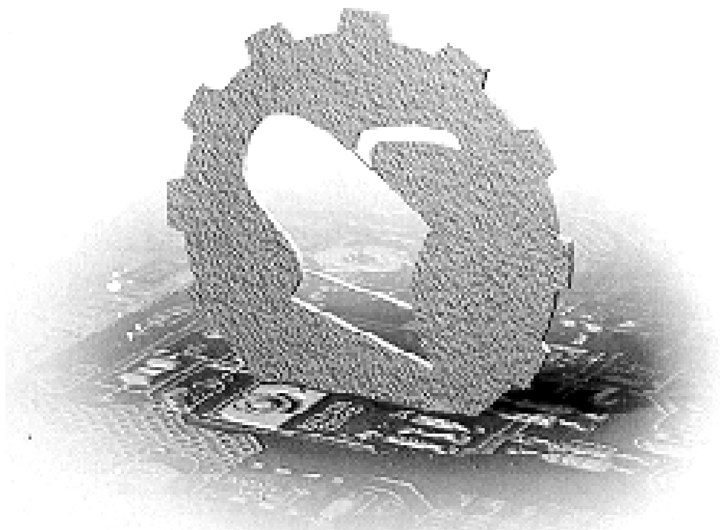
ISSN 0554-5587
UDK 631 (059)

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

НАУЧНИ ЧАСОПИС
SCIENTIFIC JOURNAL



УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

Година XXXVII Број 1, јул 2012.
Year XXXVII, No. 1, July 2012.

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

Издавач *(Publisher)*
Универзитет у Београду, Пољопривредни факултет, Институт за пољопривредну технику, Београд-Земун
University of Belgrade, Faculty of Agriculture, Institute of Agricultural Engineering, Belgrade-Zemun

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11080 Belgrade-Zemun, str. Nemanjina No. 6, Po. box: 127, Tel. 2194-606, 2199-621, fax: 3163-317, 2193-659, e-mail: gogi@agrif.bg.ac.rs , Account: 840-1872666-79

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UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

WEB адреса

http://www.agrif.bg.ac.rs/publications/index/pt

Техничка припрема *(Technical editor)*

Иван Спасојевић, Пољопривредни факултет, Београд

Лектор и коректура: *(Proofreader)*

Гордана Јовић

Превод: *(Translation)*

Данијела Ђорђевић, Весна Ивановић

Штампа *(Printed by)*

"Академска издања" – Земун
Часопис излази четири пута годишње

Тираж *(Circulation)*

350 примерака

Pretplata za 2013. godinu iznosi 2000 dinara za institucije, 500 dinara za pojedince i 100 dinara za studente po svakom broju časopisa.

Радови објављени у овом часопису индексирани су у базама *(Abstracting and Indexing)*:
AGRIS i SCIndeks

Издавање часописа помогло *(Publication supported by)*
Министарство просвете и науке Републике Србије

Na osnovu mišljenja Ministarstva za nauku i tehnologiju Republike Srbije po rešenju br. 413-00-606/96-01 od 24. 12. 1996. godine, časopis POLJOPRIVREDNA TEHNIKA je oslobođen plaćanja poreza na promet robe na malo.

S A D R Ž A J

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Godina XXXVII
Broj 1, jul 2012.
Strane: 1 - 9

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 631.331

Originalni naučni rad
Original scientific paper

USING TRACTOR TEST DATA FOR SELECTING FARM TRACTORS

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Abstract: The Nebraska Tractor Test Laboratory (NTTL) at the University of Nebraska is the official tractor testing station for the Organization for Economic Cooperation and Development (OECD) in the United States. This laboratory is responsible for testing a representative tractor of each model sold in the state of Nebraska. It also tests tractors manufactured in the USA and sold in international markets. The Laboratory publishes the results of all tests conducted. The test reports published by NTTL can be extremely useful in the selection of tractors or for comparing the performance of different makes and models of tractors. The proper selection and sizing of a tractor is important to the economic viability and sustainability of farms. This paper shows the use Nebraska Tractor Tests and test reports for that selection. A step-by-step procedure for selecting a farm tractor using published tractor test reports has been developed and demonstrated.

Key words: *tractor selection, tractor test reports, performance comparisons*

INTRODUCTION

The test reports published by Nebraska Tractor Test Laboratory (NTTL) can be extremely useful in the selection of tractors or for comparing the performance of

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different makes and models of tractors. For example, when a farmer is in the market for a tractor, the performance data in the test reports can be used to select a tractor that will meet his/her needs. Similarly, these reports can also serve as an effective tool for making tractor sales. Dealership personnel can use the performance data to compare their products to those of competitors.

For either application, familiarity with the content of the test reports and the know how to use the information effectively are essential. Therefore, this factsheet is developed with the following two specific objectives:

1. To inform users of the data within tractor testing and Nebraska Test Reports.
2. To demonstrate the use of tractor test information for the selection and performance comparison of farm tractors.

MATERIALS AND METHODS

NTTL, the official tractor testing laboratory in the US, is a member of the OECD with 27 other countries. The OECD recommends all tractors manufactured in member countries to be tested in the country where they are manufactured, following the OECD guidelines. Based on an established agreement between member countries, test reports approved by OECD are accepted by all participating countries.

*Tractor Test***.** The purpose of the tests is to collect data that can be used to assess the performance of tractors of different makes and models. For this reason, all tests are conducted under same or similar test conditions and procedures. Tractor tests are generally conducted to assess the PTO (power take-off) performance, drawbar performance, hydraulic lift capacity, and hydraulic system pressure and flow. In addition, sound level measurements are also taken at operator and bystander locations.

PTO performance tests are conducted with a dynamometer attached to the tractor PTO (Fig. 1). The purpose of the dynamometer is to apply varying loads through the PTO and to measure the power generated by the tractor. These tests are conducted within restricted range of ambient temperature and a barometer pressure. During tests, when the tractor performance has stabilized, the data is recorded at predetermined intervals.

The load applied by the dynamometer follows the operating curve of the engine at full throttle. Data collected include torque, rpm, power, and fuel consumption. A series of PTO tests are conducted at rated engine speed, at standard PTO speed (either 1000 or 540 rpm), at the engine speed where maximum power is produced, at varying load, and at maximum torque.

Drawbar performance tests (Fig. 2 and 3) are conducted in all gears between one gear below the one which provided maximum drawbar force (without exceeding a wheel slip of 15%) and a maximum speed of 16 $km/^{-1}$. In each gear, at full throttle, the load is increased until maximum drawbar power is achieved. Engine speed, wheel slip and fuel consumption data are recorded when test conditions are stabilized.

Drawbar tests are also conducted with partial loads at 75% and 50% of the maximum drawbar load (at rated engine speed). These partial load tests are also conducted at reduced engine speeds (selected by the manufacturer).

Figure 1. The tractor being tested on the PTO dynamometer
The test apparatus in the foreground is measuring fuel flow.

Figure 2. The lead tractor is being tested on the track during drawbar performance tests
The two vehicles in tow are load units.

Figure 3. Tractor running on the test course
Drawbar performance test being performed.

Hydraulic lift capacity and flow tests are conducted to determine the maximum lift capacity of hydraulic system through the full lift range. The lift capacity in the report is 90% of the maximum load carried through the full lift range.

Additional tests are also conducted to determine the pressure-flow relationship of the hydraulic system for supplying power to external actuators (such as motors or cylinders). Reports include data on delivery rate, pressure and available power.

Sound level measurements during performance tests are taken at the operator and bystander locations. At bystander location, the readings are taken by locating the microphone 7.6 m from the center line of the tractor. Sound levels are recorded using "A" scale in the sound level meter and is expressed in terms of dB (A). The "A" scale is a filter that responds like a human ear.

Nebraska Test Reports

A full OECD report is generally 30 pages long. NTTL summarizes and publishes the test results in two formats (to order, see contact information at the end). The first format is a booklet published annually with limited performance data on all tractors available for sale that year in the state of Nebraska. The summary booklet generally includes approximately 400 tractor models from different manufacturers. The second format is a more detailed report (typically 2-6 pages) covering individual tractor test results. These reports are discussed in the following paragraphs.

The summary booklet have a cover page that provides the year in which the tractors were summarized and the name and address of the person responsible for the tests. A typical page in the summary booklet provides the summary of test results of two or three tractors from a manufacturer. Included in the summary is information on tractor model, limited engine and chassis specifications, PTO and drawbar performance data, sound level, three-point lift capacity and hydraulic system parameters. The summary booklets are particularly useful for an initial review of the performance of tractors of different sizes produced by different manufacturers.

When the initial review generates interest in a particular tractor model, the user can obtain a summary report specific to that model tractor. The first page of the summary report provides information on test number, make and model of tractor tested, and transmission. It also includes results of PTO and drawbar performance tests in addition to tractor specifications in a column located on the right-hand side of the page. Fuel consumption is reported in three different ways: $l \cdot h^{-1}$, $kg \cdot kW^{-1} \cdot h^{-1}$, and $kW \cdot h \cdot l^{-1}$. Fuel consumption expressed in terms of $kW \cdot h \cdot l^{-1}$ is useful for comparing fuel consumption of tractors of different sizes [1-2]. PTO tests at varying power levels simulate a wide range of field operations using the tractor.

The drawbar performance data includes drawbar power and pull, forward speed, wheel slip, engine speed, fuel consumption, temperature and relative humidity conditions at maximum, 75% and 50% pull at maximum power. The tests at reduced engine speed also include similar data at various travel speeds.

Power measured at 75% of pull at maximum power may represent a typical operation with heavy load such as primary tillage. At 75% pull, the tractor may still have some reserve power to overcome unexpected overload situations. The average fuel consumption at 75% and 50% pull may represent tillage and seeding operations respectively on small grain farms. Similarly, the average fuel consumption at the 50%

pull tests can serve as a good estimate of fuel consumption when tractors are used in row-crop farming. This distinction between small grain and row-crop production is made because more efficient tractor-implement matching is possible for small grain production. For small grain applications, selection of implements to utilize the available tractor power can be accomplished more easily. However, the same conclusion may not be true in the case of row-crop implements.

Tractor tests are conducted on concrete or asphalt tracks. Therefore, the performance data recorded during these tests can be significantly better than what can be expected under normal field conditions. Tests are conducted on hard surface (concrete and asphalt) for consistency between tests.

At the end of the summary reports are sound levels, tire and weight information. Tractor sound level at the operator’s ear location is critical because governmental agencies have strict sound level and exposure time regulations. For example, in the US, the safety regulations permits an eight hour exposure period if the sound level in the work area is 90 dB(A). Due to the fact that a 3 dB(A) increase in sound level corresponds to doubling of sound pressure level, for every 5 dB(A) rise in sound level, the permissible exposure time is cut in half. In other words, at 95 dB(A), the allowable exposure time is only four (4) hours. It is not uncommon to have tractor sound level reaching 95 dB(A).

If the tractor tested has front wheel assist, additional drawbar tests with the front wheel assist disengaged may follow. The last page of the summary report is devoted to three-point hitch performance data, hydraulic system parameters and hitch dimensions.

Published tractor test results can also be used for estimating annual fuel consumption by knowing how the tractors are used during the year. This information is particularly useful for budgeting and management purposes.

Fuel savings are possible with practices such as “Gear-Up & Throttle-Down.” The “DRAWBAR PERFORMANCE” data documents the fuel savings possible with the practice of "Gear-Up and Throttle-Down" for light load conditions. The lines ending with the words "at Reduced Engine Speed" can be compared with the tests conducted at full throttle at the same load level. The specific fuel consumption (kW-hr/l) for the “at Reduced Engine Speed” tests will always be more efficient than the values for the full throttle with the difference being expected fuel savings.

Depending on the engine design and other controlling factors, the “Gear-Up & Throttle-Down” technique can provide fuel savings in the range of 15-30% [3]. The annual fuel savings from the use of this technique can be estimated by multiplying the total number of hours the tractor is used annually for "light load operations,” by the fuel consumption difference.

RESULTS AND DISCUSSION

Using the Test Reports for Tractor Selection. Many factors are taken into consideration in the selection and purchase of a new tractor. These may include factors such as: types of jobs to be performed, price, proximity and reputation of the dealership, desired power output at the drawbar and PTO, hydraulic system capacity, and fuel efficiency. The tractor test reports can play an important role in the decision-making process. Both summary booklets and summary reports on individual tractors are useful in selecting tractor models or for evaluating and comparing performance of different tractor models. The first step in the tractor selection process is to evaluate the need that exists. Depending upon the needs identified, the purchaser should estimate the power requirements at the PTO and drawbar. Knowing the power requirements, the next step is to identify tractor models that are capable of providing the required output power. This list may include tractors from different manufacturers if more than one dealership is available in the proximity.

Once the tractor models that meet the power requirements are identified, the next step in the selection process is to compare their performance data. This comparison can be accomplished by preparing a table. The first column of this table may include the performance variables listed in NTTL booklet plus any other variables that are pertinent to the selection process. The number of additional columns will depend on the number of tractor models identified during initial screening. The data for each column can be extracted from the test reports. This table allows easy comparison among several tractor models. The tractor information available in the summary reports may be used for the final selection. Factors such as stability, tire size, tractor configuration (2WD, FWA, 4WD), repair frequency, proximity and reputation of dealership, and price may be considered in the final selection.

To illustrate the step-by-step procedure for selecting a tractor using the Nebraska Tractor Test data, let us consider the following hypothetical example [4]. Assume farmer JS is interested in selecting a new tractor for his orchard/vegetable operation. To select the tractor for this operation, let us follow the step-by-step procedure established earlier.

Step 1. Evaluate the need and estimate the power requirement. JS considered all the different operations that need to be carried out using the new tractor during the year. He estimated that the new tractor should have a minimum rated PTO power of 52 kW.

Step 2. Identify all tractor models meeting the power requirement. A review of "Nebraska and OECD Tractor Test Data" summary booklet (MP-37) showed that 17 different tractor models will meet the power requirement.

Step 3. Prepare a table to compare the performance data of tractors identified. Table 1 summarizes the performance data of the 17 tractor models identified from the summary booklet.

Final selection of a tractor model depends on many other factors such as cost, personal preference, dealership location, safety features, fuel consumption, sound level readings, and hydraulic system capacity. For example, two service centers/dealerships (Case- IH and John Deere) are located within 32 km of JS's farm [5]. If proximity of dealership is important to JS, the list is reduced to six models from Case-IH and John Deere. With the list narrowed to six tractor models, the final selection may be made taking the factors listed earlier into consideration. Summary Reports for tractors tested since 1999 can be found at: http://tractortestlab.unl.edu/testreports.htm (at no charge) and in this example all Summary Reports are available at this website in Adobe format.

Table 1. Summary of tractors from the "Nebraska and OECD Tractor Test Data" summary booklet (MP-37)

Manufacturer	Model	Test #	2WD FWA[1]	Trans[2]	E N G[3]	Rated Power (hp)	Fuel Use[4]	Draw Test[5]	Sound Test (dBA)[6]		H[7]
AGCO	GT75A	1850	FWA	16-M	T	76.31	15.67	NA	77.3	NA	11.7
	LT75A	1883	FWA	16-PS	T	78.41	15.48	NA	74.9	81.0	25.1
CASE-IH	JX1085	571	2WD FWA	16-M	A	71.7	15.08	PART	77.9	82.1	12.7
	JX1080	529	2WD FWA	12-M	A	71.6	14.71	PART	79.3 79.1	86.0 85.5	16.4
	JX85	462	2WD FWA	12-M	T	78.4	17.11	FULL	88.2* 88.4*	NA NA	15.6
CHALLENGER	MT445B	515	2WD FWA	16-PS	T	70.7	14.16	FULL	77.3 77.3	88.2 NA	15.6
	MT455B	516	2WD FWA	16-PS	T	80.2	15.37	FULL	75.2 75.3	88.3 NA	15.6
JOHN DEERE	5652	1869	FWA	9-M	T	76.01	14.13	NA	85.8	83.3	18.6
	6215	481	FWA	16-M	TI	74.5	14.73	FULL	70.5	NA	17.8
	6220	385	FWA	24-PQ	T	75.8	15.63	FULL	71.0	NA	31.1
MASSEY FERGUSON	583	1865	2WD	8-M	A	73.61	15.06	NA	94.4*	NA	11.0
	593	1851	FWA	12-M	T	78.81	15.92	NA	94.7*	87.6	10.0
	5445	511	2WD FWA	16-PS	T	70.7	14.16	FULL	77.3 77.3	88.2 NA	15.6
	5455	512	2WD FWA	16-PS	T	80.2	15.37	FULL	75.2 75.2	88.3 NA	15.6
McCORMICK	CX85	327	FWA	16-PS	T	71.3	15.18	FULL	78.0	NA	16.5
	CX95	328	FWA	16-PS	T	79.7	16.04	FULL	77.0	NA	17.0
NEW HOLLAND	TL80A	524	2WD FWA	12-M	A	71.4	14.65	PART	79.0 79.0	85.5 85.5	16.5

1 Chassis Type: 2WD=two wheel drive, FWA=front wheel assist
2 Transmission: number of gears, M=manual, PS=power shift, PQ=power quad
3 Engine accessories, A= naturally aspirated, T=turbocharged, I=intercooled
4 Specific fuel consumption, $kw\text{-}h \cdot l^{-1}$
5 Drawbar test complete? NA-no data, PART=some data not complete, FULL= all data
6 Sound test, first column sound at operator's ear, second column at bystander @ 7.6 m
7 Hydraulic flow in l/min, may be max flow from a single outlet others may be from all ports
* Without a cab otherwise the tractor is equipped with a cab

CONCLUSIONS

The proper selection and sizing of a tractor is important to the economic viability and sustainability of farms. This paper introduces users to Nebraska Tractor Tests and test reports. A step-by-step procedure for selecting a farm tractor using published tractor test reports has been developed and demonstrated. In the case example, a farmer had 17 tractors to select from and the selection process was narrow to 6 tractor models.

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UPOTREBA REZULTATA TESTIRANJA ZA IZBOR TRAKTORA NA FARMI

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Sažetak: Laboratorija za testiranje traktora u Nebraski (NTTL), pri Univerzitetu Nebraska, je zvanična stanica za testiranje traktora, ovlašćena od Organizacije za ekonomsku saradnju i razvoj (OECD) u SAD. Ova Laboratorija je odgovorna za testiranje traktora svih modela koji se prodaju u državi Nebraska. U ovoj Laboratoriji se testiraju i traktori koji se proizvode u SAD, a prodaju na stranim tržištima. Laboratorija objavljuje rezultate svih sprovedenih testova. Izveštaji ovih testiranja, koje NTTL objavljuje, mogu biti izuzetno korisni pri izboru traktora ili poređenju performansi traktora različitih proizvođača i različitih modela. Pravilan izbor i dimenzionisanje traktora je važno za ekonomsku održivost i pouzdanost proizvodnje na farmi. U ovom radu je predstavljena upotreba rezultata objavljenih u NTTL izveštajima pri izboru traktora. Razvijena je i prikazana postupna procedura izbora traktora za farmu na osnovu objavljenih rezultata testiranja traktora.

Ključne reči: *izbor traktora, izveštaji testiranja traktora, poređenje performansi*

Datum prijema rukopisa: *Paper submitted:*	21.06.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	25.06.2012.
Datum prihvatanja rada: *Paper accepted:*	01.07.2012.

POLJOPRIVREDNA TEHNIKA
✧
Godina XXXVII
Broj 1, jul 2012.
Strane: 11 - 19

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 338.47

Originalni naučni rad
Original scientific paper

OPTIMIZATION AND RESEARCH OF TECHNOLOGICAL PARAMETERS OF SHUT-OFF DEVICE OF BIOMETHANE GAS-FILLING SYSTEM

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Abstract: The paper gives overview of working principles, modeling and testing results of new patented shut-off device. This invention is created by co-founder of *Hygen Ltd.* and relies to another invention of this company, which is used for a preparation of biomethane for its further transfer under pressure to a fuel tank of a vehicle. Research realized in close cooperation between all involved private and scientific institutions allowed to select most applicable parameters of the shut-off device and to create out most applicable construction of movable closing element. Tests of the shut-off device together with gas-filling device showed that system works immaculately and passes stability, hydraulic and temperature regime tests.

Key words: *shut-off device, bio-methane*

INTRODUCTION

The development of biogas production has been successful in recent years in Latvia. This is connected with governmental support, which guarantees that the electric power, produced in the result of burning of gas in CHP plants, have to be purchased by power company. Beside that, a number of companies are looking also for biogas cleaning and upgrading till natural gas standards, allowing get bio-methane, and utilize it in transport

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The authors gratefully acknowledge the funding from European Regional Development Fund (project Nr. 2010/0279/2DP/2.1.1.1.0/10/APIA/VIAA/163).

sector. As a result there was created special bio-methane filling system, which is more profitable in comparison with other analogues in the world.

Realized gas compression system relates to a preparation of gaseous fuel for its further transfer under pressure to fuel tank of vehicle. This object is achieved by a method for compressing gas by alternate transfer of gas into two vertically arranged compressing vessels, its compression and forcing into high-pressure vessels by filling the compressing vessels with working fluid under pressure by means of a hydraulic drive. A novelty of this method lies in that, each cycle of gas compressing and forcing out of the compressing vessels is performed until these vessels are fully filled with the working fluid contained in the compressing vessels and alternately forced out of one compressing vessel into the other in response to a signal sent by fluid-level sensor. To reduce the time for fueling a vehicle, the device may be provided with an additional accumulating vessel, to which the fuel tank of the vehicle is connected during the fuelling. Fuel tank may be filled with gas compressed up to 20 MPa (in the absence of a vehicle). The filling of the vehicle is connected to the accumulation vessel to fill the vehicle. In this case, the filling may be carried out within 5 minutes by hydraulic displacement of the gas from this vessel.

The objective of research is shut-off device that provides gas compression and secures from fluid inflow in a gas pipeline. Each of compression cylinders is equipped with shut-off device with built-in fluid-level sensor placed at the outer side of the body of the shut-off device. The shut-off device is equipped with moving closing element that has magnetic insert. There is a circular clearance between the outer wall of the tube and a body of the shut-off device that is made of non-magnetic material.

MATERIAL AND METHODS

The shut-off device construction is simple (Fig. 1). It has an inlet gas channel (1), an outlet gas channel (4), and a tube (11) connected by a T-shaped channel (5) with a high-pressure hydraulic line and low-pressure hydraulic line by electromagnetic valves. Between the outer wall of the tube (11) and a body (9) of the shut-off device made of non-magnetic material there is a circular clearance (10), which is common for the inlet and outlet gas channels (1) and (4). In the gas outlet channel (4) there is a valve comprising of a movable closing element (6) provided with a magnetic insert (7) and a seat (2) in a fitting (3). A fluid-level sensor (8) capable of detecting the full filling of a compressing vessel with working fluid placed at the outer side of the body (9) of the shut-off device and the magnetic insert (7) are located at the same level in the lower position of the movable closing element (6).

The gas filling and compression system works as follows. Gas is transferred to the fuel tank of vehicle through the circular clearance opening that is placed between an outlet gas channel (4) inner surface and movable closing element (6). At the same time compressing vessel is full filling with fluid. Once the working fluid has reached the lower edge of the movable closing element (6), said element moves upward from the lower position and closes by its tapered portion, the seat (2) of the shut-off device in the fitting (3). Simultaneously, the magnetic insert (7) leaves the area of the fluid-level sensor (4) of the compression vessel. The sensor sends a signal to the electronic control unit in order to change the hydraulic flow into a reverse mode, in which electromagnetic valves are closed [1, 2]. The working fluid from the completely filled compressing vessel begins to enter another compressing vessel.

Calculation, as also modeling in program *Autodesk Inventor*, was done before the producing of shut-off device. The calculation and modeling is obligatory to analyze the processes and factors that make impact on work of shut-off device and provides optimization of the work of shut-off device. Prototype and model was made to make sure about the shut-off device work in real life conditions.

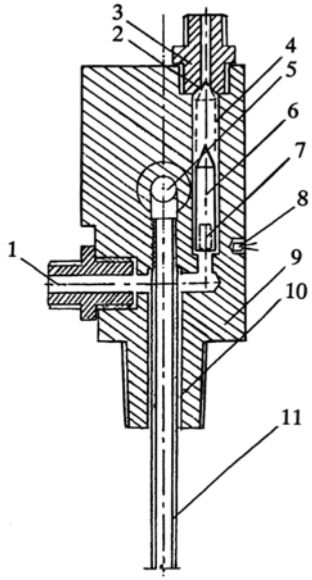

Figure 1. Shut-off device [1, 2]
1- inlet gas channel; 2 - seat; 3 - fitting; 4 - outlet gas channel; 5 - T-shaped channel; 6 - movable closing element; 7 - magnetic insert; 8 - fluid-level sensor; 9 - body of the shut-off device; 10 - circular clearance; 11 - tube

RESULTS AND DISCUSSION

In the process of calculation more attention was devoted to formation of hole range diameter of shut-off device (9–16 mm), diameter of movable closing element (7–14.5 mm), length of movable closing element (20–50 mm), cone angle (60–30º), movable closing element base surface shape (flat, bent inwards or curved). During the calculation of resistance more attention was developed to the material that was used (aluminum, brass, titanium and stainless steel). Variations were applied also to a cross-section of shut-off device (narrow hydrodynamic channel between inner cylindrical tubular and movable closing element outer surface).

Before calculations it was concluded that 2 main regimes are realized in gas passageway system – aerodynamic and hydrodynamic. Aerodynamic regime is realized when gas gets into cylindrical channel through valve that is located on the bottom of the shut-off device. At the same time gas flow affects pressure on the bottom of the shut-off device. Simultaneous gas is flooded around the surface of the movable closing element, moving through a narrow channel between the valve and the movable closing element outer surface. Hydrodynamic regime is implemented at the time when the system of shut-off device switches to spray out of fluid and movable closing element moves up till gas is displaced from the shut-off device.

Aerodynamic regime. The flow of the gas, affecting movable closing element, realize 2 processes. One of the processes is gas pressure on the movable closing element surface with force $F_1 = p_1 \cdot S_1$ (p_1 – gas flow pressure on surface S_1), and second process is symmetric gas flow around the surface of the movable closing element. In this case roughness may impact the procedure, considering the speed distribution of the gas.

For the process of calculation it is assumed that the gas flows with density ρ_2 and speed v_2 around the movable closing element with capacity V_1 and density ρ_1. It is assumed that the coefficient of the stretch of frontal resistance is equal to C=1.12 (as for a flat round plate) and cylindrical movable closing element base square is S_1. In this case the difference of pressure on the base of the movable closing element P_B and pressure on the top of the surface P_T is the following:

$$\Delta P = P_B - P_T \ll P_B, \ \Delta P = P_B - P_T \ll P_T \tag{1}$$

Within the framework of the shut-off device, it is obligatory to define such condition of the movable closing element when it is possible to realize Quasi-static conditions. To be more precise, it is not realized the movement of a movable closing element as a result of gas flow from the bottom to the top through a narrow aerodynamic channel (between inner cylindrical surface of shut-off device and outer surface of movable closing element).

The equation of the movable closing element balance condition can be put down as follows $A_1 + R + R_2 + P_1 = 0$, taking into consideration the fixed position of the movable closing element $v_1 = 0$ and plunger flooding with gas stream, where are used the following parameters (all units of measure are in SI system) [3, 5]:

- Archimedes' force:

$$A_1 = (\rho_2 - \rho_1) \cdot g \cdot V_1 \tag{2}$$

- The weight of the movable closing element:

$$P_1 = \rho_1 \cdot g \cdot V_1 \tag{3}$$

- Resistance force at the moment of movable closing element flooding:

$$R = C \cdot S_1 \cdot \frac{\rho_2 \cdot v_2^{\,2}}{2} \tag{4}$$

- Extra resistance force that is determined by the flow of the gas in a narrow aerodynamic channel, that is complicated function, consisting of several parameters: gas viscosity ν_2, cross section of a narrow aerodynamic channel d_ς, gas speed channel v_ς and the length of the effective movable closing element l_c:

$$R_2 = \psi\{\nu_2, d_\varsigma, v_\varsigma, l_c\} \quad (5)$$

The last one allows define the speed of the gas flow inside the channel of shut-off device:

$$v_2 = \sqrt{\frac{2V_1 \cdot g}{C \cdot S_1}\left(\frac{\rho_1}{\rho_2 \cdot} - 1\right) - R_2} \cdot \quad (6)$$

It was concluded that the speed of gas flow inside the channel of shut-off device is 0.2 m·s^{-1}, but gas flow rate is ≈9.6 l·min^{-1}.

Hydrodynamic regime. In this case it is assumed that fluid flow with density ρ_2 and speed v_2 are moving towards the movable closing element with capacity V_1 and density ρ_1.

It is assumed that the coefficient of the stretch of frontal resistance is equal to C=1.12 (as for a flat round plate) and base square of cylindrical movable closing element is S_1. In this case the difference of pressure on the base of the movable closing element P_B and pressure on the top of the surface P_T is following:

$$\Delta P = P_B - P_T << P_B, \; \Delta P = P_B - P_T << P_T \quad (7)$$

Also it is assumed that the speed of the movable closing element v_1 in comparison to the speed of the fluid in channel v_2 is $(v_1 - v_2) > 0$.

Within the framework of the shut-off device, it is obligatory to define such condition of the movable closing element when it is possible to realize Quasi-static conditions. To be more precise, it is not realized the movement of the movable closing element as a result of gas flow from the bottom to the top through a narrow aerodynamic channel (between shut-off device inner cylindrical surface and movable closing element outer surface).

Taking into consideration the situation that the movable closing element flows constantly because of fluid impact and movable closing element moves from the bottom to the top with speed $v_1 = const$ the equation of the movable closing element movement can be put down as follows [4]:

$$K_1=\rho_1\cdot g\cdot V_1=\int_0^{\tau_1}(A_1+R+R_2)dt=(\rho_2-\rho_1)\cdot g\cdot V_1\cdot\tau_1+\int_0^{\tau_1}\frac{1}{2}C\cdot S_1\cdot\rho_2\cdot v_2^{\ 2}\cdot dt+\int_0^{\tau_1}R_2dt. \quad (8)$$

In this case the equation for the speed of movable closing element in time distance 0 till τ_1 is the following:

$$v_1=\left(\frac{\rho_2}{\rho_1}-1\right)\cdot\tau_1+\int_0^{\tau_1}\frac{1}{2}C\cdot\frac{S_1}{V_1}\cdot\frac{\rho_2}{\rho_1}\cdot v_2^{\ 2}\cdot dt+\int_0^{\tau_1}R_2dt \quad (9)$$

As a result of movable closing element movement at the Quasi-static conditions, provided amount of fluid flows from the bottom pipe at the base of shut-off device and movable closing element moves constantly through the channel (faster than speed of fluid) till the exit of the channel is opened.

As example, $\rho_1=8880\ kg\cdot m^{-3}$, $\rho_2=750\ kg\cdot m^{-3}$, $l_c=0.05\ m$, $C=1.12$, $R_2=4.68\ N$:

$$v_1=\left(\frac{\rho_2}{\rho_1}-1\right)\cdot\tau_1+\int_0^{\tau_1}\frac{1}{2}C\cdot\frac{S_1}{V_1}\cdot\frac{\rho_2}{\rho_1}\cdot v_2^{\ 2}\cdot dt+\int_0^{\tau_1}R_2dt\approx$$

$$\approx\left(\frac{\rho_2}{\rho_1}-1\right)\cdot\tau_1+\frac{1}{2}C\cdot\frac{S_1}{V_1}\cdot\frac{\rho_2}{\rho_1}\cdot v_2^{\ 2}\cdot\tau_1+R_2\cdot\tau_1=$$

$$=\left(\frac{0.75}{8.88}-1\right)\cdot 0.05+\frac{1}{2}\cdot 1.12\cdot\frac{1}{0.05}\cdot\frac{0.75}{8.88}\cdot 0.2^2\cdot 0.05+5.08\cdot 0.05\approx 0.22m\cdot s^{-1},$$

At the same time consumption of fluid was $v_2\cdot S_{channel}=0.2\cdot 0.8\cdot 10^{-6}=0.16\cdot 10^{-6}$, $m^3\cdot s^{-1}$ or $v_2\cdot S_{channel}=0.16\cdot 60\approx 9.6l\cdot\min^{-1}\leq 10l\cdot\min^{-1}$ during the time used for moving of closing element under the influence of fluid flow, $\tau_1=0.05\ s$.

It was concluded that the speed movement of the movable closing element is 0.2 $m\cdot s^{-1}$ faster than the speed of fluid (considering the fact $(v_1-v_2)>0$).

In the case when the optimal effective measurement proportion and the proportion of surface of shut-off device is exceeded, it is possible that the movement of the movable closing element is variable with the acceleration $a_1=dv_1/dt$, and the equation of the movable closing element movement can be put down as follows:

$$A_1+R+R_2=\rho_1\cdot g\cdot V_1\cdot a_1 \quad (10)$$

and it can be concluded that the speed of the movable closing element:

$$v_1=\left(\frac{\rho_2}{\rho_1}-1\right)\cdot\tau_1+\int_0^{\tau_1}\frac{1}{2}C\cdot\frac{S_1}{V_1}\cdot\frac{\rho_2}{\rho_1}\cdot v_2^{\ 2}\cdot dt+\int_0^{\tau_1}R_2dt \quad (11)$$

To the constant value of the speed $v_{1,0} = \left(\frac{\rho_2}{\rho_1} - 1 \right) \cdot \tau_1$ variable parts $v_{1,1} = \int_0^{\tau_1} \frac{1}{2} C \cdot \frac{S_1}{V_1} \cdot \frac{\rho_2}{\rho_1} \cdot v_2^{\,2} \cdot dt$ and $\int_0^{\tau_1} R_2 dt$ are connected. Variable parts define the speed of the movable closing element from the beginning till the end when gas is displaced from the shut-off device with a help of fluid. As a result movable closing element closes the channel that was used for gas flow out from the shut-off device.

