Today neural network is a powerful tool in all science, including Agriculture Engineering.

Artificial Neural Network model (ANN)

The multilayer Perceptron (MLP) is one of the most widely implemented neural network topologies used for classification tasks (Haykin, 1998). MLPs are normally trained with the back propagation algorithm (Rumelhart, Hinton & Williams, 1986). Gradient descent with momentum (GDM) learning rule is an improvement to the straight GD rule in the sense that a momentum term is used to speed up learning and stabilizing convergence.

Yang, Prasher & Landry (2002) distinguished young corn plants from weeds using back propagation neural network models in corn fields. Several hundred images of corn plants and weeds were used for training the model. The ability of the ANN models to discriminate weeds from corn was tested. The highest success recognition rate was for corn at 100%, followed respectively by Abutilon Theophrasti at 92%, Chenopodium album at about 62% and Cyperus esculentus at 80%. Mahmoudi, Omid, Aghagolzadeh & Borgayee (2006) designed an intelligent system based on the combined acoustic detection and ANN for classification of four different pistachio nuts varieties (namely, Akbari, Badami, Kalle-Ghuchi and Ahmad-Agaee). The total weighted average in system accuracy was 97.5%, that is, only 2.5% of nuts were misclassified. Kavdir and Guyer (2002) sorted Empire and Golden delicious apples based on their surface quality conditions, using back propagation neural networks and spectral imaging. Mesri et al. developed a three layer perceptron neural network, with a back propagation (BP) training algorithms, for modeling of the combine performance. The model investigates the influence of the wheat yield, crop variety, crop moisture content, crop height, height of cut, threshing drum speed, concave clearance, fan speed, chaffer opening and lower sieve opening on the combine performance.

As it was mentioned in the introduction, various factors have been studied by researchers to assess the amount of MOG passing from concave. However, in none of these researches has not been mentioned to effects' priority of these factors. Objective of this research is presenting a model to predict the material other than grain (MOG) passing from concave based on artificial neural network to reduce the load of shoes in combine harvesters. Furthermore, we have tried to determine the effects' priority of important factors.

Method

This study was carried out in three stages:

Providing experiments conditions

Allexperiments were carried out on the 68's Sahand combine harvester, built in the Industry promotion of Azarbaijan co.

In this study, the parts of the head, straw walker, curtains, fan, sieve, chaffer, clean grain auger and tailing auger due to the lack of need in these experiments, were removed from the combine. Then a latticed grain tray with dimensionof 610×1050 mm^2 was made to collect MOG passing through of the concave wire rake. To empty the content of each cell of tray into, disposable containers with a dimension of 95.45×76.25 mm^2 to 88 (regarding the area of threshing unit) was used. Then tray was placed under threshing unit (cylinder and concave). In order to contineous feeding of materials to feed conveyor (feeder housing) and subsequent to threshing space, a two-meter belt conveyor with variable speed was used. Then the conveyor belt was placed in front of the combine feed conveyor. Figure 2 shows this:

Figure 2. Belt Conveyor in front of 68s Sahand combine harvester

Specification of thresher unit, which is used in this study, is as follows:

1. Threshing cylinder: threshing cylinder used in this study was rasp-bar cylinder, 1060 mm in length, 450 mm in diameter, 6 steel bar and 5 star-shaped hubs.
2. Concave: the concave used in this study was a replaceable slid to number 3 that was placed under the threshing cylinder.
3. Threshing revolution: the cylinder rotates between 650 to 1500 rpm which is adjustable from the operator's platform .

In order to provide different treatment for threshing space, regulator screw (according to the manufacturer's instruction), was used.

Sampling

Irrigate -Shiroudi wheat-cultivar, was chosen for experiments.

The product in 5kg (approximately 18-20% moisture content), a week before harvesting, was harvested by hand and transported to laboratory (Research and Development department of Industry promotion of Azarbaijan co.) To maintain the initial moisture of product and prevent the effect of its changes on experiments' results, samples were replaced in plastic bags.

Independent variables in this experiment were stem height, feed rate, threshing clearance ratio and rotational speed of threshing cylinder. MOG passing concave was considered as a dependent variable. In order to evaluating of parameters' effects on MOG passing from concave, experiment was conducted in 4×3×3 factorial pattern with Randomized Blocks design (Valizadeh & Moghaddam, 2007).

Table 1. Shows levels of treatments in this study.

Table1. levels of treatments in

Levels	Factors
85cm =A_1 65cm =A_2 45cm =A_3	Stem height (A)
kg/min 100 =B_1 kg/min 60 =B_2 kg/min 42.86=B_3	Feed rate (B)
3.75 =C_1 4.33 =C_2 2.83 =C_3	Threshing clearance rate (C)
1200rpm=D_1 1150rpm=D_2 1250rpm=D_3	Rotational velocity of threshing cylinder (D)

Run Test

Before each test repetition, identification of each test was prepared and subsequently in order to run test, product was brought out from bags and distributed on the conveyor belt. According to test number, necessary adjustments on the combine harvester (the cylinder velocity and the threshing clearance ratio) and the inverter of conveyor belt (speed of conveyor belt), respectively, was performed and then materials feed in order to feeding conveyor and subsequent to atmosphere of between threshing cylinder and concave.