According to the calculations the movable closing element functions as normal and carries out the assigned exercise. All attention was devoted to the movable closing element base surface influence on shut-off device operation accomplishing the development of the construction. Flat movable closing element base was selected to satisfy the conditions.

The spurt influence is the following, when the movable closing element has curved surface:

- Curved surface:

$$R_{convexity} = \rho_2 \cdot \frac{Q_0^{\,2}}{S_0} (\cos\varphi - 1) = C_{convexity}(\varphi, Q_0, S_0) \cdot S_1 \cdot \frac{\rho_2 \cdot v_2^{\,2}}{2} \tag{12}$$

ρ_2 – fluid density, Q_0 – fluid consumption at the entrance, S_0 – cross section of the channel at the entrance, φ – spurt declination angle;

- Bent inward surface:

$$R_{concave} = \rho_2 \cdot \frac{Q_0^{\,2}}{S_0} (\cos\varphi + 1) = C_{concave}(Q_0, S_0, \varphi) \cdot S_1 \cdot \frac{\rho_2 \cdot v_2^{\,2}}{2} \tag{13}$$

In those cases the movable closing element frontal resistance stretch coefficient $C(Q_0, S_0, \varphi)$ depends on 3 parameters: Q_0 – fluid consumption at the entrance, S_0 – cross section of the channel at the entrance and φ – spurt declination angle. These 3 parameters allow make concrete optimization in actions with shut-off device.

Modeling of shut-off device also was made using *Autodesk Inventor* program to predict the resistance of the movable closing element. The results of modeling showed that the shut-off device has high resistance and function ordinarily.

Prototype and model were made based on calculations. Shut-off device was tested on one step hydraulic gas fuel high-pressure compressor system prototype, and at the same time several tests were made:

1) Test on mechanical resistance (hydraulic test, 20 MPa);
2) Test on movable closing element action during the charge of a balloon;
3) Test on gas channel closing safety (if fluid do not get into the gas pipe);
4) Test on operation stability (every cycle time was measured);
5) Test on system on pressure changes (20 MPa), (as an example of gas – compressed nitrogen and as an example of fluid – motor mineral oil, hydraulic oil ATF);
6) Test on temperature regime.

As a result of tests it is concluded that shut-of device passed all tests and works correctly and constantly. Shut-off device closed gas channel and fluid did not get into the gas pipe. The movable closing element passed the test on regimes of temperature and pressure up to 65 MPa.

CONCLUSIONS

1. As a result of calculations appropriate shut-off device construction for bio-methane gas filling system was made.
2. Modeling showed that the shut-off device has high resistance and functions normal during short time period.
3. Therefore experiments are required to analyze the resistance of shut-off devices under repeated pressure during long term conditions.
4. Experimental results showed that using of unsuitable working fluid on shut-off device prototype can rise high-risk of corrosion.
5. As a result of tests it is concluded that shut-of device pass the hydraulic test and works correctly and constantly.
6. The movable closing element passed the tests on regimes of necessary temperatures and pressure up to 65 MPa.

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OPTIMIZACIJA I ISPITIVANJE TEHNOLOŠKIH PARAMETARA UREĐAJA ZA ISKLJUČENJE GASNOG SISTEMA ZA PUNJENJE BIOMETANA

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Sažetak: U ovom radu je dat pregled radnih principa i rezultata modeliranja i testiranja novog patenta uređaja za isključenje. U radu na ovoj inovaciji je učestvovao *Hygen Ltd.*, a rešenje se oslanja na drugu inovaciju ove kompanije, koja se koristi za pripremu biometana za njegovo dopremanje, pod pritiskom, u rezervoar za gorivo na vozilu. Istraživanje je sprovedeno u saradnji svih uključenih privatnih i naučnih institucija koje su ovlaštene da odrede najprimenjivije parametre. Parametri uređaja za isključenje se odnose na konstruisanje najprimenjivije konstrukcije pokretnog zatvaračkog elementa uređaja. Uporedna ispitivanja uređaja za zatvaranje i uređaja za punjenje gasa pokazala su da system radi besprekorno i prolazi sve testove stabilnosti, hidrauličkih i temperaturskih režima.

Ključne reči: *uređaj za isključenje, bio-metan*

Datum prijema rukopisa:
Paper submitted: 31.05.2012.
Datum prijema rukopisa sa ispravkama:
Paper revised: 05.06.2012.
Datum prihvatanja rada:
Paper accepted: 12.06.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 21 - 34

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 631.372:669-8

Originalni naučni rad
Original scientific paper

3D DISCRETE ELEMENT MODEL TO DESCRIBE THE DRAFT FORCE AND THE INFLUENCES OF THE TOOL GEOMETRY

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Abstract: Virtual DEM models were developed in correspondence with the real tests. In this article we will introduce the methods of how DEM approach was used in developing a model for the prediction of draught force on cultivator sweeps. The micro structure of soil is very complex and the conventional approach to explore the mechanical behavior of soil mainly relies on experimental shearing tests under laboratory conditions. The implementation of DEM is carried out by a series of numerical triaxial tests on granular assemblies with varying confining pressures and bond conditions. The results demonstrate that the numerical simulations can produce correct responses of the soil behavior in general, including the critical state response, as compared to experimental observations using the Mohr circles. The influences of cultivator sweep geometry was researched by DEM in 3D and were correlated with the soil bin tests results.

Key words: *soil, cultivator, DEM, modeling, tillage, soil bin, forces, 3D*

INTRODUCTION

The main function of the field cultivator is to prepare a proper seedbed for the crop to be planted into, to bury crop residue in the soil, to control weeds, and to mix and incorporate the soil to ensure the growing crop has enough water and nutrients to grow well during the growing season. Well-known that, the most influencing for the energetic requirement is the tool rake angel (β) (Fig 1.) and the operational velocity.

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This work is connected to the scientific program of the " Development of quality-oriented and harmonized R+D+I strategy and functional model at BME" project. This project is supported by the New Hungary Development Plan (Project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002 and the TÁMOP - 4.2.2.B-10/1--2010-0009.)

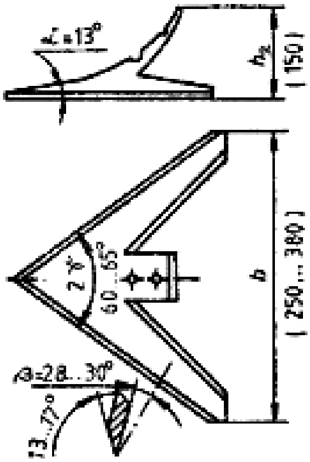

Figure 1. The Sweep-Tool geometry
(2γ=63°, β=30°)

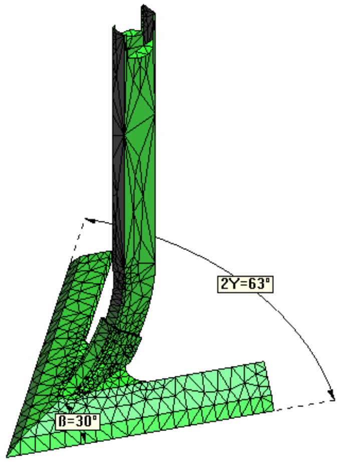

Figure 2. The mesh that define the sweep surface

MATERIAL AND METHODS

The study of soil-tool interaction is expensive and limited to certain cutting speeds [4]. As a result of the previous measurement in the soil bin study, some previous models were elaborated [5].

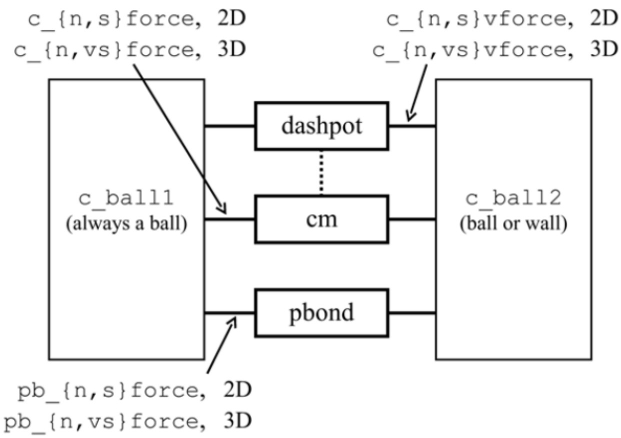

Figure 3. Components at a contact
(The cm and dashpot are always present.)
dashpot: global viscous damping
cm: contact model (linear, hertz…)
pbond: parallel bond

Description of the Parallel-Bond Model

The contact stiffnesses relate the contact forces and relative displacements in the normal and shear directions via and which are repeated here [1]. The normal stiffness is a secant stiffness:

$$F^n{}_i = K^n U^n ni \tag{1}$$

since it relates the total normal force to the total normal displacement. The shear stiffness is a tangent stiffness:

$$\Delta F^s{}_i = -k^s \Delta U^s{}_i \tag{2}$$

since it relates the increment of shear force to the increment of shear displacement.

PFC3D allows particles to be bonded together at contacts. The two standard bonding behaviors are embodied in contact bonds and parallel bonds. Both bonds can be envisioned as a kind of glue joining the two particles. The contact-bond glue is of a vanishingly small size that acts only at the contact point, while the parallel-bond glue is of a finite size that acts over either a circular or rectangular cross-section lying between the particles. The contact bond can transmit only a force, while the parallel bond [7] can transmit both a force and a moment:

$$\overline{F}_i = \overline{F}_i^n + \overline{F}_i^s \tag{3}$$

$$\overline{M}_i = \overline{M}_i^n + \overline{M}_i^s \tag{4}$$

where $\overline{F}_i^n$, $\overline{M}_i^n$ and $\overline{F}_i^s$, $\overline{M}_i^s$ denote the normal and shear component vectors, respectively. These vectors are shown in Fig. 4., where the parallel bond is depicted as a cylinder of elastic material.

Particles may be bonded only to one another; a particle may not be bonded to a wall. Both types of bonds are also created between all proximate particles within the given range, regardless of whether a normal force exists between them.

A parallel bond can be envisioned as a set of elastic springs with constant normal and shear stiffnesses, uniformly distributed over either a circular or rectangular cross section lying on the contact plane and centered at the contact point. These springs act in parallel with the point-contact springs that are used to model particle stiffness at a point, and whose constitutive behaviour. Relative motion at the contact (occurring after the parallel bond has been created) causes a force and a moment to develop within the bond material as a result of the parallel-bond stiffnesses. This force and moment act on the two bonded particles and can be related to maximum normal and shear stresses acting within the bond material at the bond periphery. If either of these maximum stresses exceeds its corresponding bond strength, the parallel bond breaks.

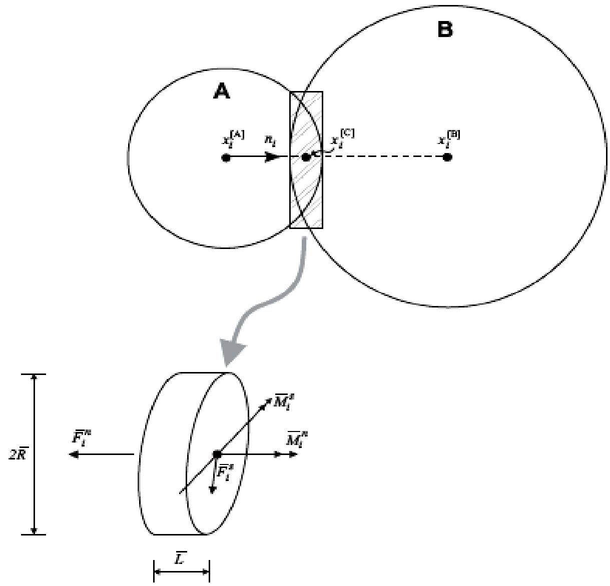

Figure 4. Parallel bond depicted as a cylinder of cementations material

A parallel bond is defined by the following five parameters: normal and shear stiffness k_n and k_s [stress/displacement]; normal and shear strength σ_c and τ_c[stress]; and bond radius R.

Mechanical Damping

Energy supplied to the particle system is dissipated through frictional sliding. However, frictional sliding may not be active in a given model or, even if active, may not be sufficient to arrive at a steady state solution in a reasonable number of cycles.

Local damping and viscous damping are available in PFC3D to dissipate kinetic energy. Local damping acts on each ball, while viscous damping acts at each contact. Local damping applies a damping force, with magnitude proportional to unbalanced force, to each ball. Viscous damping adds normal and shear dashpots at each contact [2]. These dashpots act in parallel with the existing contact model, and provide forces that are proportional to the relative velocity difference between the two contacting entities (ball-ball or ball-wall).

MATERIALS AND METHODS

The material properties and the iteration process in DEM

Using the results of the triaxial test (the peak strength and confining stress) we defined the Mohr's circles. Touching the circles we drew the Coulomb line. The angle of the line and the x axis we defined the internal friction angle. The intersection of the Coulomb line and the y-axis we defined the cohesion.

Shear Box Test

At first we generated an aggregation, with that we had to evaluate and measure the effective bearing with the shear box test. In the test result we can define the aggregation properties as soil after the real soils mechanical parameters. It is a useful method for the comparison.

Table 1. The moisture content of the sample

The moisture content of the sand:			
Dry ing temperature: 105 ºC *Drying time: 2 hour*		$N = \frac{m_1 - m_2}{m_2} \cdot 100\ [\%]$	
Sample	*Mass (before drying)*	*Mass (after drying)*	*Moisture content*
	m_1	m_2	*N*
	(g)	*(g)*	*(mass %)*
1	*149*	*139*	*7,19*
2	*152*	*143*	*6,29*
3	*128*	*121*	*5,79*
4	*148*	*139*	*6,47*
5	*128*	*121*	*5,79*
Average:	*141*	*132,6*	*6,33*

At first, we must determine the relevant behaviors of our intended physical material, and then choose the appropriate microproperties by means of a calibration process in which the responses of the synthetic material are compared directly with the relevant measured responses of the intended physical material.

A series of shear box tests were performed (Fig. 6.). The simulated mechanical behavior of granular materials is compared with those observed from the laboratory tests.

$$Tf = cA + N \tan \varphi \tag{5}$$

where:

A - the area of the sample,
c - the cohesion of the material,
φ - its friction angle.

This is called the Mohr-Coulomb failure criterion. If the stress circle is completely within the envelope no failure will occur, because on all planes the shear stress remains well below the critical value.

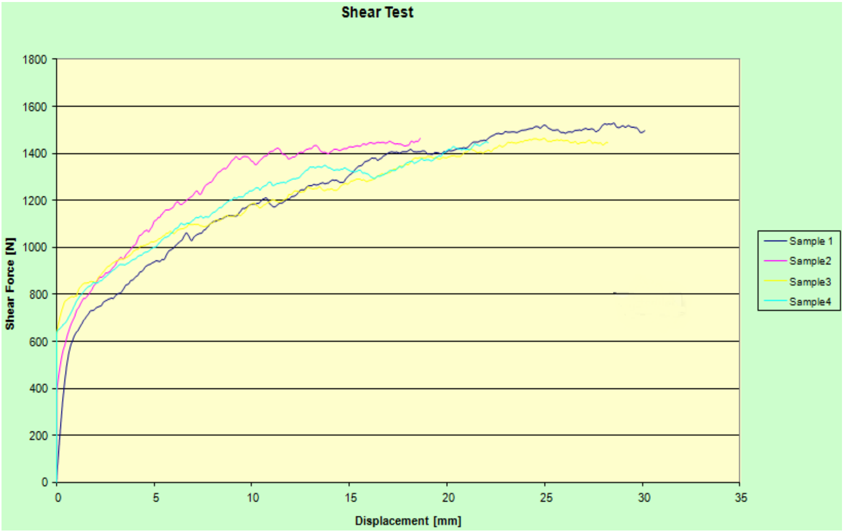

Figure 5. The Shear Box Test Results

The material properties and the iteration process in DEM

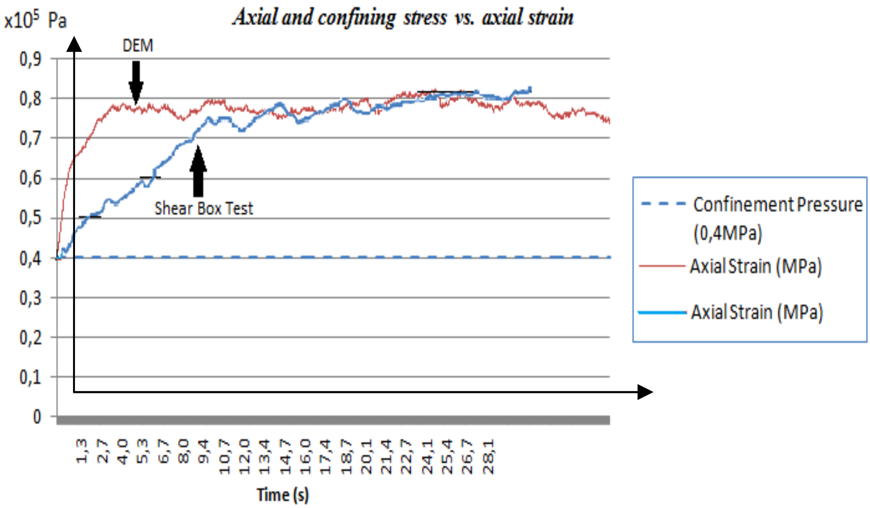

Figure 6. Axial and confining stress vs. axial strain (Triaxial Test and Shear Box Test Comparison) (CP=0,4MPa)

We can see on the Fig. 6. the resulted peak strength dependence of the confining pressure (P_c). For codes such as PFC that synthesize macro-scale material behavior from the interactions of microscale components, the input properties of the microscopic constituents are usually not known [3].

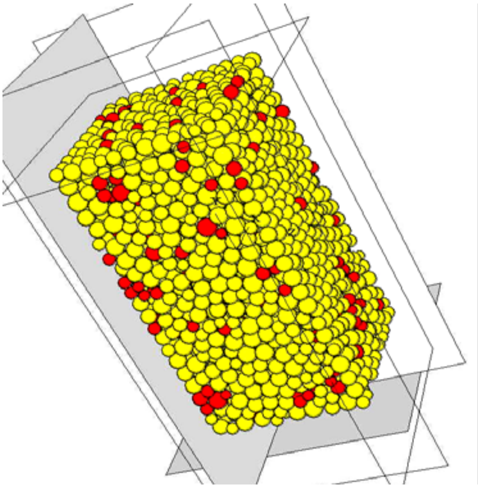

Figure 7. The TRIAXIAL TEST Process (PFC3D)

Although it is relatively easy to assign chosen properties to a PFC model, it is often difficult to choose such properties so that the behavior of the resulting synthetic material resembles that of an intended physical material.

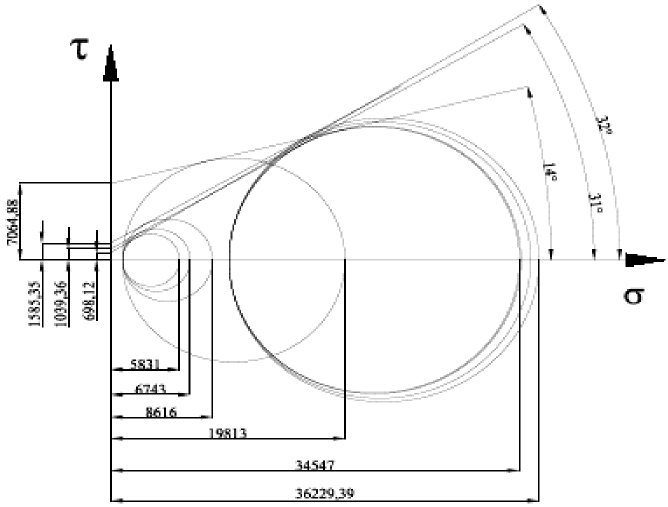

Figure 8. The Triaxial Test Result that define the soil mechanical parameters
(Φ = 32°, C = 7064,88 Pa)

For codes such as PFC that synthesize macro-scale material behavior from the interactions of microscale components, the input properties of the microscopic constituents are usually not known.

Table 2. The results of the triaxial tests

SPECIMEN (Iteration Process)		Triaxial Test Result 1.	Triaxial Test Result 2.	Triaxial Test Result 3.	Triaxial Test Result 4.
x: pack	y: Pc	sig_f	sig_f	sig_f	sig_f
	($x10^3$Pa)	($x10^4$Pa)	($x10^4$Pa)	($x10^4$Pa)	($x10^4$Pa)
1	1	0,6737	0,8616	0,5832	0,6317
1	10	3,6285	3,6201	3,5496	3,4945
	Cohesion (Pa)	698	1585	1039,36	7065
	Internal Friction Angle (Φ)	32°	31°	31°	14°
	Friction	0,3	0,5	0,5	0,5
	pb_rad	1	1	1	1
	pb_kn	1,5e2	1e4	1e4	0,3e6
	pb_ks	2,5e2	1e2	1e2	0,3e3
	pb_nstren	1e3	1e5	1e2	1e5
	pb_sstren	1e2	1e3	1e1	1e3

As we can see on the Figure 8. the cohesion is 7067,88 Pa and the internal friction angle is 32°. This soil mechanics property following the real triaxial tests is a kind of sand. With this process we can harmonize the real and the numerical methods.

Table 3. Model parameters

Parameter in DEM	Value
Bulk density (kg/m^3)	1850
Particle shape	Ball
Normal spring coefficient (K_n) [$N·m^{-1}$]	1,00E+06
Tangential spring constant (K_s)[$N·m^{-1}$]	1,00E+03
Coulomb damping (μ_g)	0,3
Friction coefficient between particles(μ)	0,3
damp viscous normal [$N_s·m^{-1}$]	0,2
damp viscous shear [$N_s·m^{-1}$]	0,2
Particle radius distribution [mm]	23,44-39,07
Friction coefficient between particle and the sweep tool	0,6
Void ratio	0,35
Parallel-Bond (heavy soil) (Result of the sinthezis)	
pb_rad	1
pb_kn ($Pa·m^{-1}$)	0,30E+06
pb_ks ($Pa·m^{-1}$)	0,30E+03
pb_nstren ($Pa·m^{-1}$)	1,00E+05
pb_sstren ($Pa·m^{-1}$)	1,00E+03
Time step of the calculation (Δt) (s)	4.0 × 10-5

The triaxial-test results presented in Tab. 2. The information was obtained from the functions as we can see on the Fig. 7. the axial and confining stress vs. axial strain. We can see the similarity of the Shear Box Test and the Triaxial Test Parameters and can use in our test these micro parameters (Fig. 6.). The soil samples were from the Soil Bin.

With these results we can draw the Mohr's circles, that's tangential line define the cohesion and the internal friction angle. In our research these two soil parameters are enough to define the material and we used these data in the iteration process (Fig. 8.).

Table 4. Key for the shear strength parameters

Soil type	*c (kN m^{-2})*	*φ (°)*	*tan φ*
sandy gravel	*0*	*31*	*0,601*
sand, slighty silty	*20*	*32*	*0,625*
silty sand	*30*	*29,5*	*0,566*
silty fine sand	*15*	*30*	*0,577*
sandy silt	*50*	*30*	*0,577*
clay, w=50%	*65*	*27*	*0,508*
moist clay	*80*	*22*	*0,404*
clay 50%<w<70%	*120*	*16*	*0,286*
clay w>70%	*170*	*20*	*0,364*

RESULTS AND DISCUSSION

The CAD support and the loosening process by DEM

To design and build the sweep tools we used the CAD support function. *PFC3D* is valued for its ability to model complex physics. While *PFC3D* offers many options for defining walls, creating complex walls with *PFC3D* may become tedious at times.

In *PFC3D*, the orientation of the walls determines the side the particles will interact with. The original normal vectors of each triangle in the model (each normal is represented at the center of gravity of each triangle).

The dynamic behavior of cohesive soils during the loosening process by a cultivator sweep was simulated by using the above established DEM mechanical model. The initialization of the interaction between the tool and cohesive soils is the complete model. The model is composed of discrete particles of different sizes. The parallel bonds produce cohesive forces between discrete particles, so parts of discrete particles are conglomerated and form particle aggregate clusters after the tillage process. The complete model is formed by bonding of elements in wide sizes. This structure of the model is similar to that of the actual cohesive soils.

We can see on the Fig. 10. the front of the sweep the parallel bond lines represent the compacted zone and the resulted forces between the particles [2].

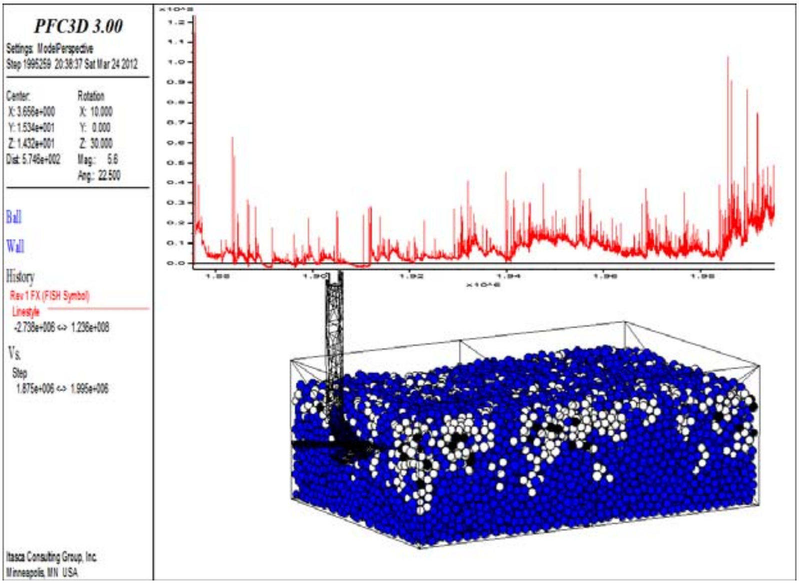

Figure 9. The soil (DEM) and the tool draft force under process
3D view of the TEST structure. Tool in 12 cm depth. (Soil Bin sizes: 2m x 1m x 0,8m)

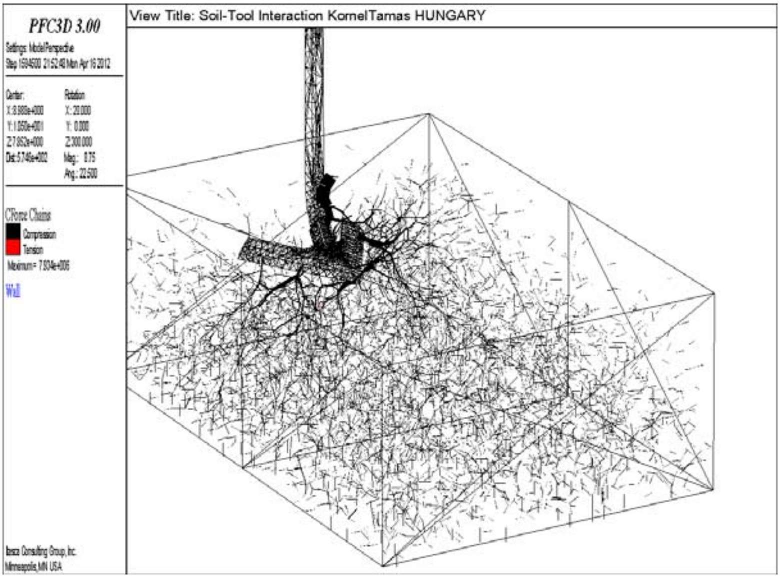

Figure 10. The force structure under the loosening process

As we can see on the Fig. 11. the DEM Draft Force is similar to the measured Soil Bin draft force. The difference could be the sampling accuracy and the noise of the soil bin cart.

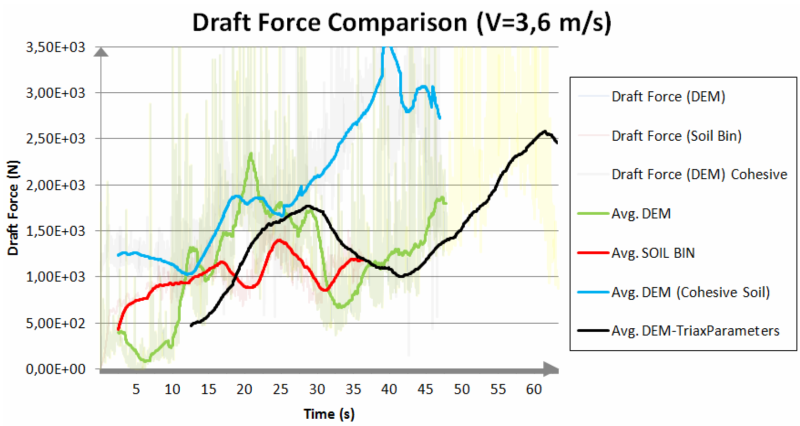

Figure 11. The Draft Force Comparison in 12cm depth and V=3,6m/s

With the CAD support function we imported the real accurate tool geometry. Under the measuring process a „routine" cumulating the draft force x components. With this routine we can measure other tillage tool draft forces.

The influence of the speed and the rake angle

The parallel-bond contact was used to describe the behavior of the cohesive soil (discontinuous) during soil-tool interface process.

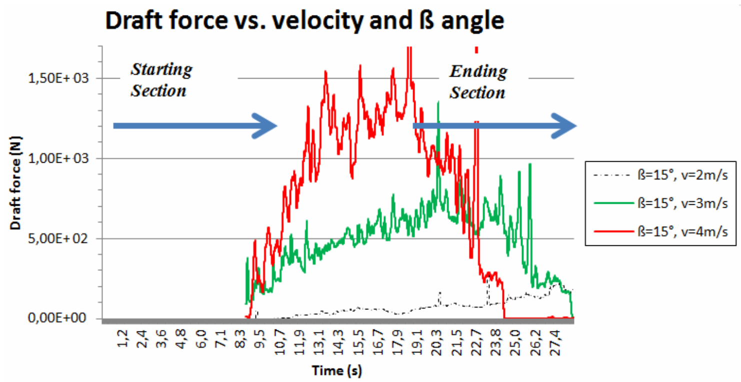

Figure 12. The influence of the speed (2,0-4,0 m/s) by DEM (ß=15°) in 20 cm depth

A series of models were analyzed with various soil properties, speed and rake angles using PFC3D Code (Fig. 12.). The results showed the significant effect of the tool rake angles and working speed on cutting forces in 20 cm depth (Figure 13.). In this research between the two extremities (2.0 - 4.0 m/s and, 5°-30°) the results are parabolic (Fig. 14.).

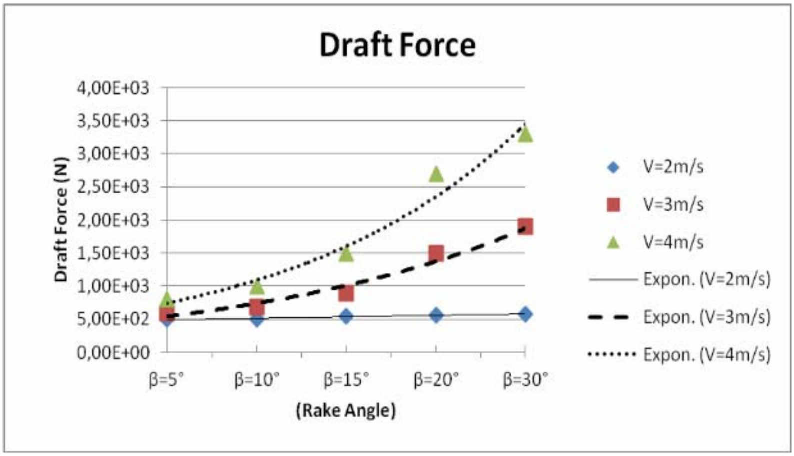

Figure 13. The Draft Forces rake angle (ß) and speed dependences in 20 cm depth

During the simulated tillage process by a cultivator sweep, soil evolves from the extrusion between soil clumps, the humping ahead of the tillage tool, and the climb along the surface of the sweep, to the rupture and separation of cohesive soil cluster

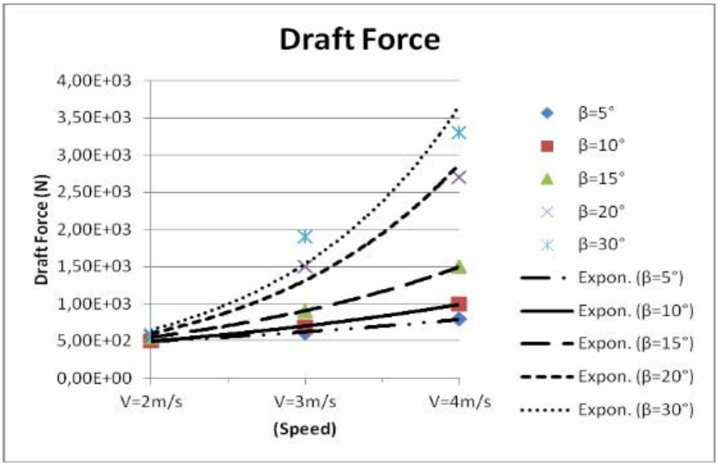

Figure 14. The Draft Forces speed and rake angle dependences in 20 cm depth

CONCLUSIONS

In this three dimensional discrete element analyses we carried out the simulation of the soil-tool interaction in agricultural soil and compared with a Soil Bin Test results. After the triaxial test method with which we validated the micro properties, a series of models were analyzed with various soil properties, speed and rake angles using in the three dimensional models. The results showed the significant effect of the tool working speed on cutting forces in 20 cm depth. In case the set of the appreciable parameters in

DEM synthetic material with parallel- bonds between the particles, we can synchronizing the virtual triaxial test (microproperties) and could be compared directly with the measured response of the physical material. The real soil macroproperties are the cohesion and the friction angle that we got from the science articles. With the parallel bonds we can model the cohesion. To use this method the Soil-Tool Interaction Model is well build to use other tool geometries.

The model can be used in development procedures of soil loosening tools for agricultural machines and technology, reducing the number of soil bin and field test.

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3D DISKRETNI MODEL VUČNE SILE I UTICAJA GEOMETRIJE RADNOG TELA

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Sažetak: Virtualni DEM modeli su bili razvijani uporedo sa realnim testiranjem. U ovom radu ćemo predstaviti metode pristupa DEM u razvoju modela za predviđanje vučne sile na krilima kultivatorske motičice. Mikro struktura zemljišta je veoma kompleksna, a konvencionalni pristup istraživanju mehaničkog ponašanja zemljišta većinom se oslanja na eksperimentalne testove u laboratorijskim uslovima. Primena

DEM je izvedena serijama numeričkih triaksialnih testova na granularnim podlogama sa različitim pritiscima i uslovima u bazenu. Rezultati pokazuju da numeričke simulacije generalno mogu korektno da predvide ponašanje zemljišta, uključujući reakciju na kritično stanje, u poređenju sa eksperimentalnim istraživanjima upotrebom Mohr krugova. Uticaji geometrija krila kultivatorske motičice su istraživani upotrebom DEM u 3D i poređeni sa rezultatima testova u zemljišnom bazenu.

Ključne reči: *zemljište, kultivator, DEM, modeliranje, obrada, zemljišni bazen, sile, 3D*

Datum prijema rukopisa: *Paper submitted:*	04.05.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	
Datum prihvatanja rada: *Paper accepted:*	04.06.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 35 - 46

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 681.3

Originalni naučni rad
Original scientific paper

INVESTIGATING MACHINERY MANAGEMENT PARAMETERS WITH COMPUTER TOOLS

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Abstract: Engineering tools have been effective in demonstrating the parameter impacts on machinery systems. This paper shows four class exercises and discusses the parameter influences and decision-making for the examples. These engineering tools are useful for complex relationships that are beyond the scope of hand calculations or applications of "rules of thumb." Engineering tools can improve the application and student understanding of complex systems involved in machinery management considerations. As students use these tools, they are able to envision how engineering tools can be used to solve new problems that they confront both in the classroom and profession.

Key words*: Machinery management, engineering tools, management parameters, decision-making, undergraduate education.*

INTRODUCTION

Many engineering tools have been effective in demonstrating the parameter impacts on machinery systems. The engineering and mechanized systems curriculum uses the problem solving environment and the problem solving techniques as fundamental principles for the development of students. Many times, system problems are complex with interacting parameters that should be considered and evaluated before a viable solution can be provided. In complex simple systems, "rules of thumb" and intuition are difficult to develop without experiencing and working with the system. Engineering tools, used in undergraduate curriculums, are useful in developing solutions to complex systems and to gain understanding of how changing parameters impact the solution. These engineering tools can show complex relationships that are beyond the scope of hand calculations or applications of "rules of thumb."

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MATERIAL AND METHODS

This paper discusses four undergraduate exercises and discusses the parameter influences and decision-making for engineered systems. The teaching objectives of these exercises are to demonstrate machinery management criteria and the various parameters that impact the system solution.

In the first example, students are asked to use a MatLab [1] interface to calculate the logistical pattern of removing round hay bales from a field. The students develop a MatLab program to determine the timing, distance and pattern of moving, handling and storing round bales. The students develop a loading pattern for a self-loading bale wagon. The goal of the project is to minimize the travel distance of the self-loading wagon.

Well-matched tractor-implement systems are important for maintaining high operating efficiency for farm operations. The spreadsheet used in this second example is based on the Brixius Model and ASABE Standard to predict tractor performance and implement draft, respectively. The program demonstrates matching of tractors with implements and implements with tractors. Optimization of weight distribution and inflation pressures for maximum power delivery efficiency can be determined and computation of field capacity and fuel consumption of the systems selected can be compared.

In the third example, an exercise uses a spreadsheet to demonstrate how field capacity and efficiency change as different planter sizes, crops and operational characteristics (travel speed) are considered. This exercise helps the student visualize the operational details and the impact of various planter options.

In the fourth example, the tractor database developed from the Nebraska Tractor Test reports make a selection problem with tractor parameters. This framework discusses various decision-making options that a producer may consider when selecting a tractor model.

RESULTS AND DISCUSSION

Example 1 – Using MatLab for Bale Logistics

In the first example, students are asked to use a MatLab [1] interface to calculate a logistical pattern of removing round hay bales from a field with a self-loading, self-propelled bale wagon. This machine self-loads six round bales from a field, travels to a storage location, and then dumps the bales into storage.

Experienced operators can drive the machine into a field where the bales are randomly distributed (as they were dropped from the baler) and experienced operators can do a good job of collecting six bales with minimum travel time between bales. The purpose of this assignment is to calculate the minimum time required to load and move 34 round bales into storage.

Each student can start with any bale they choose. They must travel to this bale from the field inlet, load the bale, and then choose the next bale. This process continues until six bales are loaded. The machine must then travel back to the field inlet. Time required is calculated as follows:

$$t_{tot} = (t_{1t} + t_{1L}) + (t_{2t} + t_{2L}) + (t_{3t} + t_{3L}) + (t_{4t} + t_{4L}) + (t_{5t} + t_{5L}) + (t_{6t} + t_{6L}) + t_R \quad (1)$$

Where:

t_{it} [s] - time to travel to bale i

i [-] - 1 to 6,

t_{iL} [s] - load time for bale *i* (t_{iL} = 30 s for all bales)
t_R [s] - travel time to return to field entrance
Average travel speed for the machine in the field is 2.23 $m \cdot s^{-1}$.

<u>*Computation of Distance between Bales.*</u> Straight-line distance between bales is calculated as shown in Fig. 1. The grid coordinates for bale 1 are x_1, y_1. In like manner, the grid coordinates for bales 2 and 3 are x_2, y_2 and x_3, y_3, respectively.

Distance from bale 1 to bale 2: $d_{12} = [(x_1 - x_2)^2 + (y_1 - y_2)^2]^{1/2}$ (2)
Distance from bale 2 to bale 3: $d_{23} = [(x_2 - x_3)^2 + (y_2 - y_3)^2]^{1/2}$ (3)

Distance between any two bales can be calculated in like manner.

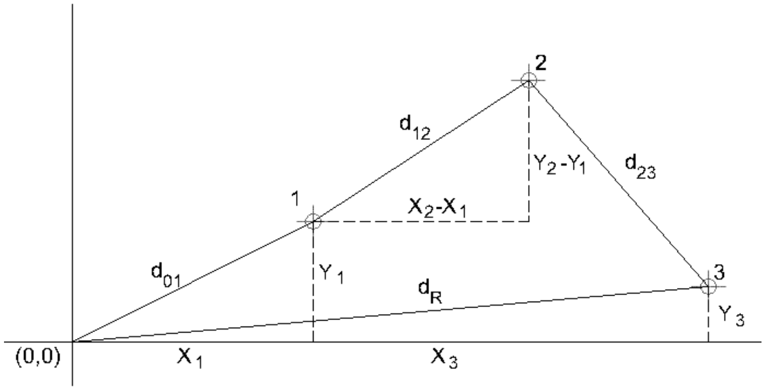

Figure 1. Illustration showing how distances between bales are calculated

The students are given Assignment #1 and asked to develop a MatLab solution to minimize the hauling distance that the loading machine has to haul the round bales from the field to the field inlet.

Assignment #1. *Student assignment for bale logistics determination for a field.*

The grid location for each bale is given in Fig. 2, and the corresponding coordinates are given in Tab. 1. Each grid division in 5 m.

$$d_R = [(x_3 - 0)^2 + (y_3 - 0)^2]^{1/2} \quad (4)$$

Note: For convenience, the entrance to the field is taken as the origin for the grid systems.
Requirements:

a. Calculate the total time to haul the first 6-bale load from the field.
b. Eliminate the six bales already hauled from the dataset. Calculate the total time to haul the second 6-bale load from the field.
c. Continue the analysis for additional loads until all the bales are hauled.
d. Describe any technique you developed to select the shortest distance to the next bale.
e. Develop a table with your results and discuss what you learned from this exercise.

Table 1. Grid locations for bales

Bale No.	*Coordinates*		*Bale No.*	*Coordinates*	
	X	*Y*		*X*	*Y*
1	*-8*	*21*	*18*	*-17*	*8*
2	*-12*	*19*	*19*	*-13*	*8*
3	*-13*	*16*	*20*	*-17*	*6*
4	*-9*	*16*	*21*	*-12*	*6*
5	*-6*	*18*	*22*	*-8*	*8*
6	*-3*	*17*	*23*	*-6*	*6*
7	*-3*	*15*	*24*	*-3*	*8*
8	*-7*	*14*	*25*	*-1*	*6*
9	*-3*	*13*	*26*	*-3*	*4*
10	*-1*	*11*	*27*	*-2*	*2*
11	*-5*	*10*	*28*	*-5*	*1*
12	*-8*	*12*	*29*	*-7*	*4*
13	*-11*	*14*	*30*	*-9*	*1*
14	*-12*	*11*	*31*	*-12*	*3*
15	*-15*	*13*	*32*	*-16*	*3*
16	*-18*	*13*	*33*	*-14*	*1*
17	*-17*	*11*	*34*	*-12*	*-1*

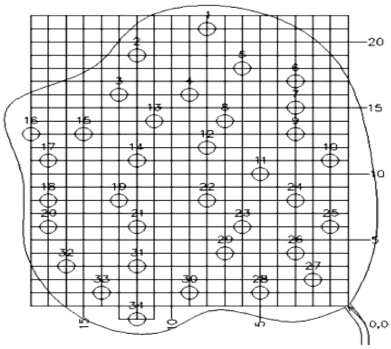

Figure 2. Grid locations of bales in field

This assignment introduces the student to topics they will explore further in their later coursework. It is possible to use a hand-held GPS unit and map the grid locations for hay bales in a field. It may be possible to develop one or more rules for hauling bales from this field using the map. If these rules increase the productivity of the self-propelled bale wagon over what can be achieved by an operator using his/her best judgment, and economic advantage is achieved.

Even if GPS cannot increase the productivity of the bale wagon, this exercise has the following objectives:

1. Introduces GPS technology
2. Application of a practical example using vector analysis.
3. Experience is gained using subscripted variables in MatLab.

Example 2 – Tractor-Implement Matching

A spreadsheet was developed based on the Brixius Model [2] and ASABE Standard [3] to predict tractor performance and implement draft, respectively. The program demonstrates the matching of tractors with implements and implements with tractors. Optimization of weight distribution and inflation pressures for maximum power delivery efficiency can be determined and computation of field capacity and fuel consumption of the selected system is possible.

The operating efficiency of a tractor-implement system depends on how well the tractor and implement are matched. When they are ideally matched, the student (and clients) should expect reduced power loss, improved operating efficiency, reduced operating costs, and optimum utilization of capital on fixed costs [4].

The students are presented with the tables and mathematical expressions in the ASABE standard for Agricultural Machinery Management data as part of ASABE D497.5 [3]. This information is used to predict the tractive ability of tractor and the draft on tillage implements in different soil types.

Traction and Tillage Mechanics. Students learn how to predict tractive performance of the tractor unit and the draft requirement of the implement. The models available to predict the tractive performance of tractors and draft requirements of implements are available in Zoz and Grisso [5] and ASABE [3] respectively. In this section, the models used to develop the spreadsheet are included.

The spreadsheet for predicting the tractor performance is based on Brixius model [2]. He developed the relationships for net traction ratio (NTR), gross traction ratio (GTR), and motion resistance (MRR) as a function of mobility number and wheel slip. They are:

$$B_n = \left(\frac{CI \cdot b \cdot d}{W}\right) \cdot \left\{\frac{1 + K_1 \cdot \left(\delta / h\right)}{1 + K_2 \cdot \left(b / d\right)}\right\} \quad (5)$$

$$GTR = \frac{T}{r \cdot W} = C_1 \cdot \left(1 - e^{-C_2 \cdot B_n}\right) \cdot \left(1 - e^{-C_3 \cdot s}\right) + C_4 \quad (6)$$

$$MRR = \frac{M}{W} = \frac{C_5}{B_n} + C_4 + \frac{C_6 \cdot s}{\sqrt{B_n}} \quad (7)$$

$$NTR = \frac{NT}{W} = GTR - MRR \quad (8)$$

Where:

B_n - the mobility numbers,
b - the unloaded tire section width,
r - the tire rolling radius,
h - the tire section height,
s - the wheel slip,
NT - is the net traction or pull,
T - the axle torque,
CI - is the cone index,
d - the unloaded tire diameter,
δ - the tire deflection,
W - the dynamic load on the tractive devices,
M - is the motion resistance,
NTR - is the net traction ratio.

Equations (5), (6) and (7) include six coefficients ($C_1 \ldots C_6$ and two constants (K_1 and K_2)). Values of these coefficients and constants depend on the type of tires (which can be for bias, radial tires, or tracks). For example for radial tires, values of C_1, C_2, C_3, C_4, C_5, C_6, K_1, K_2, are 0.88, 0.08, 9.5, 0.032, 0.90, 0.5, 5 and 3, respectively.

The spreadsheet for the implement draft prediction is based on the equation published in ASABE Standard [3] and shown below:

$$D = F_i \, [A + B\,(S) + C\,(S)\,]\; W\, T \tag{9}$$

Where:

D - the implement draft,
F_i - dimensionless soil texture adjustment
(i = 1 for fine, i = 2 for medium, i = 3 for fine textured soils),
A, B, C - machine specific parameters,
S - is operating speed,
W - implement width,
T - operating depth for major tools
(for minor tillage tools and seeding implements T=1).

ASABE [3] table provides the values for the machine and soil parameters for commonly used implements.

The spreadsheet is provided and can be downloaded at:
http://filebox.vt.edu/users/rgrisso/Dist_Lecture/Predicting_Tractor_Implemement_Sizing.xls

The student predicts the tractive performance including the pull a specifc tractor (usually specified for each individual student) can develop under a given terrain condition. The second component predicts the draft force on a soil engaging tool taking into consideration factors such as soil texture, tool width and operating speed and depth of the tool. Both components are briefly described in this section. The spreadsheet, the database and the instructions to use are available at:
http://filebox.vt.edu/users/rgrisso/Tractor.htm

A user's manual helps the student set-up and use the features of the spreadsheet application and can be downloaded at:
http://filebox.vt.edu/users/rgrisso/Papers/Ext/Spreadsheet_Instructions.pdf

The spreadsheet component developed for predicting the tractor performance is designed to predict the performance of wheeled tractors of different configurations (2WD or 4WD/MFD) in different soils. This part of the spreadsheet includes data on 700 tractors (101 AGCO, 146 John Deere, 127 Case, 123 New Holland, 122 MF, and 87 others) extracted from the published Nebraska Tractor Test Reports (NTTR). The database also includes data on 39-R1 bias tires, 51-R1 radial tires, and 17-front F2 tires (bias). Thus when the tractor model and the tire sizes are specified, the database will provide the needed information (weight distribution, power input, tire width and diameter etc.) for predicting the performance of tractors. The tractor performance component of the spreadsheet has the ability to predict the tractor performance for a specified weight distribution on the front and rear axle (performance mode) or to calculate the weight distribution and performance for a specified wheel slip (weight mode). The weight mode can be used to calculate the required weight for desired performance. This mode together with an optimizing ballast scheme can predict the optimum wheel slip and maximum tractive efficiency. A Visual Basic macro uses a golden section search [6] as the optimization algorithm when weight mode is in use. The algorithm reviews the results of changing the weight distribution and travel reduction and searches for the optimal power delivery efficiency.

The implement sizing component of the spreadsheet predicts the draft requirement of twelve major and seven minor tillage implements and twelve seeding implements. Outputs from the tractor performance component serve as input for estimating draft and implement width. For example, for a tractor-implement combination, the speed and the predicted tractor pull are inputs for computing the force per soil engaging tool and the allowable implement width.

Spreadsheet Applications. Several cases, that demonstrate the use of the spreasheet for matching tractors and implements and the results, can be reviewed in [7]. Matching the tractor with implement and vice versa are demonstrated.

In the cases considered, three tractors of different power levels and configurations were selected. Three different implements (Moldboard plow with no coulter, Disc Harrow-Tandem, and Field Cultivator) are to be matched with each tractor. These implements were operated in three different soils:

A) fine textured, loose soil,

B) medium textured, and

C) coarse textured, firm soil.

Figs 3 and 4 are typical outputs from the analysis of tractor performance and implement selection respectively. In a second set of cases, the objective is to select tractors to match a set of implements to operate in fine, medium and coarse textured soils.

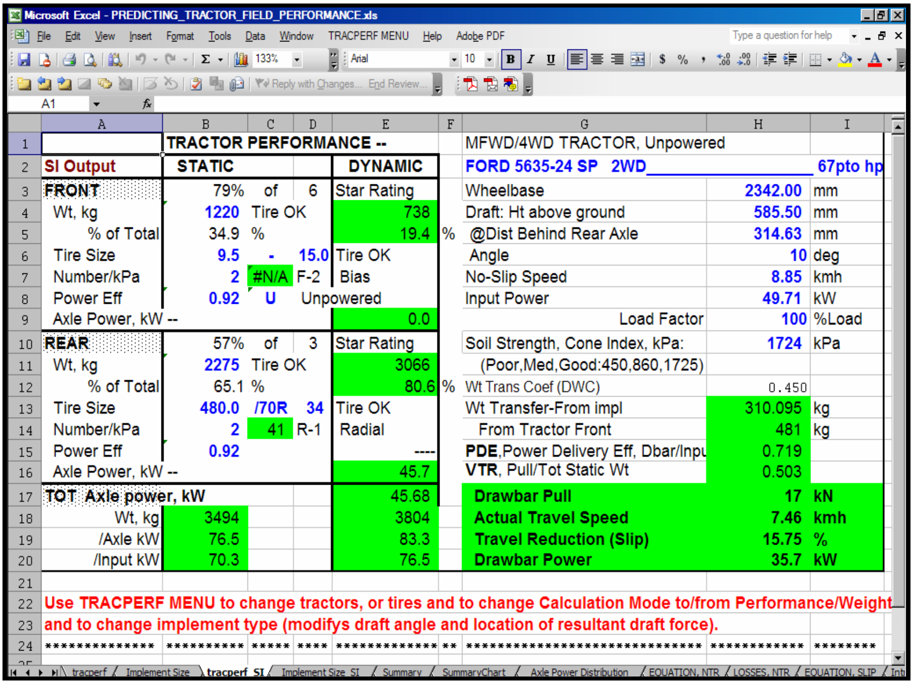

Figure 3. Tractor performance output from spreadsheet analysis for Tractor 1 (Ford 5635)

A5 MAJOR TILLAGE TOOLS

	A	B	C	D	F	G	H	I	J	K	L	M	N	O	P	Q
1	Draft (kN) =	17	Power (kW)	35.7	Fuel Consumption (gal/h)=			15.74					Calculated Tractor Power			
2	Speed (kmh) =	7.5	X-Ratio	1.00	Nred	0		15.74					Use this to select tractor			
3	Soil Type =	1	1				Sizing Implements						Given Implements			
4	Implement		Est Depth (mm)		Depth (mm)		Width (m)	FE	Capacity	Fuel Usea	Width (Est)		m	Draft	Db-hp	PTO-hp
5	MAJOR TILLAGE TOOLS			spacing (mm) between tools					ha/hr	l/ha	spacing (mm) between t			kN	kW	W
6	*Subsoiler/Manure Injector*															
7	narrow point	# tools	254	609.6	2	263.4	1.2	0.85	0.77	20.38	588	6	3.7	49.9	103	138
8	12-in winged point	# tools	203	609.6	2	203.4	1.2	0.85	0.77	20.38	588	6	3.7	51.7	107	143
9	12-in winged point + coulter	# tools	203	609.6	2	160.9	1.2	0.85	0.77	20.38	588	6	3.7	56.2	117	155
10	*Moldboard Plow (no coulters)*															
11	no coulters	m	203	NA	3	202.2	0.9	0.85	0.58	27.17	NA	12	3.7	69.3	144	192
12	w/ smooth or ripple coulters	m	203	NA	3	160.2	0.9	0.85	0.58	27.17	NA	6	1.8	39.2	81	108
13	w/ bubble or flute coulters	m	203	NA	3	153.9	0.9	0.85	0.58	27.17	NA	6	1.8	40.1	83	111
14	*Chisel Plow*															
15	2-in straight point	# tools	203	203.2	6	219.8	1.2	0.85	0.77	20.38	196	18	3.7	47.9	99	132
16	3-in shovel/14-in sweep	# tools	203	254	6	186.8	1.5	0.85	0.97	16.30	245	19	4.8	59.4	123	164
17	4-in twisted shovel	# tools	203	304.8	5	195.0	1.5	0.85	0.97	16.30	294	14	4.3	50.3	104	139
18	*Sweep Plow*															
19	primary tillage	m	203	NA	5	213.9	1.5	0.8	0.91	17.32	NA	16	4.9	52.4	109	145
20	secondary tillage	m	152	NA	10	151.2	3.0	0.8	1.82	8.66	NA	14	4.3	24.3	50	67
21	*Disk Harrow, Tandem*															
22	primary tillage	m	152	NA	9	147.3	2.7	0.8	1.64	9.62	NA	30	9.1	59.5	123	164
23	secondary tillage	m	102	NA	19	100.0	5.8	0.8	3.45	4.56	NA	24	7.3	22.1	46	61
24	*Disk Harrow, Offset*															
25	primary tillage	m	152	NA	7	161.7	2.1	0.75	1.19	13.20	NA	18	5.5	41.8	87	115
26	secondary tillage	m	102	NA	16	99.9	4.9	0.75	2.73	5.77	NA	38	11.6	41.7	86	115
27	*Disk Gang, Single*															
28	primary tillage	m	152	NA	22	152.6	6.7	0.7	3.50	4.50	NA	52	15.8	40.7	84	112
29	secondary tillage	m	102	NA	46	101.9	14.0	0.7	7.32	2.15	NA	110	33.5	41.1	85	114
30	*Coulters*															
31	smooth or ripple	# tools	76	Not a standalone unit							Not a standalone unit					
32	bubble or flute	# tools	76	Not a standalone unit							Not a standalone unit					
33	*Field Cultivator*															
34	primary tillage	# tools	127	190.5	21	124.8	4.0	0.85	2.54	6.21	196	71	14.3	58.9	122	163
35	secondary tillage	# tools	127	190.5	28	128.7	5.3	0.85	3.38	4.66	183.75	40	7.6	24.3	50	67
36	*Row Crop Cultivator*															
37	S-tine	# rows	127	254	7	128.3	1.8	0.8	1.06	14.85	245	10	2.5	24.4	51	67

tracperf / Implement Size / tracperf_SI / **Implement Size_SI** / Summary / SummaryChart / Axle Power Distribution / EQUATION, NTR / LOSSES, NTR / EQUATION, SLIP /

Figure 4. Output from spreadsheet analysis of implement selection for Tractor 1 (Ford 5635)

Results that can be discussed with students are:

- The tractor develops higher draft in coarse, firm soil than in fine, loose soils.
- Optimizing weight distribution has very little influence on predicted draft developed by the tractor and thus on the width of the implements selected.
- The optimized weight distribution provided an increase in power delivery efficiency.
- The implements selected, in general, are wider in fine, loose soils. This results from lower draft requirement per width.
- Field capacities of the implements were higher in fine, loose soil.
- Field capacity increased greatly from high-draft moldboard plow to low-draft field cultivator.
- The fuel consumption (l/ha) for each implement-soil combination are almost the same irrespective of ballasting used.
- Fuel consumption decreased greatly from high-draft to low-draft implement.

Example 3 – Field Capacity and Efficiency during Planting

In the third example, the students develop a spreadsheet to calculate how field capacity change and operational efficiency change for a given field (constant row length), turning times and operational characteristics. This exercise helps the student visualize the operational details and the impact of various planter options on the machinery performance. The class assignment is shown in Assignment #2.

The students use the criteria in Assignment #2 to develop a spreadsheet to assure calculation accuracy and speed of making adjustments. With these criteria, each student is given a specific planter size and speed. When the solutions have been collected, the collective answers are tabulated. The students draw conclusions from their exercise as well as the collective (impact of changing parameters-speed and planter size). Students discuss impact of these changing parameters. For example, class results shown in Tab. 3 indicate the impact of speed (increase of field capacity but a slight drop in field efficiency), crop system impacts (corn vs soybean), the impact of handling seed, fertilizer and chemicals, and impact of planter width (increase of field capacity but a drop in field efficiency). This exercise also demonstrates the losses that occur in normal planting operations and helps the student envision techniques that will help minimize them.

As a follow-up to this exercise, the students are asked to size the planter based on an 85% completion probability at a specific location, start and finish dates. A common start dates of: Corn: April 18th, and Soybeans: April 26th was selected. The results of this exercise are shown in Tab. 3. During the class discussions, the incorrect solutions provided by the students are not corrected and the students are asked to review the table and draw conclusion and relationships and what error may have potentially occurred. The impact of region and finish dates has an influence on planter size.

Assignment #2. Student assignment for field efficiency determination for a planter.

Objective: Determine the field efficiency of a planter from the given information.

Procedure: Follow the example outlined in class for determining the field efficiency of a planter. Find the field efficiency for the planter system traveling at **6.6, 8.0, and 10.3** km·h^{-1}.

A **4-, 6-, 8-, 12- or 16**-row planter is selected to plant 255 ha of furrow irrigated corn and 200 ha of dry land soybeans annually. Row width is 76.2 cm. The fertilizer hopper capacity is 41 kg·row^{-1}, seed capacity is 41 kg·row^{-1} and chemical capacity is 32 kg·row^{-1}. Most row lengths are 0.4 km long. Soil is a sandy loam with slopes of 4%. Planting operation is to follow a continuous pattern.

Corn: Seed (18.5 kg·ha^{-1}), fertilizer (134 kg·ha^{-1}) and chemical (4.5 kg·ha^{-1}).
Soybeans: Seed (56 kg·ha^{-1}) and chemical (4.5 kg·ha^{-1}).

Positional time: Fertilizer - 0.28 min·unit^{-1}, Seed - 0.50 min·unit^{-1}, and Chemical - 0.20 min·unit^{-1}.

Transfer of material times: Fertilizer – 210 kg·min^{-1}, Seed – 195 kg·min^{-1}, Chemical – 48.5 kg·min^{-1}.

Planter/Tractor Turn Time: **0.20 min·turn^{-1} or 0.30 min·turn^{-1}.**
Time between delays - 50 min of pass time, Time of delays - 4 min·delay^{-1}.
Personal Delays - 15 min per 180 min of pass time.

Determine the time for moving the refill vehicle. Drive the planter to the refill vehicle (in the corner of the field) at the same rate as tractor speed.

Note: Each student was given a specific crop (corn or soybeans), travel speed and planter size (number of rows – see Tab. 2).

Table 2. Example of student results for determining field efficiencies as given in Assignment #2

Student	Number of rows	Crop	Speed (km·h^{-1})	Field Efficiency	Capacity (ha·h^{-1})
1	6	Corn	6.6	76.9	2.3
2	8	Corn	6.6	75.4	3.0
3	12	Corn	6.6	72.5	4.4
4	16	Corn	6.6	69.8	5.6
5	4	Corn	8.0	77	1.9
6	6	Corn	8.0	75.1	2.8
7	10	Corn	8.0	71.7	4.4
8	12	Corn	8.0	70.1	5.2
9	16	Corn	8.0	67.1	6.6
10	4	Corn	10.3	74.8	2.3
11	6	Corn	10.3	72.6	3.4
12	10	Corn	10.3	68.5	5.4
13	12	Corn	10.3	66.7	6.3
14	16	Corn	10.3	63.2	7.9
15	4	Soybeans	8.0	77.6	1.9
16	8	Soybeans	8.0	74.6	3.7
17	10	Soybeans	8.0	73.1	4.5
18	12	Soybeans	8.0	71.6	5.3
19	16	Soybeans	8.0	69.3	6.8
20	4	Soybeans	10.3	75.6	2.4
21	6	Soybeans	10.3	73.7	3.5
22	8	Soybeans	10.3	72	4.5
23	12	Soybeans	10.3	68.4	6.4

Table 3. Student results of determining planter size and completion probabilities for specific finishing dates for the items shown in Table 2

Student	Region	Finish Date	# of Rows	Completion Probability	
				Days	pwd
1	Lincoln	5-May	8	17	0.646 50-80%
2	Southeast	10-May	8	22	0.382 >95%
3	Grand Island	15-May	6	27	0.215 >>95%
4	North Platte	20-May	6	32	0.141 >>95%
5	Southeast	5-May	8	17	0.794 <50%
6	Lincoln	10-May	6	22	0.419 >95%
7	Grand Island	15-May	6	27	0.215 >>95%
8	North Platte	17-May	4	29	0.17 >>95%
9	Scottsbluff	20-May	4	32	0.121 >>95%
10	Southeast	9-May	6	21	0.517 80%
11	Lincoln	12-May	4	24	0.311 >95%
12	Grand Island	15-May	4	27	0.175 >>95%
13	North Platte	17-May	4	29	0.14 >>95%
14	Scottsbluff	20-May	4	32	0.1 >>95%
15	Southeast	9-May	10	13	1.03 << 50%**
16	Lincoln	12-May	8	16	0.435 95%
17	Grand Island	15-May	6	19	0.299 >95%
18	North Platte	17-May	6	21	0.23 >>95%
19	Scottsbluff	20-May	6	24	0.156 >>95%
20	Lincoln	9-May	8	13	0.826 <50%
21	Grand Island	12-May	6	16	0.459 90-95%
22	North Platte	15-May	6	19	0.297 >95%
23	Scottsbluff	20-May	4	24	0.164 >>95%

Example 4 – Nebraska Tractor Test Database for Tractor Selection

In the final example, the student use a tractor database developed from the Nebraska Tractor Test reports to selection a specific tractor model for certain operating conditions. This framework provides various decision-making options that a producer might consider when selecting a tractor model. A database is downloaded at:

http://filebox.vt.edu/users/rgrisso/Pres/Nebdata_05.xls

Example Nebraska Tractor Test reports are made available so the linkage between the report and database can be established. Then the students are given a power range and asked to select a specific tractor based on fuel consumption, lugging ability and ballast configuration as shown in Assignment # 3.

Assignment #3. *The exercise using the Nebraska Tractor Test results to categorize and select tractor.*

Use the Nebraska Tractor database and find all tractors (all models) that match the between 50-75 kW

1. Get the results for: Chassis, PTO-Performance & Drawbar Performance
2. Compare the specific fuel consumption (kW-hr/l) during the maximum PTO power run. Make sure you drop out same or similar models (they have the same PTO power results). Plot your findings. Which is the best? What is the average and standard deviations?
3. Did tractor manufacturer have any impact on the specific fuel consumption within this range?
4. Review the Drawbar Performance data, drop the ones that do not have the full runs (75 & 50% runs). What is the fuel savings for "Gear-up & Throttle-Back" situations? Compare the % savings in fuel consumption ($l \cdot hr^{-1}$) within a reduced load test. Compare the % increase in specific fuel consumption ($kW\text{-}hr \cdot l^{-1}$) for a reduced load test. Then compare (graph) the specific fuel consumption at maximum drawbar power with the ballast ratio (kg/max-PTO-power). Does the ballast influence the tests within this range?

Since fuel use is an important factor in machinery management, the students review and contrast the fuel consumed during different power tests. They describe the impact of manufacturer or other factors on fuel consumption such as engine (natural aspirated, turbocharged, air-cool, etc.) and transmission (manual, power-shift, CVT) configurations. The students investigate these factors with statistical inference and graphic methods.

CONCLUSIONS

- Engineering tools can improve the application and student understanding of complex systems involved in machinery management considerations.
- As the student use these tools, they are able to envision how engineering tools can be used to solve new problems that they confront both in the classroom and profession.