The content of cells within, after the record of test number and cell number, were transferred in to small bags. After separation of grain from MOG, the MOG content of each test was weighted by digital scale with 0.1 g sensitivity. An example of how records the grains and MOG within the cell, after threshing operation, is shown in figure 3.

Figure 3. An example of records the experiment

The results of MOG passing concave of were analyzed in Neurosolution software (Neurosolution 2007) and stop training was based on the cross validation (c.v).

In developing ANN models, hyperbolic tangent function f(x) = tanh(x) is used for hidden layer and linear function f(x) = x is used for output layer. The values of 0.1 and 0.7 were used for η and α, respectively. As an additional guard against over-fitting, the data sets were divided into three randomly selected data sets; 70% of data were used for training, 15% for testing and the remaining 15% were used for cross validation. After adequate training, the network weights are adapted and employed for validation in order to determine the ANN model overall performance. Neurosolutions 5.0 was used for the design and testing of ANN models.

The topology of final MLP neural network is given in Figure 4. This figure shows a three layer network with a single hidden layer of processing elements. Each PE has a weighted connection to every PE in the next layer and each performs a summation of its inputs passing the results through a transfer function. Input layer had 4 PEs. Each of PEs is related to an input feature. The number of nodes in hidden layer was varied according to the number of inputs and network performance. Output layer had one PEs. Numbers of PEs for hidden layer were selected based on trial and error.

Finally to determine the dependence priority of dependent variables to independent variable, the sensitivity option of software was used.

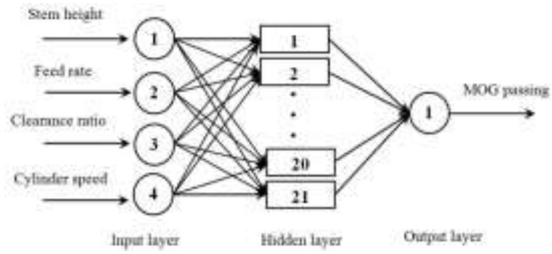

Figure 4. Topology of optimal ANN

Results

In order to minimize ANN training time, only one hidden layer was considered. If the number of hidden layer' neurons is very small, the model will not be flexible enough to model the data well. By using information about mean square error (MSE) of cross validation (CV) for different ANN models, the number of PEs in hidden layer was selected to be 21. For this purpose, MSE of cross validation for different numbers of hidden PEs was investigated. Based on data obtained network with 21 PE's in hidden layer was observed to have the least standard deviation error as well as high stability. Therefore, optimal selected model had 4-21-1 structure for function approximation. Performances of different ANN models were compared based on mean square error (MSE), correlation coefficient (r) and correct classification rate (CCR). Expression used to calculate the MSE is given by equation 5:

$$\mathbf{MSE} = \frac{1}{NP}\sum_{j=0}^{P}\sum_{i=0}^{N}\left(D_{ij} - Y_{ij}\right)^2 \qquad (5)$$

Where P is the number of output neurons, N is the number of exemplars in data set, and t_{ij} and y_{ij} are the network and target outputs for exemplar i at neuron j, respectively.

According to table 2, the coefficient of determination equal to 0.7 was obtained. It shows the existence of high dependence of the dependent variable to independent variables included in this study. In other words, 0.7 amount of MOG passing from concave in 68'S Sahand combine are related to the changes in the four variables and only the remaining 0.3 is related to other factors, which are not considered in this study.

Figure 5 shows the actual output versus trained neural network output. Figure 6 shows the effects of each independent variable, individually, in MOG passing concave.

As figure 6-a shows, the maximum amount of MOG passing from concave was obtained with approximately 480gr, 60cm in height and minimum amount with 438gr, 82cm in height, too.

The result of this factor on the amount of MOG passing is not perfect fit on the findings of research conducted by Reed et al. (Kepner et al., 1978). Paradox occurred in lower height and approximately 45cm which is probably due to experimental errors. However, according to graph 6-a, the MOG passing from concave was reduced with increasing stem height (reduction of grain-material ratio). One of the reasons it can be (in constant feed rate) reduction of existing pod in greater heights than the lower heights of stem. As well as pods with free grains and other fragmentation MOG, due to low resistance and reduce clogging of concave openings, can easily reach their own to concave and pass through it.