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ISPITIVANJE PARAMETARA UPRAVLJANJA MAŠINAMA KOMPJUTERSKIM ALATIMA

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Sažetak: Inženjerski alati su bili efikasni u demonstraciji uticaja parametara na mehanizovane sisteme. Ovaj rad pokazuje četiri klase vežbi i razmatra uticaj parametara i donošenje odluka na primerima. Ovi inženjerski alati su korisni za kompleksne odnose koji su daleko izvan mogućnosti ručnih proračuna ili aplikacija tipa “pravilo palca”. Inženjerska sredstva mogu da unaprede aplikaciju i pomognu studentu da razume kompleksne sisteme koji su uključeni u upravljanje mehanizacijom. Kako student koriste ove alate, tako stiču predstavu o načinima na koje inženjerski alati mogu biti upotrebljeni za rešavanje problema sa kojima se susreću, kako u učionici, tako i u profesionalnom radu.

***Ključne reči**: upravljanje mašinama, inženjerski alati, parametri upravljanja, donošenje odluka, do-diplomsko obrazovanje*

Datum prijema rukopisa: *Paper submitted:*	20.06.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	25.06.2012.
Datum prihvatanja rada: *Paper accepted:*	01.07.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 47 - 61

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 681.518

Originalni naučni rad
Original scientific paper

THE FRACTAL DIMENSION OF AGRICULTURAL PARCELS CONSIDERING MAIZE YIELD

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Abstract: Before making any decisions, all farm managers would like to have some indication about the effectiveness of a particular investment, especially when investing in precision agriculture technologies. Usually, the best indicator should be associated with the yield geometric complexity and its spatial and temporal dynamics. The fractal dimension of corn yield in a given year was calculated for six studied parcels, considering the fractal dimension of yield buffer zones above and below average yield. The less complex geometries usually have a fractal dimension close to the unit which can reach a value close to 2 in more complex geometries. This study shows that the number of yield buffer zones, above or below average yield, changes over time, with a different pattern, from parcel to parcel, and that there is a greater change in the smaller yield buffer zones compared to the larger ones. Fractal dimension can be a very strong indicator when the spatial complexity of a particular parcel is considered, and it is therefore a strong indicator of the greater or lesser need for precision agriculture technologies. The higher the fractal dimension of a given parcel, the higher will be the economic and environmental return of that parcel, when using precision agriculture technologies.

Key words: *fractal geometry, yield spatial and temporal variability, maize.*

INTRODUCTION

Before making any decision, all farm managers would like to have some indication about the effectiveness of a particular investment. In most cases, the risk associated with a given farming investment is not fully known and most managers make decisions on the basis of intuitive guesses. When commercial yield mapping began, in the early 1990s,

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the conventional wisdom was that certain parts of a given plot of land would always have a low yield, while other parts of the same plot would always have a high yield. This principle was linked to the idea that permanent soil characteristics would always behave in the same way, year in year out. Several authors have developed different types of methods for analyzing this spatial and temporal variability [18], [34], [16,17], [25,26]. Blackmore *et al.* [1] and Marques da Silva and Silva [21] used a similar technique for identifying the sites where production is stable over time and the sites where it is unstable. They encountered great difficulty in establishing a temporal threshold between stability and instability for the studied crop. They found that spatial trends were not stable over time. Instead, the spatial trends, in all the studied fields, became less pronounced than the variability found in the individual years.

Thus, there are two questions that can be asked:

1. Which spatial and temporal variability make the acquisition of precision agriculture technology profitable?
2. Is there an index that could help assess if a particular agricultural parcel should or should not be managed with precision agriculture techniques?

Fractal theory [19] is one of the tools that can be used to investigate and quantitatively characterize spatial variability, across a large range of measurement scales [6]. Fractal theory has been used to study topographic land features [20], [5], [14], [38], [4], [35], [37], precipitation distributions [19], vegetation patterns [12], [6], [15], soil roughness [13], [11], soil aggregates [27] [31], soil tillage practices [9], [28], soil water properties [33], [30], [32], [29] and crop variability [10], as well as crop yield [7], [8].

Therefore, the aim of this paper is to determine if fractal dimension could be useful in identifying parcels with greater or lesser need for precision agriculture technologies, considering that higher fractal dimension values indicate greater geometric complexity of the parcel and consequently the need for technologies that better manage such complexity. We also intent to see if fractal dimension of corn yield in a given parcel is temporally stable or whether it varies in time.

MATERIALS AND METHODS

Yield data collection and analysis

This study was conducted using data collected from agricultural fields in Fronteira (Lat.: 39.09307; Long.: -7.611332), located in the Alentejo region (Southern Portugal). The studied fields were Arribana (29 ha), Azarento (62 ha), Bemposta (30 ha) and Cristalino (38 ha), which were irrigated using centre-pivot irrigation systems.

The predominant soils of these fields are classified as Vertic Luvisols and Haplic Regosols (FAO, 1998) with, sandy clay loam and sandy surface texture, respectively. The topography of this region can be characterized as undulated, with soil depths varying from 0.3 m at the higher elevation positions of the fields to more than 1 m at the lower positions of the fields.

Maize yield data were collected over six years, 2002, 2003, 2004, 2006, 2007 and 2008, using a Claas Lexion 450 combine harvester with a 4.5 m cutting head, equipped with a CEBIS information system, which makes it possible to obtain grain yield data with a 5% error. The data were analysed in accordance with [18], to eliminate identifiable errors, and the weight of collected grain was adjusted for grain moisture (140 g kg^{-1}).

Yield data for all the years were standardised on a 5 m × 5 m grid using a 15 m search radius. This was to ensure that each cell of the grid had data from at least three harvester tracks avoiding the existence of cells with no information or non-typical information, when adjacent values were considered.

In the six years of the study, and in all the fields, maize was sown in late April / early May and harvested in September. The producer used a reduced tillage system, composed of a small subsoiler (30 cm depth), prior to sowing. In areas with higher slopes the farmer used reservoir-tillage [36], with the objective of storing non-infiltrated water, avoiding excessive runoff from the higher field positions to the lower ones.

Irrigation management practices were essentially the same for the studied period. Yield data were normalized, before being analyzed, considering equation (1):

$$s_{ti} = \frac{x_{ti} - x_t}{\sigma_t} \quad (1)$$

where:

s_{ti} [-] - normalized productivity of year *t* and cell *i*
x_{ti} [t ha^{-1}] - productivity of year *t* and cell *i*
x_t [t ha^{-1}] - average yield productivity of year *t*
σ_t [t ha^{-1}] - yield standard deviation in year *t*.

Fractal attributes

For each parcel and for each analyzed year, the normalized productivity was divided into two classes of polygon buffer zones:

a) polygons with productivities below average and
b) polygons with productivities above average.

For all polygon buffer zones, the area (A), the perimeter (P) and the P/A ratio average, minimum and maximum were calculated.

The fractal dimension of corn yield in a given year was then calculated for all parcels considering the fractal dimension of polygon buffer zones with:

1. below average yield (FUA),
2. above average yield (FAA) and
3. both together (FT).

For this calculation, only polygon buffer zones with a value above 100 m^2 were considered. The methodology, well described in [36], uses a linear regression between $\log_{10}$ (P/4) and $\log_{10}$ (A) for all polygon buffer zones considered. The slope of this linear relation is commonly regarded as a measure of fractal dimension. The less complex geometries usually have a fractal dimension close to the unit while a value close to 2 can be reached in more complex geometries.

RESULTS AND DISCUSSION

The fractal dimension of a particular yield buffer zone within an agricultural parcel indicates the geometric complexity associated with that particular yield buffer zone in that particular parcel. A parcel which has a fractal dimension greater than another, in a particular yield buffer zone, is geometrically more complex and can consequently provide a better economic return when using precision agriculture technologies.

Buffer zones

Considering the Azarento parcel (Table 1) in 2004, it is possible to see that the number of buffer zones with yields below average, 32, is greater than the number of buffer zones with yields above average, 17; however, in 2007 this pattern is reversed, with 17 and 33 buffer zones, respectively. Also, the geometric characteristics of these buffer areas change from year to year, a fact that can be observed in the mean, minimum and maximum P/A ratio (Tab. 1).

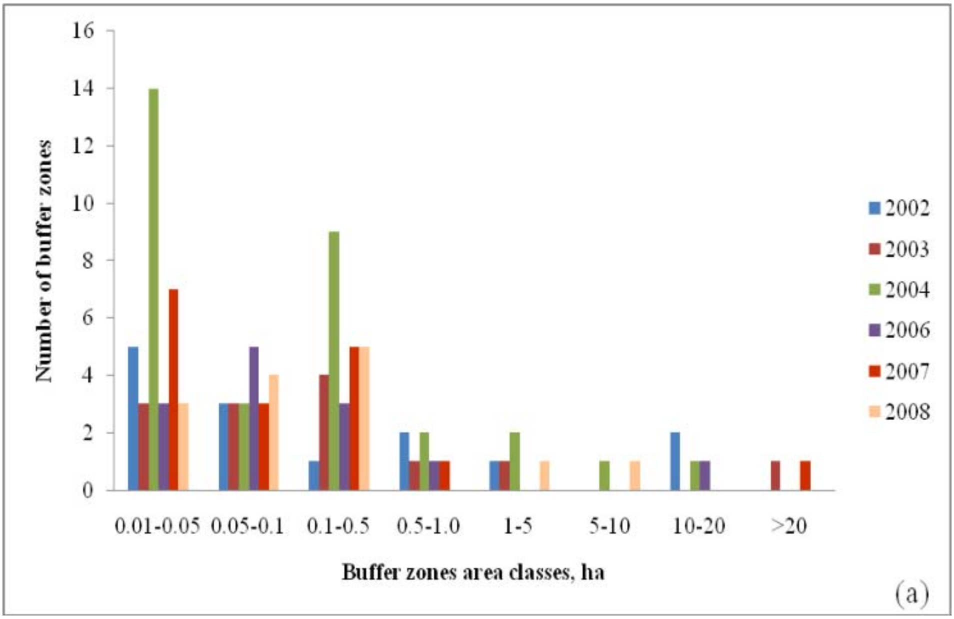
Looking at Figures 1 and 2, it can be noted that the number of buffer zones, above or below average, change over time, and this change has a different pattern from parcel to parcel, being greater in the smaller buffer zones, when compared with the larger ones. Smaller buffer zones change rapidly in number and size, from year to year, usually moving to the superior or inferior buffer zone class. This phenomenon is also observed in the larger buffer zone classes; however, the migration to adjacent classes is less evident.

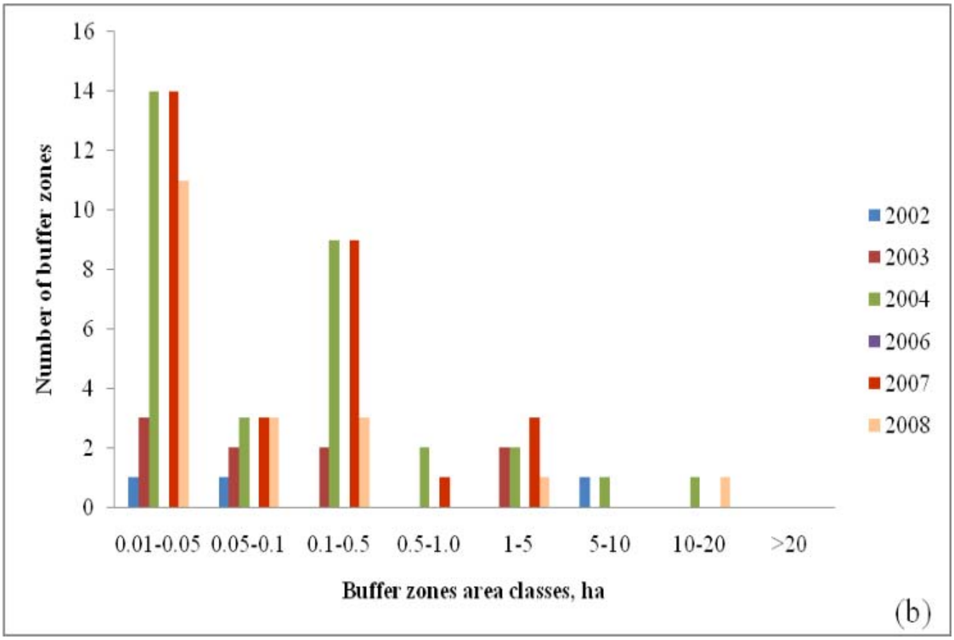
Table 1. Geometric characteristics of the parcels, considering average, minimum and maximum Perimeter/Area (P/A) ratio and the number of polygon buffer zones, within the parcel, above and below average yield

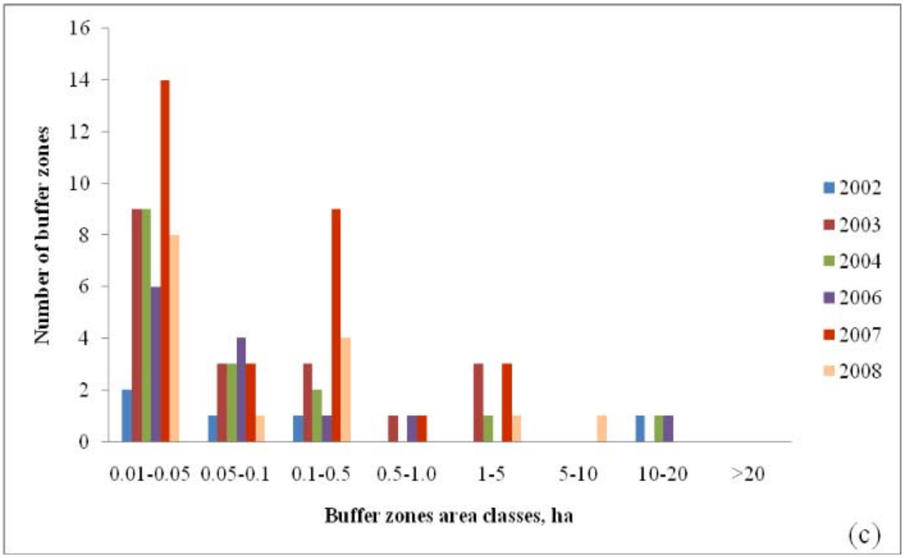
		Below average yield				*Above average yield*			
	Year	*(1)*	*(2)*	*(3)*	*(4)*	*(1)*	*(2)*	*(3)*	*(4)*
	2002	*14*	*0.158*	*0.032*	*0.374*	*11*	*0.245*	*0.030*	*0.400*
	2003	*13*	*0.122*	*0.035*	*0.222*	*8*	*0.158*	*0.030*	*0.397*
Azarento	*2004*	*32*	*0.179*	*0.036*	*0.480*	*17*	*0.253*	*0.036*	*0.500*
	*2006**	*13*	*0.186*	*0.056*	*0.374*	*8*	*0.409*	*0.043*	*1.171*
	2007	*17*	*0.205*	*0.045*	*0.446*	*33*	*0.233*	*0.030*	*0.500*
	*2008**	*14*	*0.154*	*0.061*	*0.374*	*12*	*0.219*	*0.025*	*0.461*
	*2002**	*3*	*0.185*	*0.061*	*0.318*	*15*	*0.232*	*0.040*	*0.500*
	*2003**	*9*	*0.158*	*0.057*	*0.333*	*6*	*0.196*	*0.026*	*0.425*
Arribana	*2004**	*12*	*0.190*	*0.069*	*0.405*	*5*	*0.230*	*0.032*	*0.331*
	2006	-	-	-	-	-	-	-	-
	2007	*30*	*0.208*	*0.048*	*0.405*	*3*	*0.144*	*0.032*	*0.231*
	2008	*19*	*0.219*	*0.057*	*0.333*	*7*	*0.216*	*0.035*	*0.437*
	2002	*5*	*0.181*	*0.050*	*0.320*	*12*	*0.237*	*0.039*	*0.416*
	2003	*19*	*0.212*	*0.052*	*0.461*	*7*	*0.179*	*0.037*	*0.374*
Bemposta	*2004*	*16*	*0.217*	*0.057*	*0.398*	*21*	*0.229*	*0.034*	*0.500*
	2006	*13*	*0.215*	*0.065*	*0.374*	*11*	*0.250*	*0.042*	*0.500*
	2007	*9*	*0.167*	*0.046*	*0.349*	*9*	*0.212*	*0.034*	*0.374*
	2008	*15*	*0.222*	*0.069*	*0.450*	*7*	*0.255*	*0.034*	*0.396*
	2002	*19*	*0.262*	*0.055*	*0.405*	*4*	*0.233*	*0.036*	*0.398*
	2003	*23*	*0.199*	*0.072*	*0.405*	*4*	*0.165*	*0.028*	*0.332*
Cristalino	*2004*	*33*	*0.288*	*0.058*	*0.388*	*4*	*0.158*	*0.022*	*0.500*
	2006	*26*	*0.242*	*0.057*	*0.403*	*15*	*0.235*	*0.035*	*0.399*
	2007	*18*	*0.143*	*0.069*	*0.388*	*2*	*0.152*	*0.024*	*0.280*
	*2008**	*9*	*0.248*	*0.067*	*0.500*	*4*	*0.119*	*0.023*	*0.210*

(1) Polygon buffer zone number; (2) Average P/A ratio; (3) Minimum P/A ratio; (4) Maximum P/A ratio.

* Particular year when only half of the parcel area was cultivated.


Number of buffer zones
16
14
12
10
8
6
4
2
0
0.01-0.05
0.05-0.1
0.1-0.5
0.5-1.0
1-5
5-10
10-20
>20
Buffer zones area classes, ha
2002
2003
2004
2006
2007
2008
(a)


Number of buffer zones
16
14
12
10
8
6
4
2
0
0.01-0.05
0.05-0.1
0.1-0.5
0.5-1.0
1-5
5-10
10-20
>20
Buffer zones area classes, ha
2002
2003
2004
2006
2007
2008
(b)



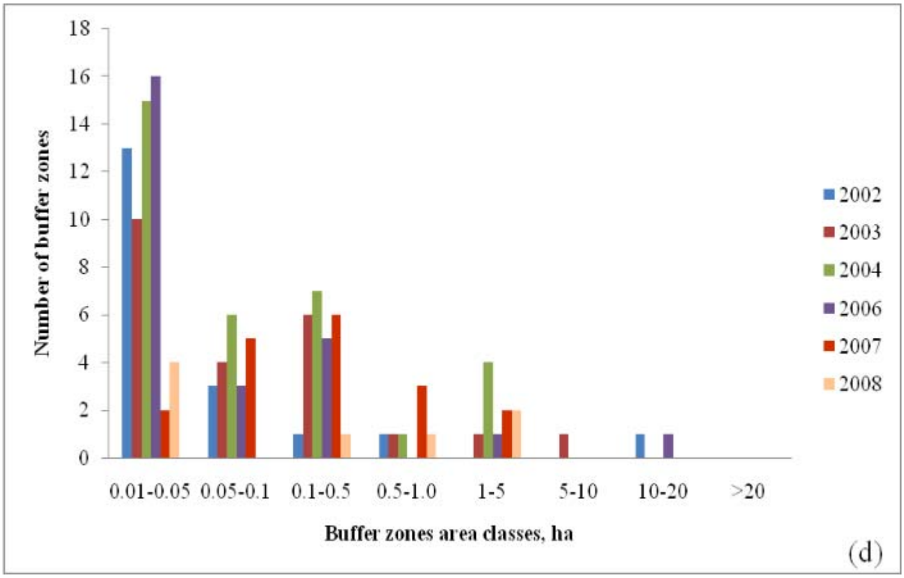
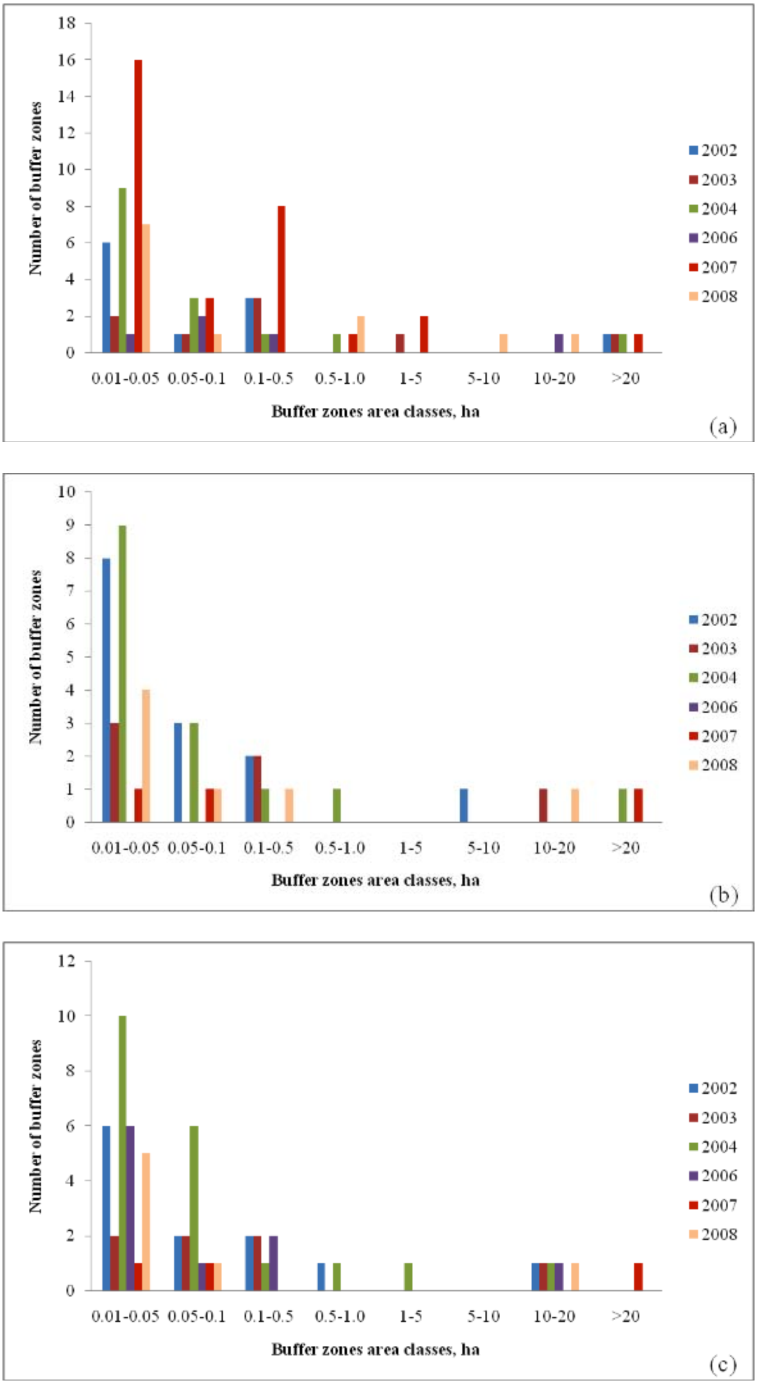


Figure 1. Polygon buffer zones below average yield: (a) Azarento; (b) Arribana; (c) Bemposta; (d) Cristalino

We can conclude that the buffer zones' geometric characteristics, in each parcel, change over time, and this change is faster in the smaller buffer zones, when compared with the larger ones. The point that needs to be considered is if these changes in the buffer zones' geometry affect the fractal dimension of corn yield in each parcel, each year.



Number of buffer zones
2002
2003
2004
2006
2007
2008
0.01-0.05
0.05-0.1
0.1-0.5
0.5-1.0
1-5
5-10
10-20
>20
Buffer zones area classes, ha
(a)
(b)
(c)

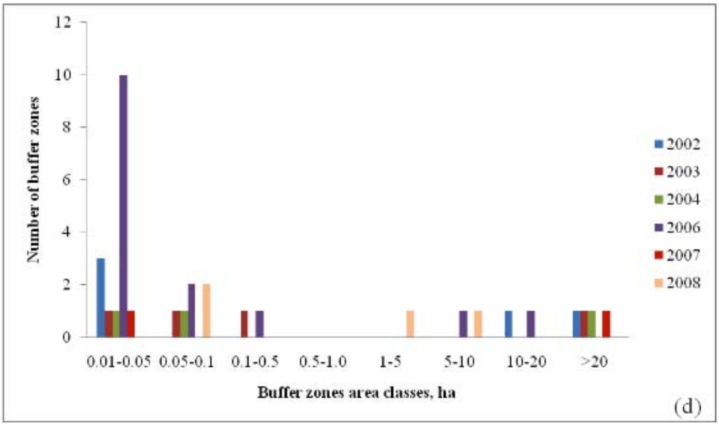


Figure 2. Polygon buffer zones above average yield: (a) Azarento; (b) Arribana; (c) Bemposta; (d) Cristalino

Fractal dimension

Table 2 shows that fractal dimension of corn yield varies from parcel to parcel, and within the same parcel, from year to year. This variation is more noticeable when the fractal dimension of corn yield above and below yield average is considered independently. If the fractal dimension of buffer zones with yields above and below the average yield are considered as a whole (Tab. 2, above and below average yield), the differences in fractal dimension are found to be in hundredths, with the Azarento parcel having the largest fractal dimension and the Bemposta parcel the lowest one. If the fractal dimension of buffer zones with yields below average yield (Tab. 2, Below average yield), are considered, it can be noted that Cristalino parcel has the highest fractal dimension and the Bemposta parcel continues to be the one with the lowest fractal dimension. If the fractal dimension of buffer zones with yields above average yield (Table 2, Above average yield) are considered, it is noted that Cristalino parcel and the Bemposta parcel continue to be the parcels with the highest and lowest fractal dimension, respectively.

The yields from buffer zones with yields below average fractal dimension are typically 0.1 fractal dimension units lower when compared with the yields from buffer zones with yields above average fractal dimension (Fig. 3). This evidence shows that the former have a less complex geometry than the latter, and the pattern holds, in general, for all the analyzed parcels. Why is this? And what are the reasons that can explain higher complex geometries in the yield buffer zones with yields below average? Marques da Silva and Silva [21-24] have shown that in undulated areas the higher yield zones are generally associated with the concave topographies and/or with the flow lines' border areas and the low productivity zones are generally associated with the convex topographies, usually the hill tops. Topographically it is easier to find a complex geometry associated with the hill tops when compared to the concave and flow lines' border areas. This can be confirmed by the fractal dimension presented in this study. The differential geometry associated with yield level, is detected by fractal dimension, however, will this remain true when a different topographic pattern, with different soils and a different crop are considered? The answer to this question falls outside the scope of this article, however, it is important to understand two aspects:

1. Is the fractal dimension of corn yield of a given parcel dependent on soil type, crop or the type of technology used?
2. Does the fractal dimension of corn yield in a given parcel represent the fingerprint of that parcel independent of the above mentioned factors?

Table 2. Fractal dimension of the parcel for: Above and below average yield polygon buffer classes; below average yield polygon buffer classes and above average yield polygon buffer classes

	Above and below average yield			
Year	*Azarento*	*Arribana*	*Bemposta*	*Cristalino*
2002	*1.52*	*1.43**	*1.44*	*1.43*
2003	*1.48*	*1.51**	*1.46*	*1.43*
2004	*1.50*	*1.49**	*1.49*	*1.52*
2006	*1.48**	*-*	*1.38*	*1.42*
2007	*1.51*	*1.48*	*1.44*	*1.43*
2008	*1.48**	*1.44*	*1.43*	*1.57**
Average	*1.49*	*1.47*	*1.44*	*1.47*
*Sd***	*0.02*	*0.04*	*0.04*	*0.06*
*Cv****	*1.21*	*2.41*	*2.69*	*4.12*
	Below average yield			
Year	*Azarento*	*Arribana*	*Bemposta*	*Cristalino*
2002	*1.51*	*1.32**	*1.33*	*1.43*
2003	*1.37*	*1.40**	*1.48*	*1.41*
2004	*1.50*	*1.45**	*1.40*	*1.48*
2006	*1.36**	*-*	*1.32*	*1.39*
2007	*1.42*	*1.51*	*1.40*	*1.37*
2008	*1.30**	*1.44*	*1.39*	*1.47**
Average	*1.41*	*1.42*	*1.39*	*1.43*
*Sd***	*0.08*	*0.07*	*0.06*	*0.04*
*Cv****	*5.79*	*4.74*	*4.09*	*3.10*
	Above average yield			
Year	*Azarento*	*Arribana*	*Bemposta*	*Cristalino*
2002	*1.50*	*1.54**	*1.52*	*1.45*
2003	*1.47*	*1.65**	*1.43*	*1.49*
2004	*1.48*	*1.55**	*1.59*	*1.60*
2006	*1.55**	*-*	*1.44*	*1.45*
2007	*1.56*	*1.42*	*1.49*	*1.54*
2008	*1.63**	*1.46*	*1.49*	*1.70**
Average	*1.53*	*1.52*	*1.49*	*1.54*
*Sd***	*0.06*	*0.09*	*0.06*	*0.10*
*Cv****	*3.97*	*5.82*	*3.92*	*6.40*

*Particular year when only half of the parcel was cultivated.
**Standard deviation
***Coefficient of Variation (%)

Through observing Fig. 4 it can be seen that there is no dependence between the fractal dimension and corn yield so, it can be assumed, that the fractal dimension can be a very strong indicator of the spatial complexity of a particular parcel and therefore a strong indicator of the greater or lesser need for precision agriculture technologies. The higher a fractal dimension of a given parcel, the higher the economic and environmental return when using precision agriculture technologies.

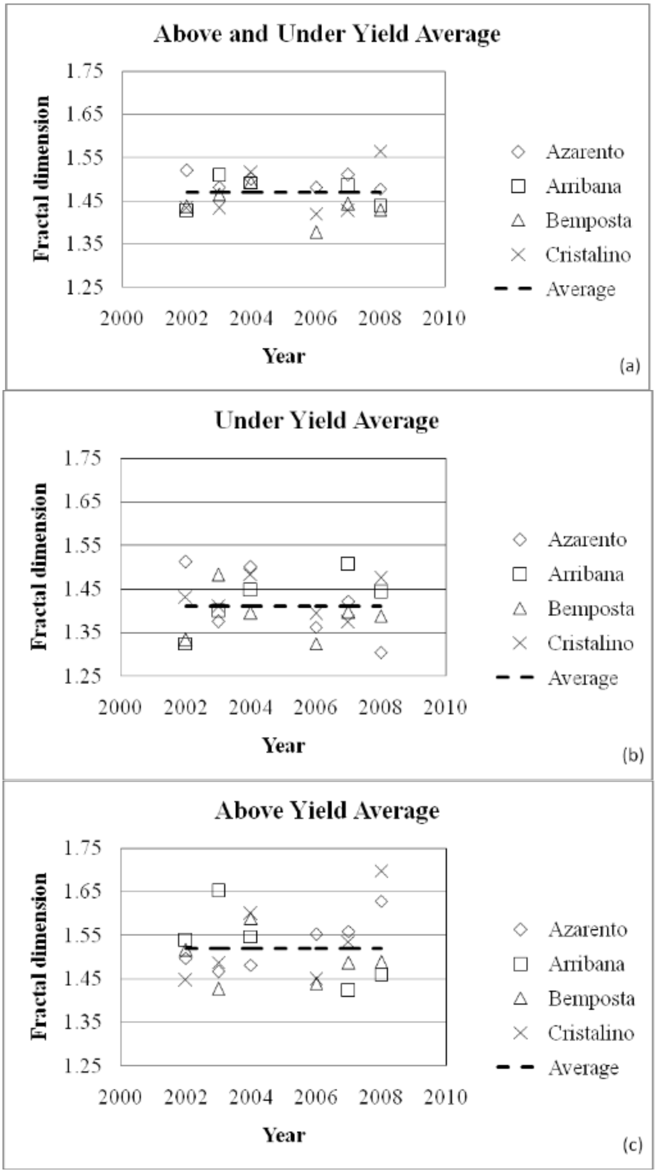
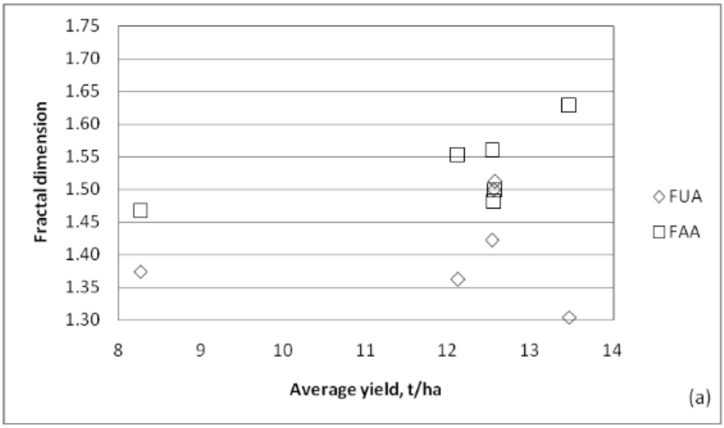
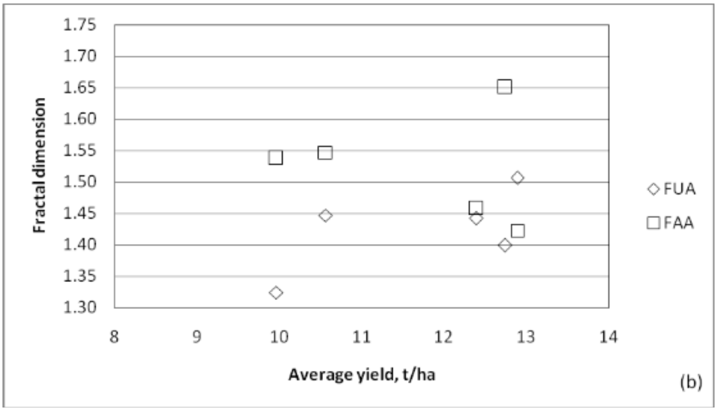
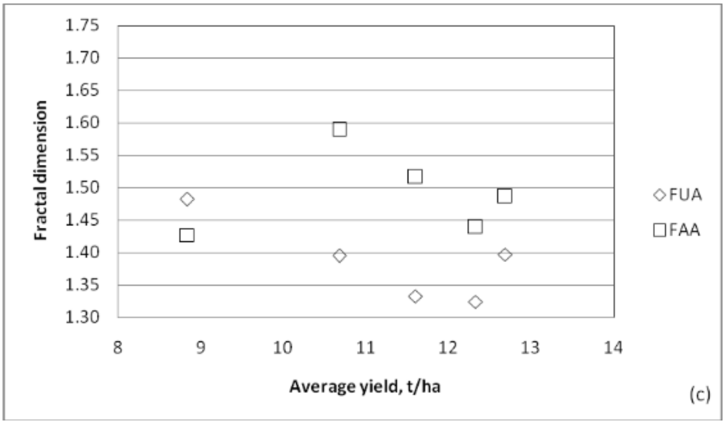


Figure 3. Fractal dimension: (a) Above and below average yield; (b) Below average yield; (c) Above average yield


Fractal dimension
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
8
9
10
11
12
13
14
Average yield, t/ha
◇FUA
□FAA
(a)


Fractal dimension
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
8
9
10
11
12
13
14
Average yield, t/ha
◇FUA
□FAA
(b)


Fractal dimension
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
8
9
10
11
12
13
14
Average yield, t/ha
◇FUA
□FAA
(c)

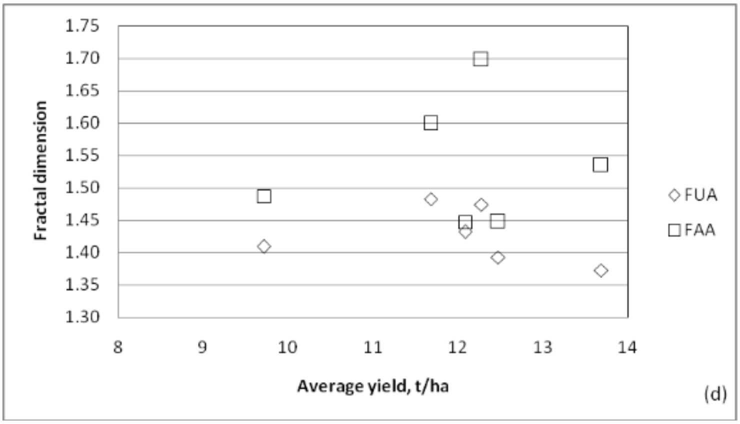


Figure 4. Relation of fractal dimension with average yield: (a) Azarento; (b) Arribana; (c) Bemposta; (d) Cristalino; (◇FUA) Fractal dimension below average yield classes; (□FAA) Fractal dimension above average yield classes

CONCLUSIONS

This study shows that the number of yield buffer zones, above or below average, changes over time, and this change has a different pattern from parcel to parcel, being greater in the smaller yield buffer zones when compared with the larger ones.

Fractal dimension can be a very strong indicator when spatial complexity of a particular parcel is considered, and is therefore a strong indicator of the greater or lesser need for precision agriculture technologies. The higher the fractal dimension of a given parcel, the higher the economic and environmental return of that parcel, when using precision agriculture technologies.

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FRAKTALNA DIMENZIJA POLJOPRIVREDNIH PARCELA PREMA PRINOSU KUKURUZA

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Sažetak: Pre donošenja bilo kakvih odluka, menadžeri farmi bi hteli da imaju neka predviđanja efikasnosti pojedinih investicija, posebno kada ulažu u tehnologije precizne poljoprivrede. Obično, najbolji indikator se može povezati sa geometrijskom složenošću prinosa i njegovom prostornom i vremenskom dinamikom. Fraktalna dimenzija prinosa kukuruza u datoj godini bila je izračunata za šest ispitivanih parcela, uzimajući u razmatranje fraktalne dimenzije dodatnih opsega prinosa iznad i ispod njegove prosečne

vrednosti. Manje kompleksne geometrije obično imaju fraktalnu dimenziju blisku jedinici koja može da postigne vrednost blisku 2 u kompleksnijim geometrijama. Ovo istraživanje pokazuje da se broj dodatnih opsega prinosa, iznad ili ispod srednje vrednosti prinosa, menja tokom vremena, na različite načine na pojedinim parcelama, kao i da značajnije promene postoje kod manjih dodatnih opsega prinosa u poređenju sa većim. Fraktalna dimenzija može da bude veoma čvrst indikator kad se razmatra prostorna kompleksnost pojedine parcele, pa je time i značajan indikator veće ili manje potrebe za tehnologijama precizne poljoprivrede. Što je veća fraktalna dimenzija jedne parcele, veći će bit ekonomski i ekološki rezultat na toj parceli, pri primeni postupaka precizne poljoprivrede.

Ključne reči: *fraktalna geometrija, prostorna i vremenska promenljivost prinosa, kukuruz.*

Datum prijema rukopisa: *Paper submitted:*	23.04.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	08.05.2012.
Datum prihvatanja rada: *Paper accepted:*	10.05.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 63 - 72

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 631.331

Originalni naučni rad
Original scientific paper

A COMPARISON OF THE FIELD AND LABORATORY METHODS OF MEASURING CO_2 EMISSIONS RELEASED FROM SOIL TO THE ATMOSPHERE

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Abstract: In the context of global climate changes the attention of the research is focused on the soil tillage technologies. Soil tillage significantly affects the amount of carbon dioxide (CO_2) released from soil to the atmosphere. Research of the soil emissions is usually conducted in field conditions. The aim of this study is to increase efficiency of the research by substitution of the field method by laboratory method of measuring CO_2 emissions released from soil. The INNOVA measuring devices equipped with the photoacoustic infrared detection sensor was used. The field method measurement is conducted directly in the field conditions. The laboratory method consists of collecting soil samples from the field by sampling probes and their subsequent analysis in laboratory. Soil conditions where the soil samples were taken: haplic luvisol with slightly alkaline soil reaction and medium content of humus. Measurements were conducted nine days after soil tillage by power harrow PÖTTINGER LION 301. Means of the measured values of CO_2 emissions released from soil ranged from 455.580 ppm to 459.392 ppm. There were not found a statistically significant difference between field and laboratory method at 99.9% confidence level.

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The paper has been prepared within the two projects:
"Application of the information technologies to increase the environmental and ecological sustainability of the production agrosystem", activity 2.1 project ITMS 26220220014, EU Operational programme RESEARCH and DEVELOPMENT, and
Rresearch projects VEGA No. 1/0055/12 "Research of environmental effects of the crop production technologies and using of biomass for energy purposes on the NOx emissions to atmosphere" of Slovak Grant Agency for Science.

The CO_2 emissions in the surrounding air were significantly lower, mean 403.125 ppm. It means that it is possible to use soil sampling laboratory method to measure CO_2 emissions released from soil to the atmosphere. Used laboratory method allows to measure CO_2 emissions released from soil at the same time in 12 points and creates the possibility for long-term complex monitoring.

Key words: *soil emissions, carbon dioxide, soil sampling, measuring methods*

INTRODUCTION

Global climate change is a phenomenon that undermines and threatens all humanity. In this context, carbon dioxide (CO_2) is generally the most mentioned gas. Agriculture is one from the major CO_2 producers. Emissions released from the soil into the atmosphere when compared with other sources are relatively small, but the total area of agricultural land is a source of a huge amount of emissions. Intensification of agriculture, continued upward pressure on food production in sufficient quantity and adequate quality causes removal of environmental aspects sidelined. The primary way to release CO_2 from the soil is diffusion. The main reasons for creating CO_2 in the soil are a breathing roots of cultivated plants and soil organisms and decomposition of organic matter [1]. The main factors affecting the amount of generated emissions include temperature, atmospheric pressure [2], soil type [3], soil organic matter content [4], fertilizers [5-8], the oppressed land [9] and tillage [10]. Moisture and precipitation distribution [1, 11] also significantly affect the release of CO_2. The biggest problem of measuring emissions from soil is deficiency of equipment.

Research on the release of CO_2 from the soil into the atmosphere is mostly implemented by a number of field methods, which are classified into the following groups: absorption, gazometric, and micrometeorological gradient method [12].

The aim of this study is to increase efficiency of the research by substitution of the field method by laboratory method of measuring CO_2 emissions released from soil.

MATERIAL AND METHODS

Experimental measurement were carried out at the experimental field near Dražovce village, district Nitra. Experiments started 9 days after soil tillage provided by power harrow PÖTTINGER LION 301 when soil has been cultivated to the depth 100 mm.

Measurement of CO_2 emissions released from the soil to the atmosphere were conducted by two methods: laboratory method and field method. During the experiment the soil samples were collected in order to provide pedological analysis.

Soil properties

Soil type was Haplic luvisol with content of clay, silt and sand for 37.70, 39.43 and 22.87 %, respectively. Soil moisture content were measured by gravimetric method and 26-28 % and pH were 7.78 and 6.87 for H_2O and KCl, respectively. Humus content was 2.799 % and Cox was 1.624 %.

Soil properties were analyzed at the Department of Soil Science a Geology at Slovak University of Agriculture in Nitra, Slovakia.

Soil tillage

Soil tillage was provided by power harrow PÖTTINGER LION 301 (Fig. 1). Basic parameters and standard equipments are shown in Tab. 1 and Tab. 2 [13].

Table 1. Basic parameters of power harrow PÖTTINGER LION 301

Parameter	Unit	Value
Working width	m	3
Rotor	pcs.	10
PTO speed	rpm	1000
Rotor speed	rpm	342
Tine dimensions	mm	18 x 320
Power requirements up to	hp	180
Transport width	m	3
Weight with bar cage roller ø 420 mm	kg	1089
Weight with packing roller 420 mm	kg	1259
Weight with packing roller 500 mm	kg	1419

Figure 1. Power harrow PÖTTINGER LION 301

Material equipments

The INNOVA devices (LumaSense Technologies, Inc., Denmark) consist of INNOVA 1412, INNOVA 1309 and notebook [14, 15].

The Photo-acoustic Field Gas-Monitor – INNOVA 1412 is a highly accurate, reliable and stable quantitative gas monitoring system. It uses a measurement system based on the photo-acoustic infrared detection method. Gas selectivity is achieved through the use of optical filters. The detection limit is typically in ppb (parts per billion) region. The accuracy of these measurements is ensured by the 1412's ability to compensate for temperature and pressure fluctuations, water vapor interference and interference from other gases known to be present.

The Multipoint Sampler – INNOVA 1309 is a 12 channel multiplexer, enabling gas samples to be drawn from up to 12 different sampling locations and delivered to the gas monitor. In addition to this, up to six temperature transducers can be connected to the 1309, providing information about the environment at these specific points, extends the area monitoring capabilities of the gas monitors. Reliability is ensured by automatic self-tests of both hardware and software. Operating status can be read-out at any time. The model 1309 contains a pressure transducer that measures the atmospheric pressure surrounding the multiplexer.

Notebook – operation software is used for control and setup the analysis and is supplied by manufacturer.

Table 2. Characteristic of seamless steel pipe

Parameter	*Unit*	*Value*
Outer diameter	*mm*	*114.3*
Internal diameter	*mm*	*106.3*
Wall thickness	*mm*	*4*
Weight of one meter	$kg{\cdot}m^{-1}$	*10.88*

Sampling probes were made from seamless steel pipe (Tab. 2).

For the experiment purposes there were made two variants of sampling probes:

- small sampling probes with length 170 mm for the field method,
- sampling probes with length 300 mm for the laboratory method.

Used cap were made from a combination of copper and steel. There were made two variants of cap, with or without the hole with 5 mm diameter due to the teflon suction hose introduction. Holes were drilled only on the caps used as a top cap for sampling probes of field and laboratory method. No drilled caps were used to close the sampling probes from the bottom.

Air pipes - each of twelve air pipes was consist of:

- teflon suction hose EN-2007 type AFO614,
- air filter EN-2026 type DS2306,
- fitting for air filter EN-2247 type UD-5041.

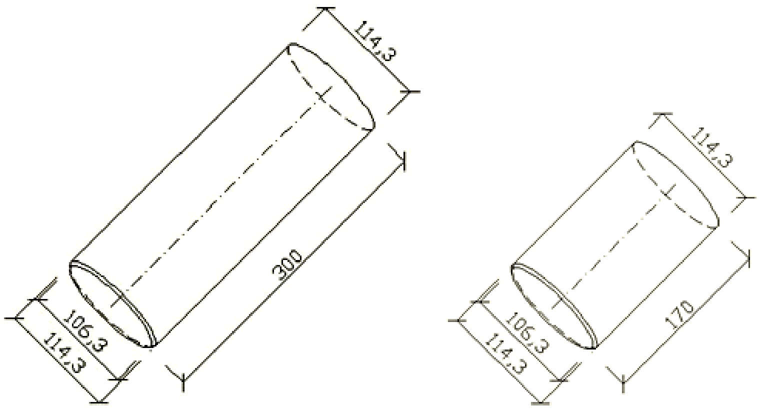

Figure 2. Sampling probes, big (left) and small (right), dimensions in mm

For soil samplings there were used additional tools: hammer, damping pad, spade, scarper and isolation tape. For easier penetration into the soil there was created outside bevel angle of 45° on the bottom of the each sampling probes.

Measuring methods

For the measuring of concentration of carbon dioxide emissions released from soil to the atmosphere it is possible to create by two methods, field and laboratory. In order to exclude the effect of temperature, humidity and atmospheric pressure there were used both methods for measuring carbon dioxide emissions conducted directly on the field. Experiment was carried nine days after soil tillage. Air column in both methods was 150 mm.

Laboratory method

The laboratory method consists of collecting soil samples from field and their subsequent analysis in laboratory. Big sampling probes were incorporated to 150 mm depth into the soil, surrounding soil has been removed and the sampling probes were closed up from the bottom. For this case the big sampling probes were left directly on the field with a goal to eliminate nature effects (pressure, air humidity, temperature).

Field method

The field method measurement was used directly on the field. Small sampling probes were incorporated to 20 mm depth into the soil surface.

Statistical analysis

Data were analysed by using ANOVA after normality test by using Kolmogorov-Smirnov test and homogeneity of variance by using Levene's test. With ANOVA P-Value < 0.05 we continued in post-hoc LSD Test. We have used software STATGRAPHICS Centurion XVI.I (Statpoint Technologies, Inc.; Warrenton, Virginia, USA). Graphic processing of results was performed using software STATISTICA 7 (Statsoft, Inc.; Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSION

There were created two variants of experiment with three replications. As a first variant there was used field method with three big sampling probes FM1, FM2 and FM3 (**F**ield **M**ethod, number). In the second variant we have was used laboratory method with three small sampling probes LM1, LM2 and LM3 (**L**aboratory **M**ethod, number).

The measurement results were compared with the concentration of carbon dioxide in the atmosphere. Concentration carbon dioxide in the air atmosphere was measured at the level of 1 meter above the field surface A (**A**ir).

By using of Kolmogorov-Smirnov test we have found out a normal distribution for all tested sets of values. P-Value of Kolmogorov-Smirnov test for all samples - set of values determined normal distribution (all P-Value > 0.5). Next, Levene's test confirmed homogeneity of variance P-Value = 0.7538 (P > 0.5). ANOVA was used after the values verification. The P-value of the ANOVA is less than 0.05. There is a statistically significant difference between the means of the six variables at the 95.0 % confidence level (Tab. 3).

Table 3. Analysis of variance for CO_2 emissions measurement

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	55370.0	6	9228.34	47.93	0.0000
Within groups	28301.7	147	192.529		
Total (Corr.)	83671.8	153			

To determine which means are significantly different from which others, there were selected Multiple Range Tests – LSD Test at the 99.9 % confidence level (Tab. 4) and statistically significant differences (Tab. 5). Three homogenous groups were identified using columns of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. Between the field and the laboratory methods there are not statistically significant differences at the 99.9% confidence level.

Table 4. LSD Test at 99.9 % confidence level

Sample	Count	Mean	Homogeneous Groups	
A	22	403.125	X	
FM1	22	455.580		X
LM3	22	456.491		X
FM3	22	456.805		X
LM1	22	456.971		X
FM2	22	458.063		X
LM2	22	459.392		X

Table 5. Statisticaly significant difference at 99.9 % confidence level

Contrast	*Sig.*	*Difference*	*+/- Limits*
A - FM1	*	*-52,4547*	*14,0484*
A - FM2	*	*-54,9378*	*14,0484*
A - FM3	*	*-53,6798*	*14,0484*
A - LM1	*	*-53,8456*	*14,0484*
A - LM2	*	*-56,2671*	*14,0484*
A - LM3	*	*-53,3658*	*14,0484*
FM1 - FM2		*-2,48312*	*14,0484*
FM1 - FM3		*-1,22508*	*14,0484*
FM1 - LM1		*-1,39092*	*14,0484*
FM1 - LM2		*-3,81237*	*14,0484*
FM1 - LM3		*-0,911068*	*14,0484*
FM2 - FM3		*1,25804*	*14,0484*
FM2 - LM1		*1,0922*	*14,0484*
FM2 - LM2		*-1,32925*	*14,0484*
FM2 - LM3		*1,57205*	*14,0484*
FM3 - LM1		*-0,165836*	*14,0484*
FM3 - LM2		*-2,58729*	*14,0484*
FM3 - LM3		*0,314014*	*14,0484*
LM1 - LM2		*-2,42145*	*14,0484*
LM1 - LM3		*0,47985*	*14,0484*
LM2 - LM3		*2,9013*	*14,0484*

* denotes a statistically significant difference.

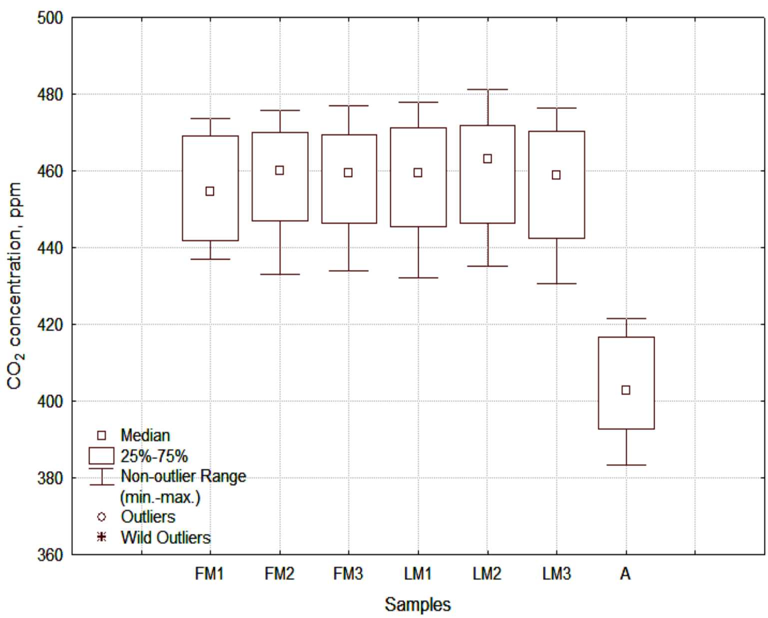

Figure 3. Box-and-Whisker diagram of concentration CO_2

Comparison measuring methods and practical verification of the laboratory method allows to use this method for measuring of carbon dioxide emission released from soil to the atmosphere. Used method allows to measure CO_2 soil emission simultaneously from 12 points at the same time and creates the possibility for long-term complex monitoring of the soil. For measuring carbon dioxide from soil to the atmosphere it is possible to use the Automated Soil CO_2 Exchange Station – ACE [16]. Major advantage for the use laboratory method by INNOVA devices over ACE is to use only one device for measuring 12 points at the same time. Measurement by one ACE allow to measure only one point at the same time.

CONCLUSIONS

The aim of this paper was to compare the field and the laboratory methods for measuring of carbon dioxide emissions released from soil to the atmosphere by INNOVA devices. The results show the way to replace the field method by the laboratory method. By statistical processing of the data obtained there was not found statistically significant differences between the used methods at 99.9 % confidence level. Based on these findings, it was confirmed that the method does not affect the measurement results and thus it may be considered them to be interchangeable with each other. Anyway it is still necessary to verify this finding in the widest range of soil conditions to be sure about these findings.

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UPOREDNA ANALIZA POLJSKIH I LABORATORIJSKIH METODA MERENJA EMISIJE CO_2 OSLOBOĐENOG IZ ZEMLJIŠTA U ATMOSFERU

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Sažetak: U kontekstu globalnih kljimatskih promena, težište istraživanja je stavljeno na tehnologije obrade zemljišta. Obrada zemljišta značajno utiče na količinu ugljen-dioksida (CO_2) oslobođenog iz zemljišta u atmosveru. Istraživanje emisija iz zemljišta obično se izvodi u poljskim uslovima. Cilj ove studije je da unapredi efikasnost istraživanja zamenom poljskih metoda laboratorijskim metodama merenja emisija CO_2 oslobođenog iz zemljišta. Korišćeni su merni uređaji INNOVA, opremljeni senzorima za fotoakustičnu i infracrvenu detekciju. Merenje poljskim metodom izvođeno je direktno u poljskim uslovima. Laboratorijski metod sastoji se od sakupljanja zemljišnih uslova sa terena i njihova naknadna analiza u laboratoriji. Zemljišni uslovi na mestima uzorkovanja zemljišta: ilovasti černozem blago bazne reakcije sa srednjim sadržajem humusa. Merenja su sprovedena devet dana posle obrade mašinom PÖTTINGER LION 301. Srednje vrednosti izmerenih emisija CO_2 oslobođenog iz zemljišta iznosile su od 455.580 ppm do 459.392 ppm. Nije utvrđena statistički značajna razlika između poljskog i laboratorijskog metoda na nivou tačnosti 99.9%. Emisije CO_2 u okolni vazduh bile su značajno manje, sa srednjom vrednošću od 403.125 ppm. To znači da je moguće primeniti laboratorijski metod na uzorcima zemljišta za merenje emisija CO_2 oslobođenog iz zemljišta u atmosveru. Primenjeni laboratorijski metod dozvoljava merenje emisija CO_2 oslobođenog iz zemljišta istovremeno u 12 tačaka i omogućuje dugotrajno kompleksno praćenje.

Ključne reči: *emisije iz zemljišta, ugljen-dioksid, uzorkovanje zemljišta, merne metode*

Datum prijema rukopisa: *Paper submitted:*	22.03.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	
Datum prihvatanja rada: *Paper accepted:*	26.03.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 73 - 80

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 338.434

Originalni naučni rad
Original scientific paper

FACTORS AFFECTING THE MECHANIZATION OF PLANT PRODUCTION IN HUNGARY

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Abstract: The natural and climatic conditions of Hungary are extremely suitable for agricultural production and producing raw materials. As a result of the historical conditions and the continuous changing of the structure of the economy, the number of the economical organizations dealing with agricultural activities went through significant changes.

In our paper, we study the following factors which affect the mechanization of plant production:

- Changes of the number of farms: it can be stated that the number of individual farms decreased continually, while the number of economical organizations increased significantly,
- Type of production: considering the type of production, nearly half of the organizations making agricultural activities are dealing exclusively with plant production, the majority of them perform mixed farming, while the number of those who are keeping only animal stock is slight compared to the previous,
- Changes of agricultural land use: based on the distribution of the cultivation methods of farms – nearly 80% – used their lands as arable lands. The rate of the orchards and vineyards did not reach 2%.
- Changes of quality and quantity of the agricultural machinery: since the role of agricultural machinery in agriculture is particularly significant. These machines basically influence the amount, quality and cost of production.
- Annual change of the contribution to the Hungarian GDP.

By processing of the results and drawing the conclusions, it will be possible to further analyze the mechanization of agriculture in detail and to compare these results with the general needs.

Key words: agricultural production, number of farms, land use, machinery

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INTRODUCTION

The natural and climatic conditions of Hungary are extremely suitable for agricultural production and producing raw materials.

As a result of the historical conditions and the continuous changing of the structure of the economy, the number of enterprises dealing with agricultural activities went through significant changes [4].

In our present paper, we study the following factors which affect the agricultural production:

- the changes of the number of farms,
- the type of production,
- the changes of agricultural land use,
- the changes of quality and quantity of the agricultural machinery.

On the basis of the results and conclusions, it will be possible to analyze the mechanization of agriculture in detail and to compare these results with foreign examples. The data in our present paper originate from the publications of the Central Statistical Office (KSH - Központi Statisztikai Hivatal), the publication of other experts [2,5].

RESULTS AND DISCUSSION

The number of farms

In the last four decades the number of enterprises dealing with agricultural activities was changing unpredictably. As a consequence of the union of the large-scale farms in the 1970's and 1980's, significant decrease was typical to this period. Then by creating new types of organizations in the 1990's, the number of economical organizations increased drastically by the millennium. After the decrease between 2000-2007, their number raised again and according to the previous results of the monitoring 8800 economic organizations were dealing with agricultural activities in 2010.

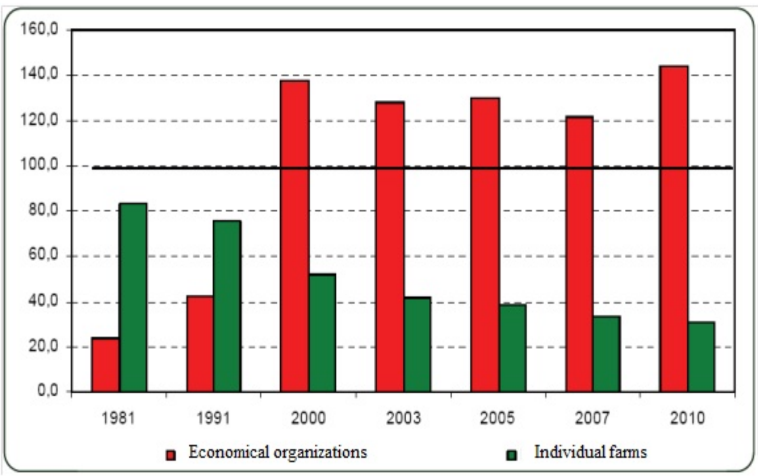

Figure 1. The number of economical organizations dealing with agricultural activities (1972 = 100)

The number of individual farms continually reduced throughout the last four decades. Between 1991 and 2000, the reduction of the number of farms mainly originated from the ending of the household farms and use of the stipend (grant) land. The nearly 40% decrease of the number of organizations in the first decade after the millennium is due to the disadvantageous farm structure, the deficit of capital and the lack of eligible specialized knowledge. According to the previous results of the monitoring, in 2010, 567 thousands of individual farms made agricultural activities.

Type of production

Forty nine per cent of the agricultural enterprises deal with plant production as the only business unit, their rate grew by 8% compared to 2000. The number of economic organizations keeping only animal stock decreased by 4% through the last 10 years, their rate is only 5,5%, while those who are performing mixed farming – with 3% increase – nearly 40%. The rate of the economic organizations performing agricultural services only – after nearly 8% decrease – does not reach 6%.

Forty nine per cent of the individual farms deal with plant production, barely more than 22% only with keeping animal stock, and 29% dealt with both in 2010. This means 9% increase for those dealing with plant production only, and the same decrease for those performing mixed farming compared to 2000. The rate of keeping only animal stock is practically constant. The rate of individual farms doing agricultural services is vanishing. The considerably inflexible structure originates from the purposes of the individual farms differ from the purposes of economic organizations.

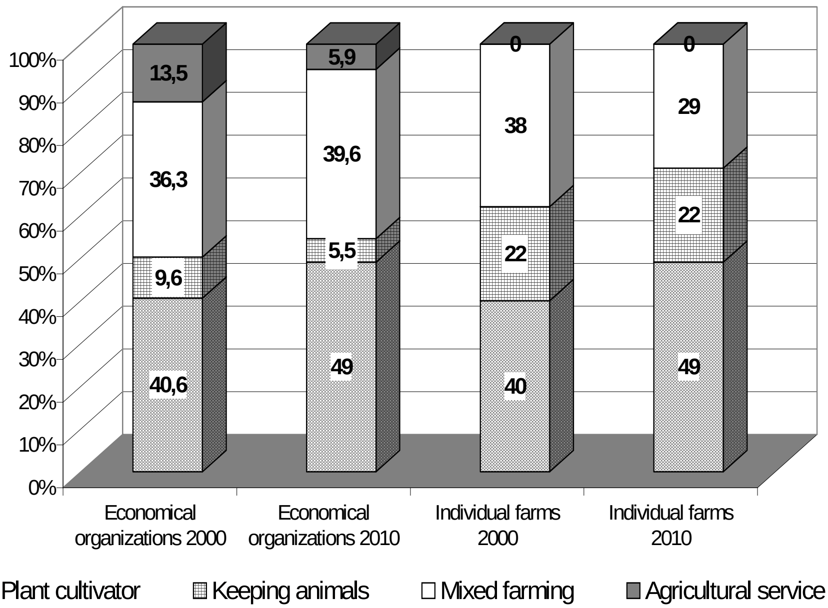

Figure 2. The distribution of the number of farms by producing type, 2000 and 2010

Agricultural land use

Similarly to the previous years, 99% of the farms having arable land, use agricultural area. The average size of this area was 337 hectares in case of economical organizations and 4,6 hectares in case of individual farms in 2010. Since 2000, the average agricultural area of economical organizations decreased by 37%, the area of individual farms increased by 85%. There was not any significant change in the distribution of the agricultural area by cultivation methods.

Sixty per cent of the economic organizations and 55% of the individual farms used arable land in 2010. The rate of it increased by 13% in the economic organizations, and decreased by 7% in the individual farms since 2000. The average size of the arable land per one farm decreased by 30% in economic organizations and doubled in individual farms in the last decade.

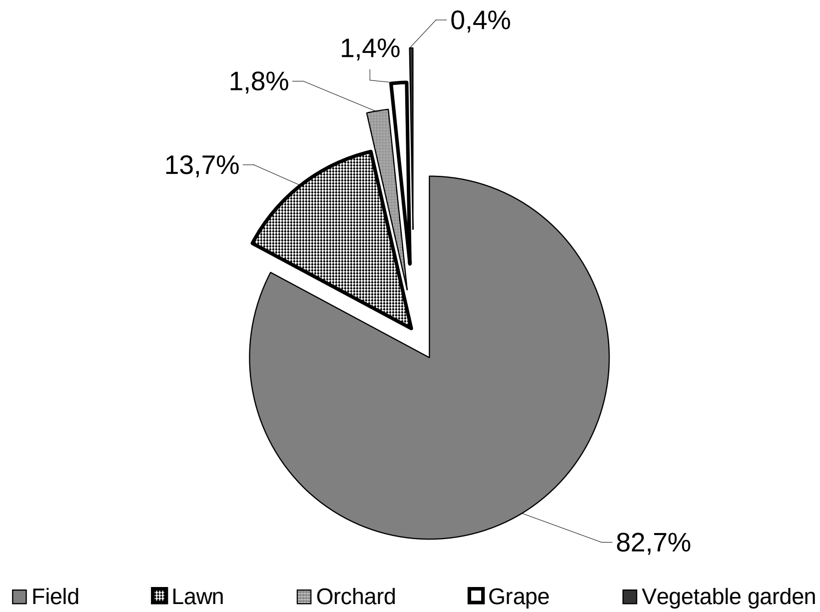

Figure 3. The distribution of the agricultural area by cultivation methods, 2010 (all farms)

Agricultural machines

The role of agricultural machines is particularly significant. These machines basically influence the amount, quality and cost of production.

Since the last total survey of the agricultural machines happened in 2000 – the statements made later were about agricultural tractors and combines only –so it could only be estimated how the equipment of agriculture is changing.

According to the results of 2000 and 2005 survey, it can be stated that the domestic machine park is quite outworn and old.

In 2005, the rate of individual farms from total is 98,9%, their average size is 3,93 hectares/farm, and their participation from all of the area cultivated by machines was 59,2%. In spite of this, these farms operated 80,4% of tractors (pieces), and 76,0% of agricultural tractors and combines (pieces).

In domestic farms, the age structure of agricultural machinery is very unfavorable and in this area the numbers of smaller farms are the worse. According to the data collected by KSH, the average lifetime of agricultural tractors was 12,4 years in economic organizations, while in individual farms it was 16,1 years. The lifetime of agricultural combines was 11,5 and 18,3 years.

According to the survey of AKI (Scientific Institute of Agricultural Economics), only 13218 pieces of tractors (on the average 2644 pieces·year^{-1}) 2220 pieces of agricultural combines (on the average 444 pieces·year^{-1}) and altogether 16888 pieces (on the average 3378 pieces·year^{-1}) of agricultural machines were purchased in the five years between 2000 and 2005. Therefore the machine park became older in this five year-period due to the lack of replacement.