The changes in graph 6-b (figure 6-b) show that the amount of MOG passing from concave is linearly reduced with increasing feed rate. So that the maximum amount of MOG passing from concave was obtained with approximately 488gr, 43.5kg/min in feed rate and minimum amount with 466gr, 91.5 kg/min in feed rate, too. High amount of MOG passing in low feed rate is due to direct impact, less depreciation of threshing cylinder on material and more time to receive several impacts. In this mod, stems become much broken and therefore the amount of it passing increases.

Figure 6-c shows the effect of threshing clearance ratio on the amount of MOG passing concave. As it can be observed, effect of the clearance ratio on the output is linearly increased. So that, the MOG passing concave increased with increasing this ratio. One of the causes is thickness reduction of MOG, which is passing from threshing space. Then, with decreasing in material thickness in threshing space, threshing cylinder affects on the material with approximately uniform impact and less depreciation and thereby breaking rate stem and leaves and passes it increases. In addition, at low space between cylinder and concave, fragmentation material such as free grains are over at low the time and place than from other materials to reach themselves to concave openings. As a result, the amount of MOG passing increases.

According to figure 6-d, the amount of MOG passing concave increased linearly with speed up threshing cylinder. This is because the action of thresher components on crop performed with greater intensity. In this case material is passing from threshing space receive great impacts. This leads to the breaking and shorter stems and other MOG too. So, the amount of MOG passing is increased. In addition, with speed up threshing cylinder, centrifugal forces which are acting on the crushed MOG are increased. It increases the pass probability of fragmentation MOG from other material and concave openings.

The results of this section (Excluding the effect of stem height) were completely consistent with the studies conducted by Reed et al. (Kepner et al., 1978). So that, MOG passing concave decreased with reduction of cylinder speed and increasing of feed rate and clearance ratio.

Figure 7 shows the output sensitivity to each of independent variables. In other words, this graph shows the dependency amount of the dependent variable to each independent variable.

Discussion

Results showed that the amount of MOG passing concave varied with speed of threshing cylinder, stem height, feed rate and threshing clearance ratio, respectively. Therefore, to minimize MOG passing concave and load of shoes and consequently, reduce foreign material in bin and minimizing combine loss, rotational speed of threshing cylinder must be reduced by combine operator, in first time. Of course, this reduction should not have negative effect on the material threshing and grain separation in the threshing unit. In recent mod, operator must reduce the stem height or must increase cut height or platform height. It should also be considering the rear loss. In recent limitation, it is best that combine operator selects the increase of feed rate method or reduction of threshing clearance ratio method. It is important if operator chooses this methods, the limitation of combine rear loss and better than being threshed materials should be considered.

Finally, a minimum amount of MOG passing from concave occurred in $A_1B_1C_3D_2$ treatment with the amount of 237gr, which is suitable to minimizing the combine losses.

However, comparison of data obtained from the material threshing and grain separation shows minimum material threshing and grain separation occurs in this treatment too. It is having negative effects on the loss minimizing of material threshing and grain separation. Because a maximum amount of material threshing and grain separation occurred in $A_3B_3C_2D_3$ treatment in which MOG passing from concave was minimum.

Table 2. Network performance with 4 -21 -1 structure

MOG Passing	Network Performance
0.02	Mean Square Error (MSE)
0.834	The Correlation Coefficient (R)
0.7	Coefficient (R^2)