The number of tractors purchased between 2005 and 2009 was 13434 pieces (2687 pieces·year^{-1}), the number of combines was 1892 pieces (378 pieces·year^{-1}) and altogether the agricultural machines were 18209 pieces (3642 pieces·year^{-1}) (Tab. 1.), thus the latter – considering all the agricultural machinery – is slightly more, but it did not restrained the further aging of the agricultural machinery park. However, the accurate data of the machinery park and the rejection are not known, calculating only with 0,5% yearly increase of tractors between 2005 and 2009, and with the number of machines in 2005 in case of the combines, based on rough estimation, the average utilization time of tractors reached 18,3 (in 2005) from 15,3 (in 2000), due to the low amount of new machine purchasing, thus in 2009 the average expected lifespan of tractors approached 40 years. In case of the combines, the average utilization time reached 16,7 years (in 2005) from 15,0 years (in 2000), and increased 17,9 years in 2009.

Table 1. The purchasing of agricultural machines

Name	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Tractors	*1401*	*2069*	*3731*	*4511*	*1506*	*2040*	*1827*	*3253*	*3261*	*3053*
Agricultural combines	*170*	*449*	*717*	*700*	*184*	*323*	*212*	*442*	*412*	*503*
Self-propelling loaders	*110*	*175*	*493*	*306*	*87*	*396*	*332*	*391*	*599*	*425*
Self-propelled harvesters	*4*	*13*	*19*	*26*	*5*	*10*	*4*	*11*	*14*	*18*
Other self-propellers	*3*	*2*	*13*	*27*	*167*	*258*	*171*	*53*	*67*	*134*
Altogether	*1688*	*2708*	*4973*	*5570*	*1949*	*3027*	*2546*	*4150*	*4353*	*4133*

The following data show that from 1985 to 2005 the number of tractors in Hungary increased more than 100%. In Fig. 4, we can see the number of tractors per 10000 hectares of arable land in Hungary.

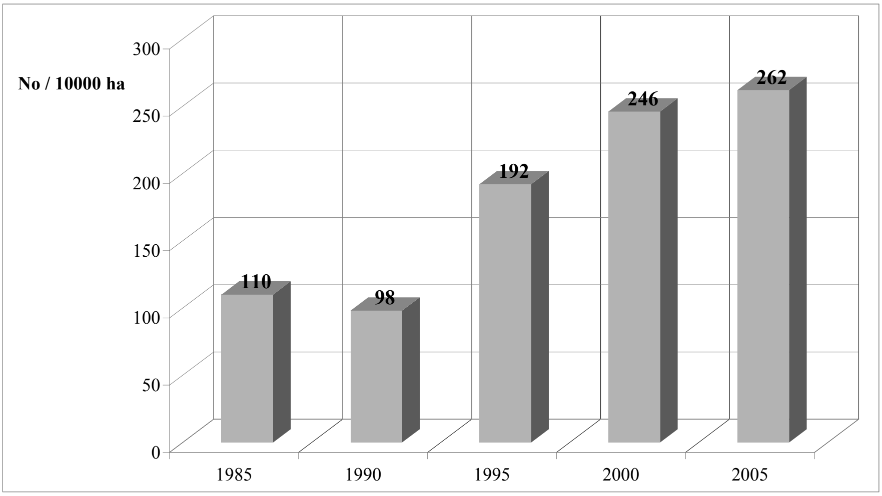

Figure 4. The number of tractors per 10000 hectares of arable land in Hungary

CONCLUSIONS

The natural and climatic conditions of Hungary are extremely suitable for agricultural production and producing raw materials.

As a result of the historical conditions and the continuous changing of the structure of the economy, the number of the economical organizations dealing with agricultural activities went through significant changes.

In our present paper, we study the following factors which affect the agricultural production:

- the changes of the number of farms: it can be stated that the number of individual farms decreased continually, while the number of economical organizations increased significantly.
- the type of production: nearly half of the organizations making agricultural activities are dealing exclusively with plant production, the majority of them perform mixed farming, while the number of those who are keeping only animal stock is slight compared to the previous.
- the changes of agricultural land use: based on the distribution of the cultivation methods of farms that have fields, it is clear, that the majority of the farms – nearly 80% - used their lands as arable lands. The rate of the orchards and vineyards did not reach 2%.
- the changes of quality and quantity of the agricultural machinery: since the role of agricultural machinery in agriculture is particularly significant, these machines basically influence the amount, quality and cost of production.

By processing of the results and drawing the conclusions, it will be possible to further analyze the mechanization of agriculture in detail and to compare these results with foreign examples.

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FAKTORI KOJI USLOVLJAVAJU MEHANIZACIJU BILJNE PROIZVODNJE U MAĐARSKOJ

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Sažetak: Prirodni i klimatski uslovi u Mađarskoj su izuzetno povoljni za poljoprivrednu proizvodnju i proizvodnju sirovih materijala. Kao rezultat istorijskih uslova i kontinuiranih promena ekonomske strukture, broj ekonomskih subjekata koji se bave poljoprivredom trpeo je značajne promene.

U ovom radu proučavali smo sledeće faktore koji uslovljavaju mehanizaciju biljne proizvodnje:

- Promene broja: može se zaključiti da je broj pojedinačnih farmi kontinuirano opadao, dok je broj ekonomskih organizacija značajno rastao.
- Tip proizvodnje: gotovo polovina poljoprivrednih organizacija se primarno bavi biljnom proizvodnjom, a većina njih ima i mešovitu proizvodnju, dok je broj onih koji se bave stočarstvom znatno manji.
- Promene u upotrebi poljoprivrednog zemljišta: na osnovu raspodele metoda obrade zemljišta na farmama - blizu 80% koriste svoje posede kao obradivo zemljište. Udeo voćnjaka i vinograda nije dostizao 2%.
- Promene u kvalitetu i kvantitetu poljoprivredne mehanizacije: obzirom da je uloga mašina u poljoprivredi posebno značajna, ove mašine imaju odlučujući uticaj na količinu, kvalitet i troškove proizvodnje.
- Godišnje promene učešća u mađarskom BDP.

Obradom rezultata i izvođenjem zaključaka biće moguća dalja detaljna analiza poljoprivredne mehanizacije i poređenje sa generalnim potrebama.

Ključne reči: poljoprivreda proizvodnja, broj farmi, upotreba zemlje, mehanizacija

Datum prijema rukopisa: *Paper submitted:*	05.05.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	22.05.2012.
Datum prihvatanja rada: *Paper accepted:*	12.06.2012.

POLJOPRIVREDNA TEHNIKA
✧
Godina XXXVII
Broj 1, jul 2012.
Strane: 81 - 91

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 631.331

Originalni naučni rad
Original scientific paper

MACHINERY PRODUCTIVITY ESTIMATES FROM SEED TENDERS

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Abstract: Several methods and machines have been introduced during the last five years that can improve the timeliness and productivity of planting operations. Several manufacturers claim these devices can increase productivity by more than 50% over conventional methods. This paper provides insights on the improvement of corn and soybean planting systems, while using a seed tender and other similar devices. A comparison between machine operations is analyzed with the assumptions made by these claims. While the claims may be valid, farm clientele deserve to know the conditions under which these improvements can be expected. The results can assist farmers in evaluating how these purchases influence machine productivity, and how to identify potential operational areas that can improve their productivity with existing machinery systems. It also provides better estimates for parameters currently listed as ranges within the ASABE Standards.

Key words: *seed tenders, machinery management, management parameters, decision-making, machine productivity*

INTRODUCTION

Machine capacity information is crucial for machinery management decisions. Machine capacity is used to predict how equipment will perform in a farm system and determines timeliness of operation. If a series of operations contain an activity that becomes a “systems bottleneck” [1] by increasing the time to perform an individual step,

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the entire system will have lower capacity, and timely completion of a task will be affected [2]. Timeliness is defined as the "ability to perform an activity at such a time that crop return is optimized considering quantity and quality of product" [3,4].

MATERIALS AND METHODS

Machine Capacity versus Field Efficiency. Most farmers focus mainly on capacity (ha/h) of a machinery operation when discussing machinery decisions. Their interest in capacity provides a quick evaluation of the ability to complete the task. However, most farm operations usually include other unit operations that must be completed during the task. For example, during planting, operators must refill seed and agrochemical boxes or tanks as they are emptied. Or in a harvest operation, grain is moved away from the combine or forage harvester so that these units remain operational with minimal delays. In logistics terms, unit operations are usually the infrastructure that supports a desired task.

This discussion focuses on field efficiency because field efficiency addresses the impact of supporting activities during the operation. The field efficiency value evaluates the impact of machinery decisions and different operational strategies. For example, as a farmer increases the size of a planter unit by increasing the number of rows, thereby increasing the width, the theoretical field capacity increases linearly with the width. However, if the supporting unit operations, such as refilling seed hoppers, remain the same, the effective field capacity of the planter deviates further from theoretical because the same time is required to handle seed as with the smaller planter. Therefore, productivity for the larger planter does not increase linearly.

Field Efficiency Definition. According to Hunt [5], "time efficiency is a percentage reporting the ratio of the time a machine is effectively operating to the total time the machine is committed to the operation."Strict definitions are required for determining time losses associated with operation of the machine. The following list describes the time elements that involve labor, which are associated with typical field operations, and that should be included when computing the capacities or costs of machinery associated with various farm enterprises:

1. Machine preparation time at the farmstead, including removal from and preparation for storage and also shop work;
2. Travel time to and from the field;
3. Machine preparation time in the field both before and after operations, including daily servicing, preparation for towing, etc.;
4. Theoretical field time which is the time the machine is operating in the crop at an optimum travel speed and performing over its full width of action;
5. Turning time and time crossing grass waterways while machine mechanisms are operating;
6. Time to load or unload the machine's containers, if not done on-the-go;
7. Machine adjustment time, if not done on-the-go, including unplugging;
8. Maintenance time, including refueling, lubrication, chain tightening, etc., if not done on-the-go, but does not include daily servicing;

9. Repair time, which is the time spent in the field to replace or renew parts that have become inoperative; and
10. Operator's personal time.

The operator's personal time (Item 10) is a highly variable quantity and is usually unrelated to the operating efficiency of the machine. Consequently, it is often not considered as time lost and is not charged against machine operation. For similar reasons, Items 1, 2, and 3 are often excluded from consideration. The remaining elements (Items 4-9) are the items included in field efficiency.

Specifically, field efficiency [4] is the "ratio between the productivity of a machine under field conditions and the theoretical maximum productivity." Field efficiencies for specific machines can vary widely.

By definition, field efficiency requires timing of non-productive activities (lost time). According to Bainer *et al*. [6], the field efficiency can be written as:

$$e = \frac{kt_p}{t_p + t_h + t_a} \tag{1}$$

Where

e - field efficiency (decimal),

k - implement width utilization (decimal),

t_p - theoretical field time (item 4),

t_h - time loss due to interruptions that are not proportional to area,

t_a - time loss due to interruptions that tend to be proportional to area.

Von Bargen and Cunner [7] defined field efficiency as the primary activity time (item 4) divided by the sum of all field activities, shown as:

$$e = \frac{t_p}{\left\{ t_p + \sum_{i=1}^{n} t_i \right\}} \tag{2}$$

Where

t_i - other activity times

With the field efficiency established, an equation for effective field capacity can be determined:

$$C = \frac{Swe}{c} = C_T e \tag{3}$$

Where

C [ha·h^{-1}] - effective capacity,

C_T [ha·h^{-1}] - theoretical capacity,

S [km·h^{-1}] - travel speed,

W [m] - rated width of implement,

C [10 m-km·ha^{-1}] - unit conversion constant.

Machinery performance studies have traditionally required the use of stopwatches with observations recorded on a clipboard [7-11]. Time-motion studies are tedious, time consuming, and require the researcher to be on–site during the operation. Recent research demonstrated the use of precision farming data to extract machinery performance information and field efficiencies [12-13].

Results of the analysis of machine performance studies are similar to other time-motion studies used in industrial applications, where the inefficiencies of a given process can be identified and quantified, and economic impacts can be assessed. Management strategies can be implemented to minimize inefficiencies and solutions verified. The analysis can be used to compare various machinery operation techniques and practices. Producers can also compare different methods [14] such as the time saved during a planting operation by using bulk seed versus seed in bags. During harvest, producers can assess time saved due to unloading on-the-go versus keeping the grain cart out of the field. Finally, assessment of machinery and operator costs can be estimated for each field or subsection instead of using whole farm enterprise averages.

Field efficiency of row-crop planting operations ranges from 50 to 75 percent and is typically 65 percent [4]. Taylor *et al*. [15] examined field efficiency and capacity of corn planters in northeast Kansas. They concluded that field capacity increased and field efficiency decreased as planter width increased. Since field efficiency decreases as a function of planter width, the relationship between planter width and field capacity is not 1:1. Thus, doubling planter width does not double field capacity.

Several engineering tools are effective in demonstrating the parameter impacts on machinery systems. One tool, a spreadsheet, can demonstrate how planter capacity and field efficiencies change as new devices and operational characteristics are considered. This exercise provides insights to the farm clientele concerning operational details and the impact of various planter options that can be applied to their specific operation.

The results detail the calculations and assumptions made by advertisers and sale representatives. Other questions considered are:

- How large are the individual seed hoppers, and how many times daily do they require filling?
- Are individual hoppers being filled with an auger from a mini-bulk seed supply?
- Or hand handling with bags?
- How do these units influence travel speeds, road transport, field compaction, and turning time?
- Are these devices cost effective?

General Machinery Management Models. Farm managers, consultants, and others working with machinery management data use capacity information to estimate costs, and select machinery to complete field operations within the time available. General machinery management models have been used to select machinery and evaluate the economics and performance of farm systems [16-18]. Timeliness costs have been shown to be an influential input into the machinery selection process [2, 19-23]. Computer models have been developed to aid the selection of optimal machinery systems for farms. The major model types include static machinery selection algorithms [20-21, 24] and dynamic simulation models [18, 25-27]. In each of these models, the number of days suitable for fieldwork is an important component in the selection and analysis of machinery systems. In order to predict the amount of work that can be accomplished, the time available within the optimal period for the required operation must be known. Most of these models assume that the field efficiency is constant no matter the size (capacity) of the equipment.

RESULTS AND DISCUSSION

Farmers have found that one of the most time-sensitive operations on the farm is planting. This finding has increased their interest in reducing the planting window to gain the advantages of early planting (without frost damages) such as better canopy closure and increased weed control, thereby resulting in increased yields. The farmer's desire to increase planter capacity has increased due to the advantages of the planter system combined with the pressure of off-farm employment, reduced labor force, increased farm size, and time commitments with other farm enterprises.

Manufacturers have complied with farmers' wishes by increasing operational planter widths and developing supporting units such as seed tenders. Seed tenders typically handle bulk seed that are carried in tanks or containers along with the planter, and then convey seed to the planter boxes during refill. In this context the tender is an on-board central seed hopper device rather than a separate tender vehicle frequently associated with nutrient or pesticide application. Various devices offer automatic refill, conveyance systems, or positioning for multiple box refills.

Several manufacturers claim seed tenders can increase planting productivity by more than 50% over conventional methods. The objective of this paper is to provide a discussion and insights on the improvement of corn and soybean planting systems while using a seed tender device with central hopper. A comparison between machine operations is analyzed using assumptions made by these claims. While the claims may be valid, farm clientele desire to know the conditions under which these improvements can be expected.

Fig. 1 and 2 show manufacturers' claims for an 18.3-m planter unit for seeding corn and soybeans, respectively. The estimated improvement from using the seed tender for the corn plant operation was 12.8% while the estimated improvement for the soybean plant operation was 52%. The only differences in the comparison are the handling of seed by hand or the use of tender device to automatically refill the planter boxes and the seeding rate differences between corn and soybean.

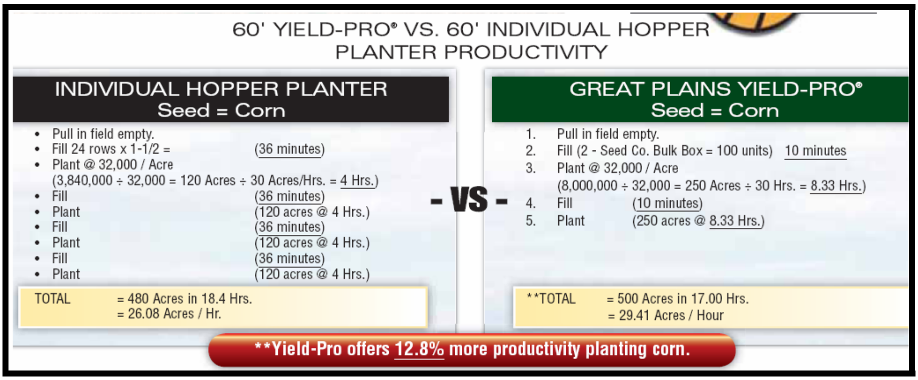

Figure 1. Manufacturing advertising claim for the improved productivity of corn planting

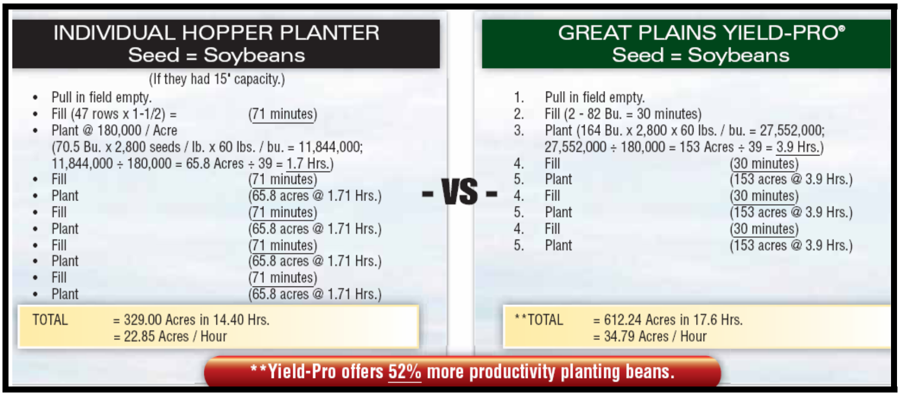

Figure 2. Manufacturing advertising claim for the improved productivity of soybean planting

<u>Review of Claims.</u> First, to gain insights into the manufacturer's estimates, the theoretical capacity (CT) of the planter units was computed. For corn planting, the 24-row machine width of 18.3 m (76.2 cm row spacing) with a travel speed of 8 km·h^{-1} results in a theoretical capacity of 14.7 ha·h^{-1}. The soybean planter was assumed to have the same width resulting in 47 rows at a 38.1cm row spacing with an operational speed of 10.5 km·h^{-1}, giving a theoretical capacity of 19.1 ha·h^{-1}. With these estimates, the field efficiency of the corn planting operation with handling seed bag and seed tenders is 72 and 81%, respectively. For soybean planting, the field efficiency for these same two systems is estimated to be 48 and 73.6%, respectively. These computed field efficiencies are close to the estimates projected by the ASABE Standards [4]. The soybean planting efficiency using the conventional method is below the lower limit of the ASABE Standards [4].

The individual components of these efficiency differences can now be examined. It is estimated that during corn and soybean planting, 17.5% of the time is used for all other support items such as turns at the end of rows, maintenance, etc. Thus, the remainder, 11 and 2% of the planting time, is estimated to be spent refilling the hopper by hand and using the tender, respectively. During soybean planting, refilling soybean hoppers accounts for 34 and 9% of the planting time spent for refilling the hopper by hand and by tender, respectively.

The manufacturer estimated that refilling hoppers by hand using corn seed bags would take 36 min to refill all 24 units, or 1.5 min·hopper^{-1}, which is a reasonable estimate for handling corn seed bags. This same estimate was used for a narrow row soybean planter having 47 row units or a total refill time of 71 min. While the refill rate is an estimated value it might be more accurate to base the refill rate on the mass handled instead of the row unit. Grisso *et al*. [28] estimated that the transfer time for a mechanical system at 195 kg·min^{-1} and 0.5 min to position the device over the row unit. Using these estimates the handling of seed would be 0.73 and 0.71 min·hopper^{-1} for corn and soybean, respectively. These values are about half of the estimated rate.

In these examples, the most dramatic impact occurs during the soybean planting operation; considering the seed volume and the number of row units to service, this result seems reasonable. Thus, the addition of a tender unit for corn planting would probably not result in the large improvements of productivity seen with the soybean planting operation.

Planter Size. These estimates (i.e., assuming 1.5 min·hopper^{-1} for filling individual seed hoppers and the total time specified by the manufacturer for filling the tender, seed population) were compared for several planter sizes (24-, 12-, and 6-row units with 76 cm rows) to estimate the impact of the seed tenders. The field efficiency for these three sizes of planters is shown in Fig. 3. There is less improvement in productivity from using a seed tender with planters having smaller widths. However, even with the 12-row unit, significant improvements result while sowing soybeans. Individual farmers should evaluate whether the increased productivity would warrant the additional cost of the tender unit for their planting operation. These impacts on planter capacity can be seen in Fig. 4.

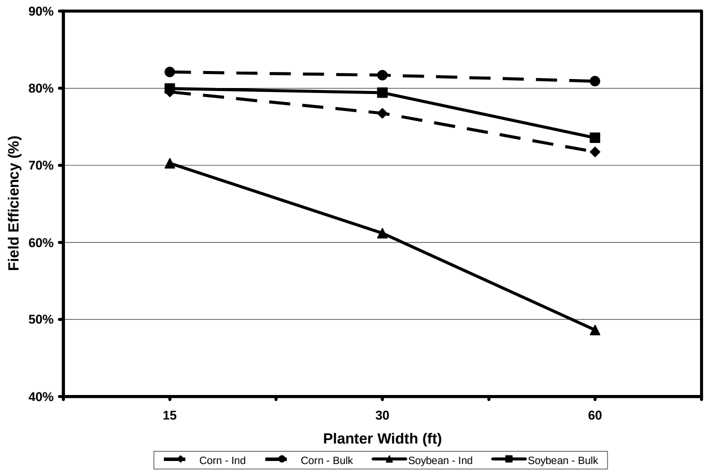

Figure 3. The field efficiency analysis of the bulk tender compared with individuals handling seed bags as a function of planter width

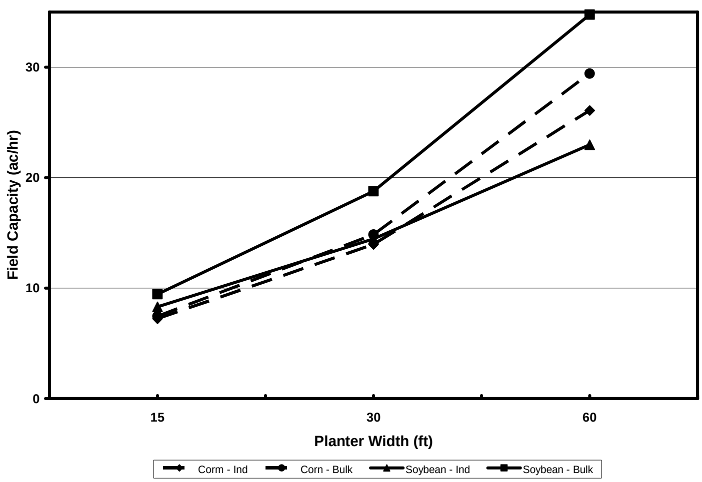

Figure 4. The effective field capacity of the bulk tender compared with individuals handling seed bags as a function of planter width

Seed Rate. The major difference in productivity increase between corn and soybean operations was the impact of seed rate and the accompanying frequency required to refill and handle the seed. The manufacturer's example uses a seeding rate of 13,000 seeds·ha^{-1} for corn and 73,000 seeds·ha^{-1} for soybeans. As a comparison, the soybean operation was evaluated over a seeding rate range from 20,200 to 85,000 seeds·ha^{-1} for different seeder widths. The estimates were based only on the changes required to handle seeds at refilling. Fig. 5 shows the impact of soybean seeding rate and the corresponding productivity improvement of using a seed tender. Smaller planters have little productivity gains from the seed tenders, but even at low seeding rates for soybeans, the productivity increases for an 18.3 m planter, exceeding 20%.

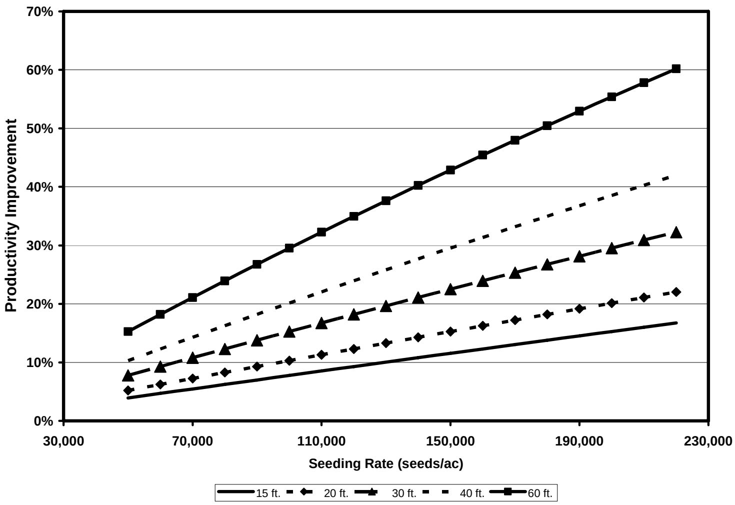

Figure 5. The productivity improvement of seeding soybeans with a bulk tender compared with individuals handling seed bags as a function of planter width and seeding rate

Economic Impact. The economic impact can be viewed in two primary ways. The first way is timeliness cost. "Does the loss of productivity during planting result in a decrease in yield at the end of the season?" Answering this question relates to the crop and variety impact on the growing degree-days and seasonal influence for untimely planting. Since this estimate is based on calendar days, timely completion can be computed. The other evaluation method determines whether the improved productivity from the seed tender meets the operator's criteria. For example, suppose the cost of investing in a larger 48 row (18.3 m) unit rather than replacing an existing 24 row (9.1 m) soybean planter was \$25·ha^{-1} and the potential gain in machine field capacity was projected to be 6.9 ha·h^{-1}. The impact for a farm operation having over 405 ha results in completion in 60 h quicker than the smaller planter or a Return on Investment (ROI) of \$167·h^{-1}. If the larger planter was unable to capture the full potential capacity and was reduced by 50% due to efficiency losses, the resulting capacity gain would be only 3.9 ha·h^{-1}. Then the difference would mean that the larger planter would only gain 30 hours over the smaller planter. If the cost of owning and operating the tender offsets this value, then the tender should be purchased and implemented during soybean planting. However, with the corn example, if the addition of a tender cost \$25·ha^{-1} but the capacity lost was only 1.2 ha·h^{-1} then the small loss may not justify the investment of the seed tender.

Implications of Supporting Units. There are similar farm operations that have the characteristic that as their capacity is increased the supporting activities become more critical in maintaining high field efficiency. Examples include: forage chopper vs. truck to haul away the chopped forage; combine vs. grain cart/truck or on-the-go unload; biomass harvest vs. logistics to biorefinery; spray applicator vs. nurse truck; nitrogen applicator vs. nurse tank; and grain dryer vs. safe storage. Equation 2 shows that, when the supporting activities/operations (t_i) become more than 25% of the productivity time (t_p) then productivity suffers. In the case of the soybean planting operation, the 48-row planter showed a field efficiency drop below 50% and that 50% of the time while in the field other activities instead of planting were being done. To maintain field capacity the supporting activities cannot take longer than 15 minutes during an hour of field operation.

As an estimate, if the potential capacity is doubled (by doubling the operating width) while the supporting activities remain unchanged, then the supporting activities increase from 25% to 50% and loss of productivity is dramatic. This result requires the farmer to understand and be able to compute the time required for these supporting activities, and that he has a good understanding of how conditions will change them.

Other implications of using seed tenders include the following: investment in more machinery; possibility of increased soil compaction as the heavier machine traverses the field; and maintenance and repair might increase above simpler individual hoppers. An operator could preload the tender but that increases over-the-road weight and raises concerns of safety issues such as equipment braking and steering stability.

CONCLUSIONS

This paper validates the claims for a seed tender. Implications also show that no supporting activities can take more than 25% of the productivity time, or a drop in field capacity occurs. Challenges on justifying additional economic investment into improving productivity is based on the need for the additional capacity and the cost of owning and operating a seed tender.

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PROCENE PRODUKTIVNOSTI MAŠINA SA UPOTREBOM POKRETNIH REZERVOARA ZA TRANSPORT I PUNJENJE SEMENA

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Sažetak: Tokom prethodnih pet godina predstavljeno je više metoda i mašina koje mogu da unapređe kvalitet i učinak setvenih radova. Proizvođači tvrde da ovi uređaji mogu da povećaju produktivnost za više od 50%, u odnosu na konvencionalne metode. U ovom radu su predstavljene analize poboljšanja sistema za setvu kukuruza i soje, uz primenu pokretnog rezervoara za transport i punjenje semena i drugih sličnih sredstava. Poređenje rada pojedinih mašina analizirano je u odnosu na navedene tvrdnje. Ukoliko su ove tvrdnje tačne, farmeri zaslužuju da znaju uslove pod kojima se navedena poboljšanja mogu očekivati. Rezultati mogu da pomognu farmerima da procene kako bi nabavka ovih uređaja uticala na radni učinak mašine i kako da prepoznaju operacije čija efikasnost može da se poboljša postojećim mašinama. Takođe, ovim su date bolje procene parametara koji su navedeni u preporučenim opsezima u ASABE Standardima.

Ključne reči: *rezervoari za seme, menadžment mašina, parametri menadžmenta, donošenje odluka, produktivnost mašina*

Datum prijema rukopisa: *Paper submitted:*	21.06.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	25.06.2012.
Datum prihvatanja rada: *Paper accepted:*	01.07.2012.

POLJOPRIVREDNA TEHNIKA
✧
Godina XXXVII
Broj 1, jul 2012.
Strane: 93 - 99

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 621.91

Originalni naučni rad
Original scientific paper

ECOLOGY AND WORK QUALITY OF FAN FLAT NOZZLES

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Abstract: Working parameters of fan flat nozzles which affect drop tracks size were the subject of the study. New nozzles and nozzles after laboratory wear were tested. The influence of nozzles wear on drop tracks size were examined. It was found that increase in liquid flow rate results in higher values of mean diameter of drop track. Then increase in working pressure or working speed respectively cause decrease in drop tracks size and reduce merging of drops on spray surface. Increase in wear degree was followed by increased coverage rate. This phenomenon is especially dangerous when using nozzles with a considerable degree of wear for agricultural spray since it ecological threat to the environment. These results can be used in practice, because the conducted experiment explained that nozzle wear degree has influence on ecological characteristics of agricultural spray.

Key words: *wear nozzle, drop tracks, flow rate*

INTRODUCTION

The quality of spraying machine work is affected by several technological, technical and climatic factors, the most important of which include the type of machine, choice of nozzles, appropriate spray parameters, temperature and humidity as well as following the instructions of plant agents producers [3].

It should be noted that nozzle wear degree has a decisive effect on spray quality. Speed wear nozzle depends on their outlet size and nozzle material as well as working time [4]. The consequence of nozzle wear is increase in drops mean diameter. Nozzle wear influences merging degree of drops, which causes drops to flow off the surface of protected plants. Consequently, plant protection agents permeate into underground water

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and contaminate environment [1]. If nozzles generate very small drops, they are drifted away by wind or the liquid evaporates before falling on protected plants.

MATERIAL AND METHODS

The aim of the study was to determine the influence of changes of agricultural nozzles technical condition on ecological characteristics of agricultural spray.

Flat fan nozzles working in laboratory conditions on the stand for accelerated nozzle wear (destructive testing) were taken for evaluation.

Laboratory nozzle wear tests were conducted in the Department of Machinery Exploitation and Management in Agricultural Engineering, Agricultural University in Lublin.

New nozzles (LECHLER 120-03 S) of nominal flow rate 1,17 $l \cdot min^{-1}$ were destroyed by 3 bar pressure. A testing stand with sprayer boom speeds of 5 $km \cdot h^{-1}$ (1,39 $m \cdot s^{-1}$), 7 $km \cdot h^{-1}$ (1,94 $m \cdot s^{-1}$), 9 $km \cdot h^{-1}$ (2,50 $m \cdot s^{-1}$) was used for drop placement on a model surface. The model surface consisted of film strip of the size 100 x10 cm. Measurements were recorded at the pressure of 1 bar (0,1 MPa), 3 bars (0,3 MPa), 5 bars (0,5 MPa). The tests were performed with 5 repetitions.

The nozzles were destroyed to reach 5 i 10% wear rates, which was calculated by comparing changes in liquid flow rate from each nozzle to nominal flow rate. Water solution of kaolin was used for destroying nozzles. 9,8 kg of kaolin were added into 150 l of water [2].

The following ranges of drop track diameter were taken for evaluation:

- < 150 μm,
- 150÷250 μm,
- 250÷350 μm,
- 350÷450 μm,
- > 450 μm.

After drying up of the drops 5 images of the size 5 x 5 cm were scanned from each film strip. The first image was scanned in the nozzle symmetry axis, and then 10 and 20 cm on the left and right sides of such an axis. Drop track diameter, spray coverage degree and number of drops were calculated using the computer program Image Pro+ made by Media Cybernetics.

RESULTS AND DISCUSSION

Fig. 1 shows change in mean diameter of drop track on pattern surface as a function of change in flow rate from nozzle.

Y-axis shows that flow rate values correspond to the flow rate for new nozzles as well as worn nozzles with 2%, 4%, 6%, 8%, 10% of wear degrees. Analysing the tests results (Fig. 1) it was found that with the nominal flow rate nozzles produce drop track which can be qualified as small drop spray and medium drop spray. Increase in flow rate changes classifications of spray drop track. After achieving 10% of nozzle wear degree, nozzles produce drop track which can be qualified as large drop spray. Increase in flow rate and drop spectra have influence on dropping of plant protection agents off plant surfaces, which causes pesticide to permeate into soil and underground water. Also excessive number of drops on plant surface causes drop merging, which deteriorates spray quality and incurs economic loss.

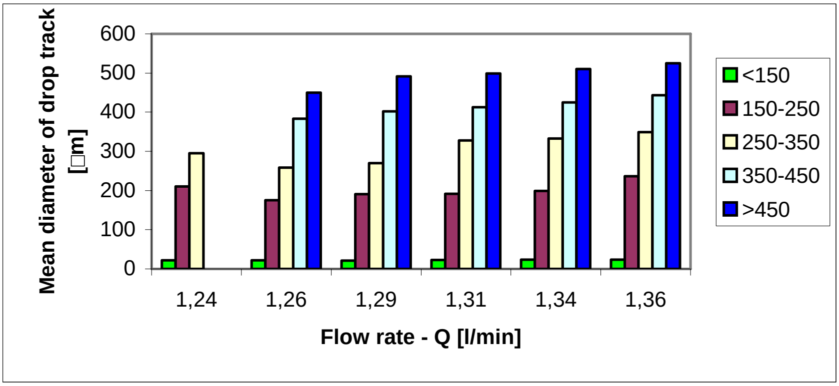

Figure 1. Change of track drop size as a function of flow rate respectively for new nozzles and nozzles of 2%, 4%, 6%, 8%, 10% wear. Nozzles LECHLER 120-03 S

Laboratory investigations of nozzle wear show increase in mean diameter of drop tracks coinciding with increase in flow rate. It is the results of nozzle slit expanding.

Fig. 2 shows graphic interpretation of the results concerning the coverage degree as a function of changes in working pressure and working speed.

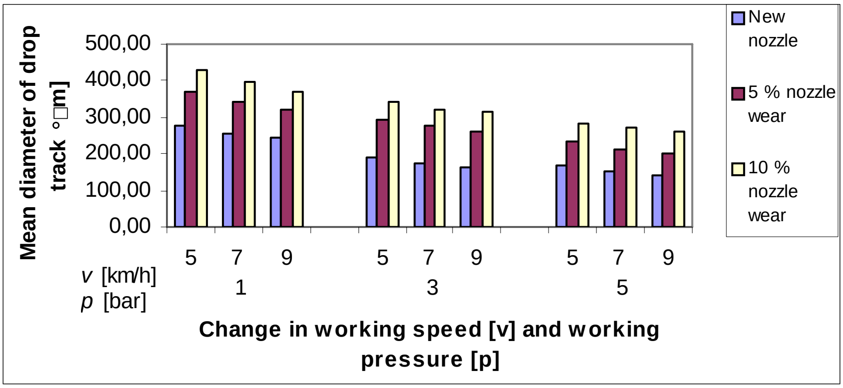

Figure 2. Change in coverage degree as a function of changes in working pressure (respectively for new nozzles and 5% and 10% wear rates). Nozzles LECHLER 120-03 S

Rise in working pressure increases coverage degree. The explanation to this fact is that large pressure causes nozzles to produce small drops in spite of their wear. As a result, worn out nozzles dose large volumes of liquid and consequently, coverage degree also increases. Increase in working speed was found to coincide with decrease in coverage degree.

In order to determine which mean values of drop tracks size differ from each other there was conducted Tukey's test for homogeneous groups in relation to working pressure and working speed. Tukey's confidence intervals confirmed that mean diameter of drop track left on sprayed surface is mainly influenced by change in working pressure (Tab. 1).

Table 1. Division of mean diameter of drop tracks into homogeneous groups in relation to working pressure

Working pressure [bar]	Average	Contrast	Difference	L.S.D. p = 0,05
1	328,26	1-3	55,74*	33,89
3	272,52	1-5	116,59*	
5	211,67	3-5	60,85*	

* – *difference statistically significant*

The test results of coverage degree as a function of changes in working pressure and working speed were presented in Fig. 3.

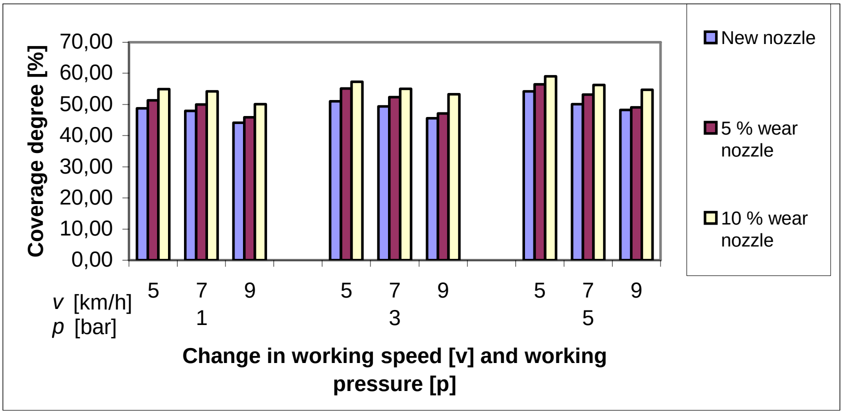

Figure 3. Change in coverage degree as a function of changes in working pressure (respectively for new nozzles and 5% and 10% wear rates) Nozzles LECHLER 120-03 S

A rise in working pressure increases coverage degree. This happens because higher working pressure makes a nozzle produce smaller drops despite its wear. A worn nozzle, in turn, doses a higher volume of liquid, and consequently coverage degree increases. A rise in working speed was found to coincide with a decrease in coverage degree. Statistical analysis revealed that coverage degree of sprayed area is affected by working pressure (Tab. 2) and working speed (Tab. 3).

Table 2. Division of mean values of coverage degree into homogeneous groups in relation to working pressure

Working pressure [bar]	Average	Contrast	Difference	L.S.D. p = 0,05
1	49,59	3-1	2,17*	0,72
3	51,76	5-1	4,06*	
5	53,65	5-3	1,89*	

* – *difference statistically significant*

Table 3. Division of mean values of coverage degree into homogeneous groups in relation to working speed

Working speed [km·h⁻¹]	*Average*	*Contrast*	*Difference*	*L.S.D. p = 0,05*
5	*53,55*	*5-7*	*1,68**	*0,72*
7	*51,87*	*5-9*	*3,98**	
9	*49,58*	*7-9*	*2,30**	

** – difference statistically significant*

Fig. 4 shows graphic interpretation of the results concerning the number of drops per 1 cm^2 as a function of changes in working pressure and working speed.

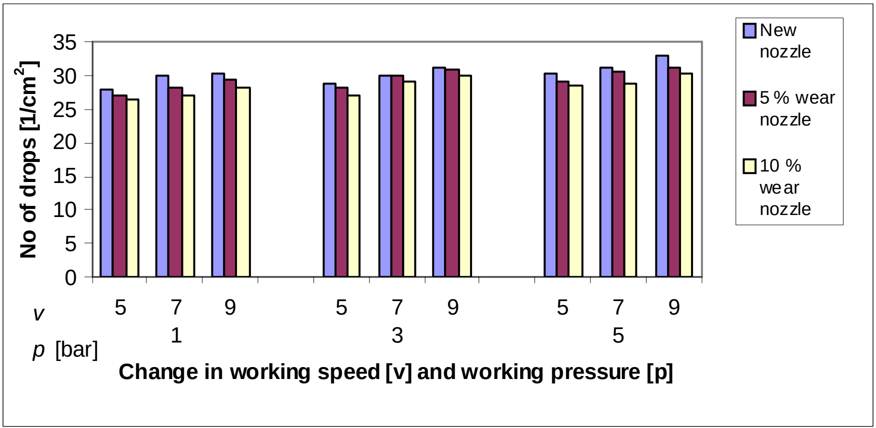

Figure 4. Change in the number of drops per 1 cm^2 as a function of changes in working pressure (respectively for new nozzle and 5% and 10% wear rates). Nozzles LECHLER 120-03 S

In order to determine which mean numbers of drops differ from each other there was conducted Tukey's test for homogeneous groups in relation to working pressure and working speed. Tukey's confidence intervals confirmed that the number of drops generated by nozzles is influenced by working pressure (Tab. 4) and working speed (Tab. 5).

Table 4. Division of mean numbers of drops into homogeneous groups in relation to working pressure

Working pressure [bar]	*Average*	*Contrast*	*Difference*	*L.S.D. p = 0,05*
1	*28,27*	*3-1*	*1,61**	*0,35*
3	*29,87*	*5-1*	*2,86**	
5	*31,12*	*5-3*	*1,25**	

** – difference statistically significant*

Table 5. Division of mean numbers of drops into homogeneous groups in relation to working speed

Working speed [km·h^{-1}]	*Average*	*Contrast*	*Difference*	*L.S.D. p = 0,05*
5	*28,51*	*7-5*	*1,35**	*0,35*
7	*29,86*	*9-5*	*2,38**	
9	*30,89*	*9-7*	*1,03**	

** – difference statistically significant*

CONCLUSIONS

The investigation confirmed the influence of nozzle wear on spray ecological characteristics. Increase in nozzle wear degree causes changes in track size left on spray surface. In this case it must be taken into consideration that large drop spray has limited effectiveness, for example in relation to fungi diseases, and at the same time drops flow off protected plant onto ground surface. Increase in nozzle wear causes rise in coverage degree. This relation results from generating drops by worn nozzles which leave tracks with larger diameter. Increase in working speed causes decrease in coverage degree. These results can be used in practice, because the conducted experiment explained that nozzle waer degree has influence on ecological characteristics of agricultural spray.

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EKOLOGIJA I KVALITET RADA LEPEZASTIH MLAZNICA

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Sažetak: Predmet ovog istraživanja bili su radni parametri lepezastih mlaznica koji utiču na dimenzije mlaza. Ispitivane su nove mlaznice i korištene mlaznice posle habanja u laboratoriji. Ispitivan je uticaj pohabanosti mlaznica na dimenzije mlaza. Rezultati su pokazali da povećanje protoka tečnosti dovodi do povećanih vrednosti srednjeg prečnika mlaza. Zatim, povećanje radnog pritiska i radne brzine uzrokuju smanjenje dimenzija mlaza i smanjuju lepljenje kapljica na tretiranoj površini. Veći stepen habanja bio je praćen povećanjem stepena preklapanja. Ova pojava je posebno opasna pri korišćenju jako pohabanih mlaznica za prskanje poljoprivrednih površina, jer predstavlja ekološku pretnju životnoj sredini. Ovi rezultati se mogu upotrebiti u praksi, obzirom da je izvedeni ogled objasnio uticaj stepena pohabanosti mlaznica na ekološke karakteristike poljoprivrednih prskalica.

Ključne reči: *habanje mlaznice, putanja kapljice, protok*

Datum prijema rukopisa:
Paper submitted: 28.06.2012.
Datum prijema rukopisa sa ispravkama:
Paper revised:
Datum prihvatanja rada:
Paper accepted: 02.07.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 101 - 109

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 621.36

Originalni naučni rad
Original scientific paper

NITROUS OXIDE AND CARBON DIOXIDE CONCENTRATION IN FARROWING PENS WITH PERMANENT LIMITED RANGE OF MOTION FOR LACTATING SOWS

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Abstract: Nitrous oxide (N_2O) and carbon dioxide (CO_2) are two of the most important gases causing global warming. Production of mentioned gases is pig housing considerable. The aim of the paper was a comparison of the N_2O and CO_2 concentration in the different places in pig barn. Measurements were done in the Experimental Centre for Livestock of Department of Animal Husbandry in FAaFR, SUA in Nitra, Slovakia, where sows of Large White breed with their piglets were housed. There were individual farrowing pens with permanent limited range of motion for lactating sows. Samples of air were collected in each pen both in sow zone and piglets zone. The photo acoustic field gas system consisted of INNOVA devices (photo acoustic field gas-monitor INNOVA 1412 and multipoint sampler INNOVA 1309). There were used for measurement of the gases concentration. Data were analysed by using Kruskal-Wallis Test after normality test by using Kolmogorov-Smirnov test and homogeneity of variance by using Levene's test. Used software was SAS® 9.2. Average values of N_2O and CO_2 concentration ranged from 0.51898 to 0.52106 ppm and from 515.293 to 519.580 ppm, respectively. Data have shown no statistically significant differences between N_2O and CO_2 concentration in the zones of lactating sows and piglets at the 95.0% confidence level. Air circulation between the zones of lactating sows and piglets in the pig barn was on the sufficient level.

Key words: *lactating sow, piglets, farrowing pens, limited motion, nitrous oxide, carbon dioxide*

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This paper was prepared with the support of research project VEGA No. 1/0609/12 of the Slovak Grant Agency for Science

INTRODUCTION

Agriculture contributes significantly to total greenhouse gases (GHGes) emissions [1, 2, 15]. Approximately 20 and 35 % of the global greenhouse gas (GHG) emissions originate from agriculture [3]. Livestock is the source of many pollutants such as gases, odors, dust and microorganisms. In the livestock buildings were found 136 gases [4]. Ventilation systems reduce and control dust concentration in pig houses [5, 6].

Agriculture in general, and livestock production in particular, contribute to global warming through emissions of the GHGes: nitrous oxide (N_2O) and carbon dioxide (CO_2). Air pollution is the third largest threat to our planet after biodiversity loss and climate change (most affected by CO_2).

Global atmospheric concentration two of these the most important greenhouse gases have increased significantly within the last 150 years [3] and it affects the atmospheric environment – increased GHG emissions [7].

Nitrous oxide is related to the nitrogen (N) cycle with chemical fertilizers and manures as the most important sources. Nitrous oxide production only takes place under specific conditions since it results from combined aerobic and anaerobic processes nitrification and denitrification, respectively. Normally, conditions in manure are strictly anaerobic and nitrification and denitrification processes will not occur [1]. Most of the N_2O is produced in the field (manure excreted during grazing, animal manure and chemical fertilizers applications to land), and from animal houses where straw or litter is used [8, 9]. Nitrous oxide warming potential is 290 to 310 times higher in the comparison with carbon dioxide warming potential [10]. Carbon dioxide can usually estimate that livestock production is compensated by photosynthesis of plants used as feed [11].

Carbon dioxide emissions differ from one rearing system to another, e.g. weaning and fattening pigs [2, 12-15]. Gases, especially CO_2, production by animals and waste are an essential parameter for ventilation rate estimation using a mass balance method [16]. Methods of manure removal affect the production of harmful gases in the evaluated barns for fattening pigs [17].

The process of releasing GHG into the atmosphere depends on methods of livestock husbandry, nutrition conditions, manipulation with slurry and manure and its storage and land application [18], number and weight of animals, type and time of manure removal, temperature in barn, moisture, pH reaction of litter, C:N ratio, etc. Type and power of the ventilation system significantly affects gas concentration in the pig building [19, 20]. The gaseous emissions from livestock houses are thus dependent on the housing and on the floor systems [14].

The aim of our research was a comparison of the CO_2 and N_2O concentration in the different places in pig barn in the zones of lactating sows and piglets.

MATERIAL AND METHODS

Research place

Measurements were done in the Experimental Centre for Livestock of Department of Animal Husbandry of Faculty of Agrobiology and Food Resources of the Slovak

University of Agriculture in Nitra, Slovakia. Pigs were housed in farrowing pens with permanent limited range of motion of lactating sows (Fig. 1).

Figure 1. Farrowing pens with permanent limited range of motion for lactating sows

Animal characteristics

Sows of Large White breed with their piglets were used in the experiment. Basic characteristics of pigs are shown in the Tab. 1.

Table 1. Basic characteristic of lactating sows and piglets

Sample point	*Sow weight (kg)*	*Piglets age (days)*	*Piglets weight range (kg)*	*Average piglet weight (kg)*	*Order of farrowing*	*Number of piglets (pcs)*
1	*303*	*8*	*1.26 – 2.69*	*1.99*	*5*	*14*
2	*333*	*15*	*2.35 – 7.50*	*6.03*	*4*	*6*
3	*304*	*14*	*3.97 – 5.06*	*4.62*	*3*	*9*

Samples of air were collected in each pen both in sows zone and piglets zone.

Measuring devices

Devices of INNOVA (LumaSense Technolgies, Inc., Denmark) were used for measurement of the gases concentration [21, 22].

Measuring system consist of three main parts:

- INNOVA 1412 – Photoacoustic field gas-monitor. Measurement system is based on the photoacoustic infrared detection method. Gas selectivity is achieved through the use of optical filters. Detection limit is typically in the ppb (part pre bilion) region.
- INNOVA 1309 – multipoint sampler. This devices is a 12 channel multiplexer, enabling gas samples to be drawn from up to 12 different sampling locations and delivered to the gas monitor INNOVA 1412.
- Third main part is computer with software supplied by manufacturer where data were saved.

Statistical analysis

Data were analyzed by using Kruskal-Wallis Test after normality test by using Kolmogorov-Smirnov test and homogeneity of variance by using Levene's test. Used software was SAS ® 9.2 (SAS Institute, Inc.; Cary; North Carolina, USA).

Graphic processing of results was performed using software STATISTICA 7 (Statsoft, Inc.; Tulsa, Oklahoma, USA).

The Kruskal-Wallis test tests the null hypothesis that the medians within each of the six samples are the same. Since the P-Value is greater than or equal to 0.05, there is not a statistically significant difference amongst the medians at the 95.0 % confidence level.

RESULTS AND DISCUSSION

There were monitoring three farrowing pens with permanent limited range of motion in the same barn. Samples of air were collected in each pen both in **L**actating **S**ow **Z**one (**LSZ**, number) and **P**iglets **Z**one (**PZ**, number).

Nitrous oxide

Table 2. Summary statistics of N_2O concentration for all sampling places

Sampling place	*Sample size*	*Average (ppm)*	*Standard deviation*	*Minimum (ppm)*	*Maximum (ppm)*	*Range (ppm)*
LSZ1	*248*	*0.518977*	*0.0432896*	*0.425695*	*0.674368*	*0.248673*
LSZ2	*248*	*0.521060*	*0.0397523*	*0.438490*	*0.661470*	*0.222980*
LSZ3	*248*	*0.520767*	*0.0403427*	*0.424323*	*0.635510*	*0.211186*
PZ1	*248*	*0.520834*	*0.0413241*	*0.422859*	*0.704919*	*0.282061*
PZ2	*248*	*0.520576*	*0.0421729*	*0.423914*	*0.641467*	*0.217553*
PZ3	*248*	*0.519975*	*0.0421712*	*0.428340*	*0.631028*	*0.202688*

Average of N_2O concentration ranged from 0.51898 to 0.52106 ppm (Tab. 2). The P-Value in the Kruskal-Wallis test is greater than 0.05 (P-Value = 0.991333) (Table 3). There is not a statistically significant difference among the medians of N_2O concentration in the three farrowing pens in the zones of lactating and piglets at the 95.0 % confidence level.

Table 3. Kruskal-Wallis test of N_2O concentration for all sampling places

Sampling place	Sample Size	Average Rank
LSZ1	248	727.024
LSZ2	248	748.387
LSZ3	248	749.373
PZ1	248	750.667
PZ2	248	746.841
PZ3	248	744.728

Test statistic = 0.521028,   P-Value = 0.991333

Differences in the range between the minimum and maximum values are relatively high. It could be cause by the outlier values, especially in the first piglet zone and in the first and second lactating sow zones (Fig. 2).

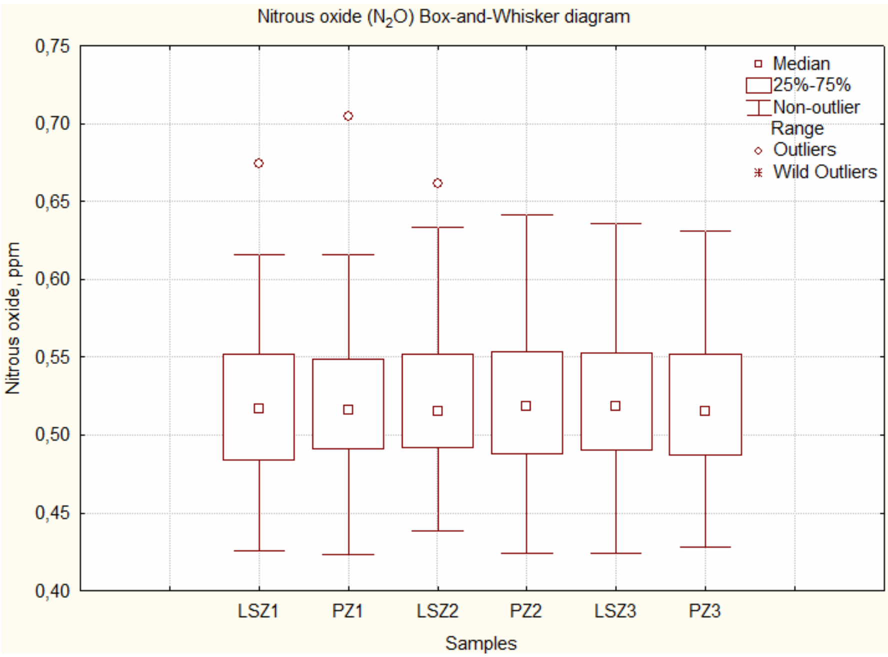

Figure 2. Box-and-Whisker plot of N_2O concentration for all sampling places

Carbon dioxide

Average of CO_2 concentration ranged from 515.293 to 519.580 ppm (Tab. 4). The P-Value in the Kruskal-Wallis test is greater than 0.05 (P-Value = 0.989537) (Tab. 5). There is not a statistically significant difference among the medians of CO_2 concentration in the three farrowing pens in the zones of lactating sows and piglets at the 95.0 % confidence level.

Table 4. Summary statistics of CO_2 concentration for all sampling places

Sampling place	Sample Size	Average (ppm)	Standard deviation	Minimum (ppm)	Maximum (ppm)	Range (ppm)
LSZ1	248	515.293	75.6973	329.270	662.563	333.293
LSZ2	248	517.817	74.1871	338.775	659.284	320.509
LSZ3	248	518.303	75.9395	331.052	659.448	328.396
PZ1	248	515.397	75.2527	337.468	642.123	304.654
PZ2	248	517.553	74.5180	322.925	667.537	344.611
PZ3	248	519.580	75.4791	334.014	663.164	329.150

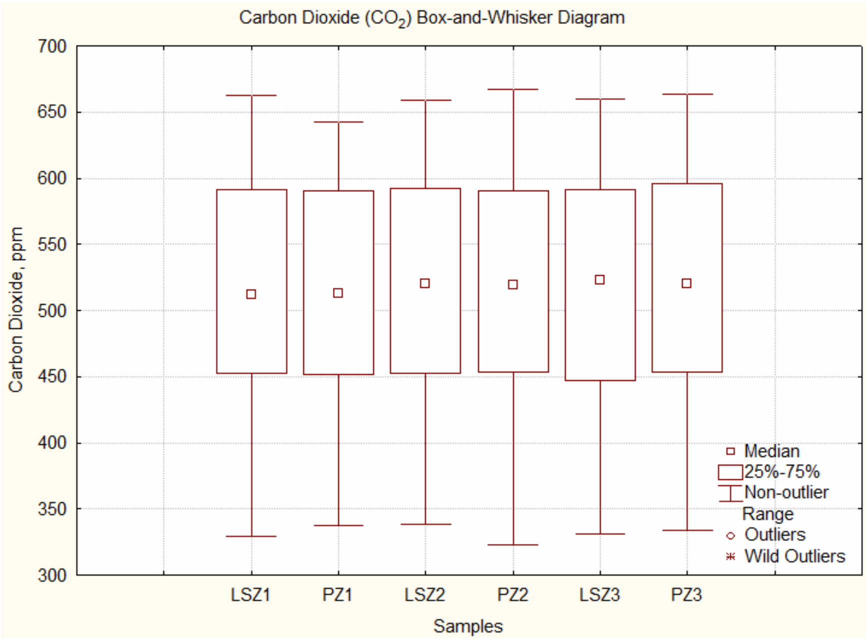

Figure 3. Box-and-Whisker plot of CO_2 concentration for all sampling places

Lowest and highest ranges of values were measured in the first and second piglets zones, respectively. It could be cause by the activity of piglets, because it was in the pens where piglets had a different age and weight (Tab. 1).

Table 5. Kruskal-Wallis test of CO_2 concentration for all sampling places

Sampling place	Sample Size	Average Rank
LSZ1	248	734.060
LSZ2	248	747.117
LSZ3	248	748.679
PZ1	248	734.093
PZ2	248	745.179
PZ3	248	757.871

Test statistic = 0.565285, P-Value = 0.989537

CONCLUSIONS

The aim of our evaluation was a comparison of the nitrous oxide and carbon dioxide concentrations in the zones of lactating sows and piglets in the farrowing pens. Pigs were housed in farrowing pens with permanent limited range of motion. Sows of Large White breed with their piglets were used in the experiment. Three farrowing pens in the same barn were monitored. Air samples were collected in each pen both in lactating sows zone and piglets zone. Average values of greenhouse gases ranged from 0.51898 to 0.52106 ppm and from 515.293 to 519.580 ppm for nitrous oxide and carbon dioxide, respectively. There was used Kruskal-Wallis test. The P-Values in the Kruskal-Wallis test for nitrous oxide and carbon dioxide were 0.991333 and 0.989537, respectively. P-Value for each gas were greater than 0.05. There is not a statistically significant difference among the medians of N_2O and CO_2 concentration in the three farrowing pens with permanent limited range of motion in the zones of lactating sows and piglets at the 95.0 % confidence level. Differences in the range between the values of N_2O gas were relatively high. It could be caused by the outlier values, especially in the first piglets zone and in the first and second lactating sows zones. Lowest and highest ranges between the values of CO_2 gas were measured in the first and second piglets zones. It could be caused by the activity of piglets, because piglets had a different age and weight. Based on our results, air circulation between the zones of lactating sows and piglets in the pig barn was on the sufficient level.

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KONCENTRACIJA N_2O I CO_2 U BOKSOVIMA ZA PRAŠENJE SA STALNO OGRANIČENIM PROSTOROM ZA KRETANJE KRMAČA U LAKTACIJI

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Sažetak: N_2O i CO_2 su dva najvažnija gasa koji izazivaju globalno zagrevanje. Produkcija pomenutih gasova u objektima za svinje je značajna. Cilj ovog rada bilo je poređenje koncentracija N_2O i CO_2 na različitim mestima u objektu za svinje. Merenja su izvršena u eksperimentalnom Centru za stočarstvo Departmana za stočarstvo na FAaFR, SUA kod Nitre u Slovačkoj, gde se drže krmače rase Large white sa prasadima. Objekti za prašenje su opremljeni pojedinačnim boksovima za prašenje sa stalno ograničenim prostorom za kretanje krmača u laktaciji. Uzorci vazduha su uzimani u svakom boksu i u obe zone: zoni krmača i zoni prasadi. Foto akustični system se sastoji od uređaja INNOVA (foto akustični monitor gasova INNOVA 1412 i višekanalni sempler INNOVA 1309). U ovom slučaju uređaj je upotrebljen za merenje koncentracije gasova. Podaci su analizirani upotrebom Kruskal-Wallis testa, posle testa normaliteta upotrebom Kolmogorov-Smirnov testa i homogenosti varijanse upotrebom Levene testa. Korišćen je programski paket SAS® 9.2. Srednje vrednosti koncentracija N_2O i CO_2 nalazile su se u intervalima od 0.51898 do 0.52106 ppm i od 515.293 do 519.580 ppm, redom. Rezultati su pokazali da nema statistički značajnih razlika među koncentracijama N_2O i CO_2 u zonama krmača i zonama prasadi, pri nivou poverenja od 95.0%. Strujanje vazduha između zona krmača i prasadi u objektu bilo je zadovoljavajuće.

Ključne reči: *krmača u laktaciji, prasad, boksovi za prašenje, ograničeno kretanje, N_2O, CO_2*

Datum prijema rukopisa: *Paper submitted:*	12.04.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	
Datum prihvatanja rada: *Paper accepted:*	16.04.2012.

POLJOPRIVREDNA TEHNIKA
Godina XXXVII
Broj 1, jul 2012.
Strane: 111- 117

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 662.756.3

Originalni naučni rad
Original scientific paper

BIOGAS YIELD FROM ANAEROBIC BATCH CO-DIGESTION OF SISAL PULP AND ZEBU DUNG

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Abstract: Co-digestion of various materials has been shown to improve the digestability of the materials and biogas yield. The degradation and biogas production potential of sisal pulp could be significantly increased by co-fermenation with zebu dung. Batchwise anaerobic digestion of sisal pulp and zebu dung was studied both with the wastes separately and with mixture in various proportions. While the highest methane yields from sisal pulp and zebu dung alone were 1.8 and 88 l $CH_4 \cdot kg^{-1}$ volatile solids (VS), co-digestion with 80% of sisal pulp and 20% zebu dung gave 173 l $CH_4 \cdot kg^{-1}$ VS. All experiments were carried out at total solids (TS) of 5%.

Key words: *sisal pulp, zebu dung, anaerobic co-digestion,*

INTRODUCTION

With today's energy-demanding lifestyles, the need to explore and exploit new energy sources that are renewable and ecologically sound is mandatory. In most developing countries, agro-industrial residues are available in abundance. Through anaerobic digestion and biogas production, these have very great potential in catering for the energy demand, especially in the small-scale or local energy sector. The biogas from sisal pulp, a waste product of the sisal industry, is of great interest as a renewable energy carrier that could be used for cooking and/or power generation [1]. Currently, the material has no specific technical application and creates huge disposal and ecological problems. Sisal is mainly grown on large estates (several thousands of hectares), with a central factory in the middle of the estate. Between the age of 2 and 4 years, the plant is

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ready for its first cutting and further cuttings occur at 12-monthly intervals. After cutting, the leaves are transported to the central factory (decorticator) where the fibre is extracted from the leaf and the sisal waste is ‘‘produced’’. After decortication, the fibre is dried, brushed and packed for export or as basic material for sisal-based products. According to some decortication tests [2], 19 tones of sisal waste are produced for every tone of dry sisal fibre.

Table 1. Global sisal fibre production in kilo tons (2001 – 2007) [1]

	2001	2002	2003	2004	2005	2006	2007
Africa	**64**	**59**	**60**	**68**	**68**	**71**	**78**
Tanzania	24	24	24	27	28	31	37
Kenya	23	22	25	27	26	26	28
Madagascar	12	8,4	8,6	10	10	10	10
South Africa	2	2	2	2	2	2	2
Mozambique	1	1	1	1	1	1	1
Angola	1	1	1	1	1	1	1
Ethiopia	1	1	1	1	1	1	1
L. America	**141**	**151**	**155**	**153**	**133**	**139**	**127**
Brazil	127	138	142	140	119	126	113
Mexico	35	35	35	35	27	27	27
Venezuela	11	11	11	11	11	11	11
El Salvador	7	7	7	7	7	7	7
Haiti	2	2	2	2	2	2	2
Jamaica	0.3	0.3	0.3	0.3	0.3	0.3	0.3
China	**37**	**38**	**35**	**35**	**35**	**35**	**35**
Total	**241**	**248**	**250**	**255**	**236**	**246**	**241**

Estimated global sisal fibre production exedeed 241 kilo tons in year 2007 (see Table 1). It is estimated that global sisal waste procuction is aproximately 4500 – 5000 kilo tons of sisal pulp annualy (see Table 2) which is alignocellulosic short fibre residue, composed of 62% cellulose, 16% pentosans, 12% hemicellulose and 8% lignin on a dry weight basis [3]. A large part (40–50%) of the total solids in sisal fibres consists of biofibres. Biofibres can only be partially degraded during the biogas process [4]. Owing to a lack of feasible conversion technologies, the use of sisal fibre waste for renewable energy production has not become a practical technical option yet.

Currently, this waste is mainly landfilled and dumped in nearby rivers or in fields, where microorganisms degrade it. As a result, the untreated waste cause a consumption of oxygen in the recipient watercourses which leads to oxygen-deficient water zones with a negative effect on fish and other living organisms. In the anaerobic part of the degradation process, methane is produced and emitted into the atmosphere. Methane has a global warming potential that is 21–56 times higher than that of carbon dioxide, and is estimated to contribute to 18–21% of the overall global warming [1,5,6].

Table 2. Estimated global sisal waste generation in kilo tons (2001 – 2007) [1]

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Africa	**1210**	**1121**	**1142**	**1286**	**1288**	**3308**	**1490**
Tanzania	447	448	454	509	528	587	701
Kenya	209	420	475	505	486	502	524
Madagascar	228	160	122	181	181	175	173
South Africa	32	30	30	30	30	30	30
Mozambique	19	19	19	19	19	19	19
Ethiopia	13	13	13	13	13	13	13
Angola	10	10	10	10	10	10	10
L. America	**2673**	**2871**	**2945**	**2901**	**2529**	**2643**	**2419**
Brazil	2419	2624	2698	2654	2263	2385	2153
Mexico	665	665	665	665	494	494	494
Venezuela	209	200	200	200	200	200	200
El Salvador	124	124	124	124	124	124	124
Haiti	40	40	40	40	40	40	40
Jamaica	6	6	6	6	6	6	6
China	**703**	**722**	**665**	**665**	**665**	**665**	**665**
Total	**4587**	**4714**	**4752**	**4853**	**4482**	**6616**	**4573**

MATERIAL AND METHODS

The sisal pulp used in the experiment was collected from a sisal-processing factory at Fort Dauphin, Madagascar. Sisal pulp was reduced to 1-5mm particle size by hand mixer. Zebu dung was collected at farm in Vyškov, Czech Republic. Inoculum used in experiment was collected at biogas plant Zemědělská stanice Krásna Hůrka, Czech Republic. Composition of sisal pulp and zebu dung is shown in Table 3. All materieals were stored at 4°C until used.