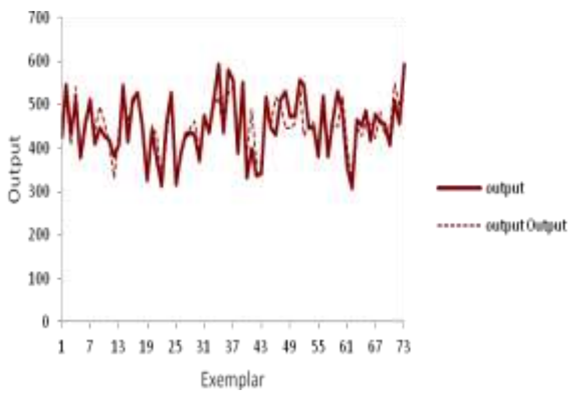

Figure 5. Actual output verses ANN output

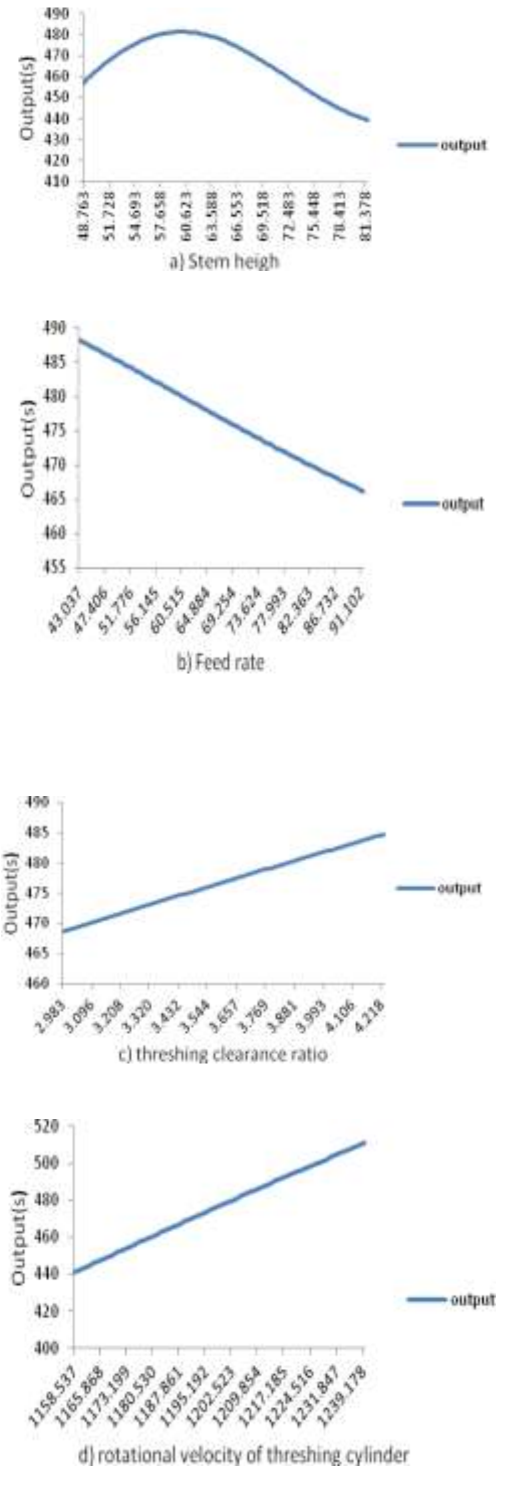

Figure 6. Effects of Independent variables on MOG passing

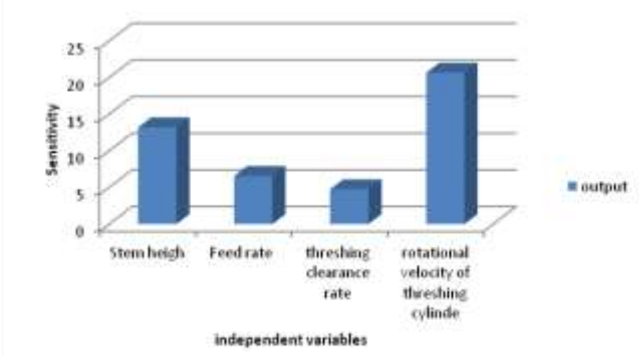

Figure 7. Sensitivity analyzes of independent variables

References

FAO.org [FAOSTAT data base]. Rome: Food and Agriculture Organization of the United Nations; 2008. Available from: http://www.faostate.fao.org/.

Haykin S. Neural Networks: A Comprehensive Foundation (2nd ed). New Jersey, Prentice Hall; 1999.

Kavdir I, Guyer DE. Apple sorting using Artificial Neural Network and Spectral imaging. Trans. ASAE. 2002; 45: 1995–2005.

Kepner RI, Barjer EL, Bainer R. Principles of farm machinery (3d ed). Avi Pub Co; 1978.

Mahmoudi A, Omid M, Aghagolzadeh A. Borgayee AM. Grading of Iranian's Export Pistachio Nuts Based on Artificial Neural Networks. International Journal of Agriculture & Biology. 2006; 3: 371–6.

Mesri TG, Ghasemzadeh HR, Abdollahpour SH, Navid H. Application of Artificial Neural Network in Prediction of the Combine Harvester Performance. Journal of Food, Agriculture & Environment. 2010. 8(2): 721 - 4.

Miu PI. Mathematical modeling of material other than grain separation in threshing units. ASAE Meeting Presentation, ASAE/CSAE Annual International Meeting, Toronto, Ontario, Canada. 1999. Paper No. 993208.

Rumelhurt DE, Hinton GE, Williams RJ. Learning internal representations by back-propagation errors. Nature. 1986. 322, 533–6.

SijPaul KK, Drew LO, Huber CD, Jones CD, Roller WL. Testing the concept of an integral separator and cleaner unit for a combine. Trans. ASAE. 1977. 20: 243-7.

Srivastava A, Georing C, Rohrbach, R. Engineering principles of agricultural machinery (2nd ed). ASAE Publication 801M0206; 1993.

Valizadeh M, Moghaddam M. Experimental Designs In Agriculture (3d ed). Tabriz, Parivar Press; 2007.

Yang CC, Prasher SO, Landry JA. Weed Recognition in Corn Fields Using Back-Propagation Neural Network Models. Canadian Biosystem Engineering. 2002. 44, 7.15-7.22