Table 3. Composition of sisal pulp and zebu dung

	Sisal	Zebu dung	inoculum
TS	16.60%	18.14%	7,50%
pH	4.39	9.1	7.8
C/N	45	14.6	
VS [% of TS]	87.5	86	
COD [$g \cdot kg^{-1}$]	60	160	

The experimental set-up consist of 7 anaerobic digesters, using wide-mouth 1.25 l Erlenmeyer flasks whitch had a working volume 0.9l. Each bioreactor was connected by silicon tubes with 15l plastic flasks for collecting biogas. Biogas was measured by amout of water displaced from 15l plastic flasks filled with solution of destiled water, H_2SO_4 (0.06 ml per l) and NaCl (10.2 $g \cdot l^{-1}$) in order to prevent disolving CO_2 into water. Bioreactors were mixed by hand shaking 2 times per day for 1 minute. The amout of biogas was measured minimum once per day. In order to keep the constant temperature at 30°C, the bioreactors were placed in waterbath. Measured pH at the beginning of the experiment ranged from 4.66 up to 9.1 (listed in Table 4) and there was not used any method to change pH to optimal range for anaerobic digestion (6.5 - 7.5). Methane content was measured by gas monitor EX2000C.

RESULTS AND DISCUSSION

The yield of methane from digestion of sisal pulp, zebu dung and co-digestion of sisal pulp and zebu dung in various concentratios is depicted in Table 4. The average CH_4 content of biogas produced from zebu dung alone was 59% and from digestion of sisal pulp the biogas content was 29%. The average CH_4 content of biogas produced from co-digestion of sisal and zebu dung ranged from 48% (60:80; sisal pulp : zebu dung) up to 61% (80 : 20). Interestingly, the best results were obtained from the mixture with ratio 40:60 and 80 : 20.

Table 4. Parameters of anaerobic co-fermetation of sisal and zebu dung

Fermentor	*Sisal:Zebu [%]*	*Sisal TS [g]*	*Zebu TS [g]*	*Inoculum TS [g]*	*pH start [-]*	*pH end [-]*	*Metan [%]*	*CH_4 [l $CH_4 . kg^{-1}$ VS]*
1	*20:80*	*5*	*20*	*22.5*	*7.51*	*7.3*	*53*	*144.4*
2	*40:60*	*10*	*15*	*22.5*	*6.2*	*7.54*	*52*	*170.8*
3	*60:40*	*15*	*10*	*22.5*	*5.48*	*5.91*	*48*	*48.7*
4	*80:20*	*20*	*5*	*22.5*	*4.66*	*4.9*	*61*	*173.3*
5	*0:100*	*0*	*25*	*22.5*	*9.1*	*7.44*	*59*	*88.4*
6	*100:0*	*20*	*0*	*22.5*	*4.39*	*7.3*	*29*	*1.8*
7	*inoculum*	*0*	*0*	*22.5*	*7.8*	*7.83*	*38*	

According to the results of the study higher content of sisal in fermented mixture increases the production of biogas and slightly increases the content of CH_4 in biogas. There can be found trend in the intial values of pH with regards to the sisal pulp content. Sisal pulp itself had at the beginning of the experiment pH 4.39. When increasing the content of zebu dung, the initial pH also increased accordingly.

Generally, the trend is as follows. With the increasing content of sisal pulp in the mixture, the amount of produced biogas increases up to the ratio of sisal 80:20, which lead to the production of 173.3 litres of CH_4 per kg of VS added. With the increasing amount of biogas produced in the higher percentage mixtures of sisal pulp also increases the % of CH_4 in biogas; the best result was 61% of CH_4 produced in the mixture of 80:20.

Interrestingly, the fermentor 3 with ratio of sisal:zebu dung (60:40) had shown different results than the established trend of other fermentations. The initial very fast and high biogas production stopped after 69 hours of fermentation. Fermentor 4 with ratio of sisal : zebu dung (80:20) had shown fast and high biogas production as well.

When looking at the pH values at the end of the experiment, one can observe that the values for fermentor 3 and fermentor 4 are slightly lower than the rest of the end pH values. The reason for this might be unwanted acidification of the fermentation mixture that lead to the premature stop of the process of fermentation compared with the other fermentors.

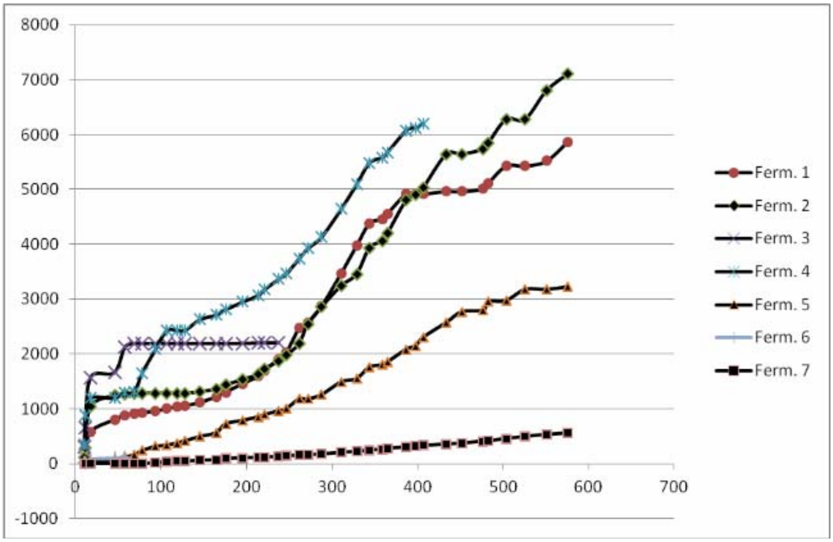

Figure 1. Amount of biogas in ml

First fermentor where the premature stop of the fermentation occurred was fermentor 3 which ended fermentation process after only 69hours of fermentation (see Figure 1 for details). The end pH of fermentor 3 was 5.91, whereas the fate of fermentor 4 was slightly more dramatic.

After 407 hours of fermention in fermentor 4, the inhibition of fermentation reaction occured and pH droped to 4.9. The fermetation process stoped. We would like to prevent this occurrence in the future experiments by stabilising pH at the beginning of the experiment to pH 7.0.

The experiement with anaerobic fermentation of pure sisal pulp shown very low biogas production 1.8 CH_4 per 1kg VS added with the methane content of 29% only. The probable cause of this is the high content of fibre and lignocellulose that requires hydrolysis in anaerobic conditions.

The results suggest that the optimal ratio of mixture of sisal pulp and zebu dung was between 60 : 40 to 80 : 20. Further exeperiments to verify this trend will be held. Although the amout of biogas produced by all bioreactors during the experiement was much lower than reported in literature[8], we believe that the future adjustments of this methodology can surely yield higher amounts of biogas produced.

CONCLUSIONS

This study has shown that anaerobic co-digestion of sisal and zebu dung is feasible process. Furthermore, the anaerobic co-digestion of sisal pulp and zebu dung is a viable alternative for recovering energy in the form of biogas with 48 - 61% methane content, while at the same time abating environmental pollution. The observations have shown that co-digestion of sisal pulp and zebu dung enhances anaerobic digestion and improve the biogas yield. The highest amout of biogas (173.3 l $CH_4 \cdot kg^{-1}$ of VS) was produced by bioreactor filled with 80% sisal pulp and 20% zebu dung at 5% of TS with highest content of methane as well (61% of CH_4). The sisal industry produce globaly over 4500 kilotons of sisal waste that can be use for biogas production. This can help to improve the economy of sisal producer and reduce ecologial and disposal problems of sisal industry. The batch anaerobic co-digestion can be applied in developing countries where low and cheap technology is needed in any cases.

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PRODUKCIJA BIOGASA PRI ANAEROBNOJ FERMENTACIJI MEŠAVINE USITNJENE MASE SISAL AGAVE I TEČNOG STAJNJAKA ZEBU GOVEDA

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Sažetak: Zajednička fermentacija različitih materijala je upotrebljena kako bi se poboljšala razgradivost materijala i povećala produkcija biogasa. Razgradivost i potencijal pulpe sisal agave za proizvodnju biogasa mogu se značajno povećati njenim mešanjem sa tečnim stajnjakom zebu goveda i fermentacijom dobijene smese. Anaerobna fermentacija pulpe sisala i zebu stajnjaka proučavana je posebno na ovim materijalima pojedinačno i na njihovim smesama u različitim odnosima. Najveće dobijene količine metana pojedinačno iz sisal pulpe, odnosno zebu stajnjaka, iznosile su 1.8 i 88 l $CH_4 \cdot kg^{-1}$ (redom) isparene suve materije (VS), dok je pri fermentaciji smese sa 80% sisal pulpe i 20% zebu stajnjaka dobijeno 173 l $CH_4 \cdot kg^{-1}$ VS. U svim ogledima je korištena masa sa 5% ukupne suve materije (TS).

***Ključne reči**: pulpa sisal agave, tečni stajnjak zebu goveda, anaerobna ko-fermentacija*

Datum prijema rukopisa: *Paper submitted:*	10.06.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	12.06.2012.
Datum prihvatanja rada: *Paper accepted:*	22.06.2012.

POLJOPRIVREDNA TEHNIKA
✧
Godina XXXVII
Broj 1, jul 2012.
Strane: 119 - 126

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 338.434

Originalni naučni rad
Original scientific paper

MECHANISATION AND LOGISTICAL COST OF THE FIELD VEGETABLE PRODUCTION TECHNOLOGIES

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Abstract: The economic investigation of field vegetable production is introduced by using the production technology of the most important vegetables: sweet corn, green peas, onion, tomato, carrot and cucumber as examples. The paper aims to promote the popularization of the modern technology of field vegetable production by reviewing production technology and providing useful pieces of information on the operational and economic figures of the machines necessary for production.

The investigations prove that the machine operation costs of field vegetable production are higher than the cost of cereals and oil seeds production. In addition to that the annual utilization level of special harvesters is very low and there are few opportunities to increase it. It is because of the fact that vegetables are produced on smaller territory of land and there is low demand for machine work rent.

Key words: *mechanization, logistics, field vegetable production technology, machine investments and usage costs*

INTRODUCTION

Onion is a very important vegetable that plays a very significant role in human nutrition. Seed-grown vegetable onion is gradually gaining ground on the traditional onion set production method. In our present days there are good seed-grown species available for farmers. These species can provide good quality products and can be stored well. In addition to that lands can be irrigated well and there are good herbicides available, therefore this production method can be applied safely [4].

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Tomato is one of the most popular vegetables in the world, produced on very large lands. Canning tomato is a very significant vegetable in Hungary as well, traditionally produced on a very large land, by transplanting or direct seeding methods.

Root vegetables and also *carrot* is a very important vegetable for fresh consumption as well as for the deep freezing and for the canning industry. Due to the many different ways of its use, different methods are applied in *root vegetable* production. Early spring vegetables are offered in bundles, later on washed, defoliated ones are offered for fresh consumption. The late varieties are produced either for prompt procession for the canning industry or for long term storage. In accordance with the growing methods there is a wide selection of varieties and different production technologies are applied [2].

The *cucumber* is one our most important vegetable crops, not only the Hungarian consumption but the exported quantity is also remarkable. The annual demand of the canning industry for 6-9 cm and 9-12 cm calibrated cucumber is generally 50-60.000 tons. Though the picking of smaller size-fractions (under 6 cm) reduces the quantity of crop the revenues can be increased notably due to the higher price of this fraction.

The most important link in the chain of production and distribution is the solid inland processing industrial background which is inevitable for the export of fresh produce as well.

MATERIAL AND METHODS

Apparently, the machine working time necessary for the cultivation of the 20 or 100 hectare growing area in case of connected machines has been stipulated related to the individual operations [3]. On this basis the direct operational cost of the connected machines can easily be calculated by multiplying the *direct operational cost of the machine per hour* with the effective working time. Furthermore, the additional cost of connected machines has also been stipulated which is affected by the capital return on fixed and current assets as well as by the general costs of farming. As a result the cost of the individual operations related to 20 or 100 hectare growing area has been defined the total of which equals the total production costs onion and canning tomato production for 100 hectares and root vegetables and cucumber production on 20 hectares and also the specific cost per hectare has been stipulated.

RESULTS AND DISCUSSION

Economic and logistical investigations of onion and tomato production on 100 hectares

The results show that the operation costs of working machines for *onion production* are less than half (25.764 EUR) of that of tractors (47.903 EUR), while the total machine operation cost is 73.667 EUR. Its value per hectare is 736 EUR [9].

It is important to state that the transport of onion during the harvest required a low capacity, only 600 operating hours. It is because of the fact that in this case the crop was transported to the storage of the farm and not to the plant of the processing company which can be even 100 km away from the place of harvest. In that case road transport would be required which is much more costly.

However the machine operation costs of crop transport add up to 30 percent of the total machine operation costs of onion production. It is followed by picking-up (13 percent) and the proportion of other operations to total costs is less than 10 percent, and does not exceed 1 percent in some cases.

The investment costs of machines used in this *onion production technology* are 601.949 EUR, of which 382.686 EUR is the cost of working machines (64 percent of the total) and 219.263 EUR is the costs of tractors (36 percent of the total). Soil cultivation tasks require a tractor with a power of 140 kW while nutrient supply, plant protection, sowing and harvest require two tractors with a power of 65-70 kW. That results in relatively low investment costs and high tractor efficiency. The total time of machine operation of onion production on 100 hectares is 2.064, of which the tractor with the higher power has a significant part during soil cultivation and harvest, but the operation time of the two smaller tractors is also significant during plant protection and harvest.

The *technology of canning tomato production* is different from the onion technology in the use of the self-propelled harvester. Another difference is that the crop after the harvest is directly transported to the processing company on road which means extra work and additional costs.

The operation costs of working machines used in this tomato production technology is 19.876 EUR (15 percent of total machine operation costs) and the operation costs of tractors are 125.772 EUR (85 percent). The total machine operation cost is 145.648 EUR, while its value per hectare is 1456 EUR [6].

The capacity need of transport during tomato harvest is very high, 2500 operating hours, since in this case crop was directly transported with vehicles of 15 tons of capacity to the processing company which was 80 km away from the place of harvest. Our calculations show that the crop of one hectare requires four turns from transport vehicles. The time of one turn is about 6 hours which means that 4 turns require about 25 hours.

Not surprisingly, 43 percent of the total costs are related to crop transport. It is followed by harvest (25 percent) and the proportion of other operations of the technology is under 4 percent, even under 1 percent in some cases.

The total investment cost of machines in this *canning tomato production technology* is 694.024 EUR of which the cost of working machines is 297.996 EUR (43 percent) and the cost of tractors is 396.027 EUR (57 percent). In this case the investment cost of the self-propelled harvester significantly increases the costs of machines. Despite the fact that machines with low investment and operation costs were applied in this technology for transport tasks, transport costs still remained high. *Canning tomato production* on 100 hectares require 4.698 hours of machine operation of which the transport vehicle works for 2500 hours. The tractor of higher power does not have too many tasks except soil cultivation which means that its operation time is not very high. However tractors of lower power are operated for a much longer period during plant protection and harvest tasks. The operation of the self-propelled harvester is also very significant (500 operating hours). Moreover extra tractor capacity is also required during harvest because it has to draw a trailer synchronized with the harvester to collect the crop because naturally the road transport vehicle is not appropriate for moving slowly beside the harvester.

Economic and logistical survey of root vegetable production on a 20 hectare

It can be stated on the basis of the results that in case of *root vegetables production for canning purposes* the operational cost of the power machines (6631 EUR) is less than the half of that of the working machines (14.979 EUR). The total operational cost amounts to 21.610 EUR, 1080 EUR per hectare. In case the *goods are meant for the fresh market* the above indexes are as follows: the operational cost of the working machines (16.790 EUR) is nearby equal to the operational cost of the power machines (17.812 EUR). The total operational cost is 34.602 EUR, 1730 EUR per hectare [7].

It can be stated that the drag picking method harvesting for fresh consumption causes an extra cost of about 500 EUR per hectare plus the 200 EUR/hectare cost of grading.

In view of the operational cost relations it can be stated that in case the final product is meant for industrial use the cost of road transport is about 35 %, and the delivery from the field to the depot by tractor about 10 % of the total cost. In case the final product is meant for the fresh market this order is different. The major cost factor is harvesting with 40 %, road transport and delivery by tractor follows with 22 % resp. 5 %.

The investment cost of the machines applied in the production technology amounts to 602 thousand EUR *(554 thousand EUR*[1]), out of which the purchasing price of the working machines amounts to 288 thousand EUR, which equals about 48 % of the total investment cost *(292 thousand EUR – 53 %)*, while the purchasing price of the power machines is 314 thousand EUR, about 52 % of the total cost of machines *(262 thousand EUR – 47 %).* In case of power machines it can be stated that one power machine with an engine capacity of 140 kW is needed for the hard cultivation works, while the tasks of nutrients delivery, plant protection and crop cultivation, sowing, harvesting tractor delivery are fulfilled by 70 kW main and a 60 kW aid machine [11]. For moving the goods in the depot a telescopic loader is also required, first of all in case of root vegetables meant for industrial use. For the road transport of the crop a low-cost trailer can be used. With the above method of applying power machines lower acquisition costs and a more effective utilization of power machines can be achieved.

Root vegetables production on 20 ha demands 726 shift hours of machine work, out of which the two lower capacity tractors represent a great proportion due to delivery of nutrients, sowing, ridge bed renewal, crop protection and harvesting and transport by tractor and the shift hour performance of the high capacity power machine in the course of cultivation is also significant. Road transport with its 300 shift hour capacity demand is the most time-demanding operation.

In case of production meant for fresh consumption the 70 kW tractor works even more shift hours due to the time-demanding harvesting. Furthermore, the grading of the crop produced on 20 has demands about 700 shift hours of machine work according to our calculation. In this case the total number of the shift hours performed in the course of the technology is 1526.

Economic and logistical survey of cucumber production on a 20 hectare area

The operational cost in case of *cucumber production* of the working machines (11.196 EUR) is the half of that of the power machines (22.567 EUR). The total

[1] Investment cost values in case of technology when the goods are meant for the fresh market.

operational cost amounts to 33.763 EUR, 1688 EUR per hectare. Taking the manipulation costs amounting to 2238 EUR into consideration the total cost of machine utilization is 36.001 EUR, 1800 EUR per hectare [8].

In view of the operational cost relations it can be stated that the cost of planting is about 16 %, and the cost of foil tunnel preparation about 12 % of the total cost. The cost of harvesting is also 12 %. The delivery by tractor for pre-grading and the consecutive road transport to the processing factory represents a proportion of 7 resp. 10 %.

The investment cost of the machines applied in the production technology amounts to 593.996 EUR out of which the purchasing price of the working machines amounts to 197.300 EUR, which equals about 33 % of the total investment cost while the purchasing price of the power machines is 313.096 EUR, about 53 % of the total cost of machines. The purchase price of manipulating machines is 83.600 EUR, about 14 % of the total investment.

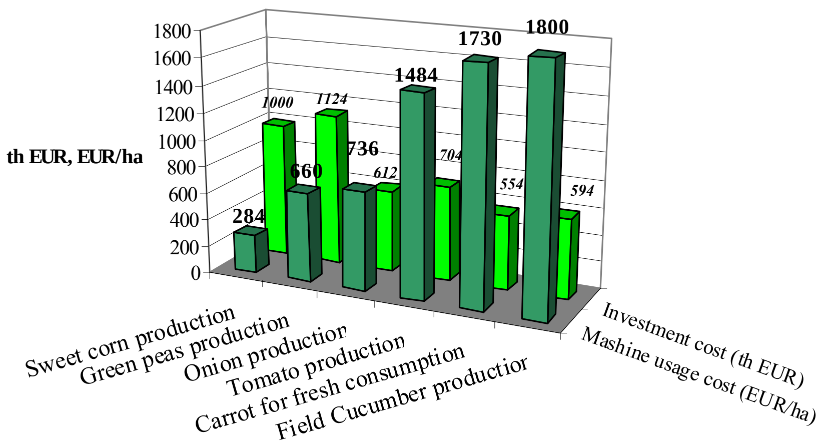

Figure 1. The production costs and investment of the examined field vegetables

In case of power machines it can be stated that one power machine with an engine capacity of 140 kW is needed for the hard cultivation works, while the tasks of nutrients delivery, ridge-bed preparation, mulching, hauling the hosepipe, planting, foil tunnel preparation, plant protection, harvesting and tractor delivery are fulfilled by a 70 kW main and a 60 kW aid machine. For the road transport of the produce a low-cost trailer can be used. With the above method of applying power machines lower acquisition costs and a more effective utilization of power machines can be achieved.

Cucumber production on 20 ha demands 1080 shift hours of machine work, out of which the two lower capacity tractors represent a great proportion, about 800. In comparison to this the 44 shift hour performance of the high capacity power machine in the course of cultivation is negligible. Road transport with its 150 shift hour capacity demand is one of the most time-demanding operations.

The figures of the present survey are calculated on the basis of high quality and valuable power machines which ensure effective performance. Consequently the acquisition and operational costs of the power machines are also substantial. The prescribed operations can naturally be realized by using power machines of a lower technical level under strict control and in this case the operational cost of the machines can be less than that figuring in the survey [5].

CONCLUSIONS

It is favorable for onion production that harvest is implemented with tractor-drawn machines without using expensive self-propelled harvesters. The investigations show that the self-propelled tomato harvester completely utilizes its annual operating hour by harvesting 100 hectares of land, which means that its utilization and specific cost is favorable but very cost-demanding because of the high investment cost.

The surveys have proved that the machine work costs of field root vegetable production are higher than the production cost of above mentioned vegetables (Fig. 1). Taking into consideration the extra work connected to grading and consumer packing substantial additional costs arise which can lead to specific costs per hectare exceeding 1700 EUR. In case of a 60 t/ha yield it can easily be calculated that operational costs of machines themselves exceed 3 EURO Cent·kg^{-1}, and we have to take into consideration the costs of seeds, fertilizers, pesticides, labor and irrigation water.

Also the surveys conducted have proved that the machine work costs of field foil covered cucumber production compared to the production costs of other field vegetable varieties are the highest. The significant hand labor demand is characteristic of this product by planting as well as by the preparation of the foil tunnel but first of all by harvesting when the expert and quality work of 28 persons might as well be needed. But it comes at a price. The picking personnel of 16-28 persons represents a remarkable loan cost but knowing the domestic wage levels this cost is not so very remarkable and the competitiveness of production can be ensured. The present study focuses on the costs of machine operations only the production cost is, therefore, 15 Euro Cent·kg^{-1} besides a calculated average yield of about 12 t·ha^{-1}. The cost of hand labor applied during production and the costs of material and other inputs necessary for production were not defined. All these demand further substantial expenditure adding further to the production cost and the cost of the final product.

These figures are characteristic of large-scale production costs and they grow further in case of smaller production units with less effective automation. Considering machine and logistical costs it is advantageous if, as in the studied cases, harvesting is done by tractor-pulled working machines instead of expensive self-propelling harvesting machines with high operational costs, as the acquisition cost of connected working machines is more favorable and a better utilization and lower specific operational costs of power machines can be achieved by the use of tractors.

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TROŠKOVI MEHANIZACIJE I LOGISTIKE POVRATRASKE POROIZVODNJE

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Sažetak: Ekonomsko ispitivanje proizvodnje povrća je predstavljeno na primerima tehnologija proizvodnje najvažnijih vrsta povrća: kukuruza šećerca, zelenog graška, crnog luka, paradajza, šargarepe i krastavca. Cilj rada je da promoviše popularizaciju modernih tehnologija proizvodnje povrća na otvorenom prostoru, pregledom tehnologije i donošenjem korisnih informacija o operativnim i ekonomskim podacima mašina koje su neophodne za ovu proizvodnju.

Istraživanja su potvrdila da su troškovi rada mašina u proizvodnji povrća na otvorenom prostoru viši od troškova koji nastaju pri proizvodnji žitarica i uljarica. Pored toga, nivo godišnje iskorišćenosti specijalnih kombajna je veoma nizak, uz postojanje nekoliko mogućnosti za poboljšanje. Razlog ovome je činjenica da se povrće proizvodi na manjim površinama, čime se smanjuje potražnja za iznajmljivanjem mašina.

Ključne reči: *mehanizacija, logistika, ekonomija, investiranje u tehničke sisteme, troškovi korišćenja*

Datum prijema rukopisa: *Paper submitted:*	22.03.2012.
Datum prijema rukopisa sa ispravkama: *Paper revised:*	03.04.2012.
Datum prihvatanja rada: *Paper accepted:*	28.04.2012.

ПОЉОПРИВРЕДНА ТЕХНИКА
AGRICULTURAL ENGINEERING
✧
Научни часопис
Scientific Journal

Пољопривредни факултет
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Предмет и намена: ПОЉОПРИВРЕДНА ТЕХНИКА је научни часопис који објављује резултате основних и примењених истраживања значајних за развој у области биотехнике, пољопривредне технике, енергетике, процесне технике и контроле, као и електронике и информатике у биљној и сточарској производњи и одговарајућој заштити, доради и преради пољопривредних производа, контроли и очувању животне средине, ревитализацији земљишта, прикупљању отпадака и њиховом рециклирању, односно коришћењу за производњу горива и сировина.

УПУТСТВО ЗА АУТОРЕ

Захваљујући вам на интересовању за часопис ПОЉОПРИВРЕДНА ТЕХНИКА молимо вас да се обратите Уредништву ако ова упутства не одговоре на сва ваша питања.

Рад доставити у писаној и електронској форми на адресу Уредништва

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Мада сви радови подлежу рецензији за оригиналност, квалитет и веродостојност података и резултата одговарају искључиво аутори. Подразумева се да рад није публикован раније и да је аутор регулисао објављивање рада с институцијом у којој је запослен.

Тип рада

Траже се оригинални научни радови и прегледни чланци. Прегледни радови треба да дају нове погледе, уопштавање и унификацију идеја у односу на одређени садржај и не би требало да буду превасходно изводи раније објављених радова. Поред тога, траже се и прелиминарни извештаји истраживања у форми краћих прилога. Ова врста прилога мора да садржи нека нова сазнања, методе или тех-нике који очигледно представљају нове домете у одговарајућој области. Кратки прилози објављиваће се у посебном делу часописа. У часопису је предвиђен прос-тор за приказе књига и информације о научним и стручним скуповима.

Рад треба да буде написан на српском језику, по могућству ћирилицом, а прихватају се и прилози на енглеском језику. Будући да су области пољопривредне технике интердисциплинарне, потребно је да бар увод буде писан разумљиво за шири круг читалаца, не само за оне који раде у одређеној ужој области. *Научни значај рада и његови закључци требало би да буду јасни већ у самом уводу* - то значи да није довољно дати само проблем који се изучава већ и његову историју, значај за науку и технологију, специфичне појаве за чији опис или испитивање могу бити употребљени резултати, као и осврт на општа питања на која рад може да да одговор. Одсуство оваквог прилаза може да буде разлог неприхватања рада за објављивање.

Поступак ревизије

Сви радови подлежу ревизији ако уредник утврди да садржај рада није прикладан за часопис. У том случају се враћа аутору. Уредништво ће улагати напоре да се одлука о раду донесе у што краћем периоду и да прихваћени рад буде објављен у истој години када је први пут поднет.

Припрема рада

Рад треба да буде штампан на хартији стандардног А4 формата, у фонту Times New Roman (tnr), font size 10 pt, проред Single space, са Justify поравнањем (justified alignment), уз увлаку првог реда 0,63 cm (Format→Paragraph→Indents and Spacing→Special→First Line 0,63), маргине: Top 4,6 cm, Bottom 4,6 cm, Left 4,25 cm, Right 4,25 cm. Дужина рада је ограничена на 10 страна, укључујући слике, табеле, литературу и остале прилоге.

Наслов - Наслов рада треба да буде кратак, описан и да одговара захтевима индексирања **(**фонт: **tnr 12 PT BOLD, centrirano)** . Испод наслова навести име сваког од аутора и установе у којој ради *(tnr 10 pt italic, (centrirano)* . Сугерише се да број аутора не буде већи од три, без обзира на категорију рада. Евентуално, шира прегледна саопштења могу се у том смислу посебно размотрити, у току ревизије.

Сажетак - У изводу треба дати кратак садржај онога шта је у раду дато, главне резултате и закључке који следе из њих. Дозвољени обим сажетка је 100 до 250 речи. У оквиру сажетка није дозвољено приказивање података табелама, графиконима, схемама или сликама, те навођење литературних извора. Уз сажетак навести максимално десет кључних речи, одвојених зарезом.

Abstaract - дати на крају рада на енглеском језику у форми као сажетак, са кључним речима.

Литература - У попису литературе се не смеју наводити референце које у тексту нису цитиране. Литературу писати са фонтом tnr 9 pt, нумерисати са бројевима у великој загради. Референце треба да садрже аутора(е), наслов, тачно име часописа или књиге и др., број страна од-до, издавача, место и датум издавања.

Табеле - Табеле треба бројати по реду појављивања. Табеле, графикони и фотографије (црно беле с високим контрастом) морају бити укључене у текст (Таб. 1). Бројеве табела и наслове писати изнад табела. Текст у табелама писати у Font size 9 pt. Све текстуалне уносе у табелама дати упоредо на српском и енглеском језику. Свака табела мора да има означене све редове и колоне, укључујући и јединице у којима су величине дате, да би се могло разумети шта је у табели представљено. Свака табела мора да буде цитирана у тексту рада.

Слике - Слике треба да буду доброг квалитета укључујући ознаке на њима. Све слике по потреби треба да имају легенду. Објашњења симбола и мерне јединице треба да се дају у легендама слика. Све слике треба да буду цитиране у тексту. Слике и графиконе (Граф. 1) такође треба нумерисати, а бројеве и наслове писати испод графикона или слика (Сл. 1). Наслов слике или графикона треба да буде написан на српском и енглеском као и сви остали словни уноси у графиконима и сликама (*italic*).

Математичке ознаке (формуле) - писати у едитору формула (MS Equation ili Mathtype) са величином основног фонта tnr 10 pt. Формуле (центриране) обавезно нумерисати бројевима у загради (1) са десним уравњањем.

МОГУЋНОСТИ И ОБАВЕЗЕ СУИЗДАВАЧА ЧАСОПИСА

У одређивању физиономије часописа ПОЉОПРИВРЕДНА ТЕХНИКА, припреми садржаја и финансирању његовог издавања, поред сарадника и претплатника (правних и физичких лица), значајну подршку Факултету дају и суиздавачи - радне организације, предузећа и друге установе из области на које се мисија часописа односи.

ПОЉОПРИВРЕДНА ТЕХНИКА је научни часопис који објављује резултате основних и примењених истраживања значајних за развој у области биотехнике, пољопривредне технике, енергетике, процесне технике и контроле, као и електронике и информатике у биљној и сточарској производњи и одговарајућој заштити, доради и преради пољопривредних производа, контроли и очувању животне средине, ревитализацији земљишта, прикупљању отпадака и њиховом рециклирању, односно коришћењу за производњу горива и сировина.

Права суиздавача

Суиздавач часописа може бити свако правно лице односно грађанско-правно лице, предузеће или установа које је заинтересовано за ширење и пласирање информација у области пољопривредне технике, односно науке, струке и других делатности од значаја за модерну пољопривредну производњу и производњу хране или модерније речено - за успостављање и развој одрживог ланца хране.

Фирма која жели да постане суиздавач, уплатом, једном годишње, на рачун издавача суме која је једнака отприлике износу 10 годишњих претплата стиче следећа права:

- Делегирање свога представника - стручњака у Савет часописа;
- У сваком издању часописа који излази једанпут годишње, као четвороброј у тиражу од по 350 примерака, могуће је у форми рекламног додатка остварити право на бесплатно објављивање по једне целе стране свог огласа, а једном годишње та страна може да буде у пуној боји; Напомињемо овде да цена једне рекламно-информативне стране у пуној боји у једном броју износи 20.000 динара.
- Од сваког броја изашлог часописа бесплатно добија по 3 примерка;
- У сваком броју рекламног додатка му се објављује, пуни назив, логотип, адреса, бројеви телефона и факса и др., међу адресама суиздавача;
- Има право на бесплатно објављивање стручно-информативних прилога, производног програма, информација о производима, стручних чланака, вести и др.;

Како се постаје суиздавач часописа ПОЉОПРИВРЕДНА ТЕХНИКА

Пошто фирма изрази жељу да постане суиздавач, од ПОЉОПРИВРЕДНОГ ФАКУЛТЕТА добија четири примерка уговора о суиздавању потписана и оверена од стране издавача. Након потписивања са своје стране, суиздавач враћа два примерка Факултету, после чега прима фактуру на износ суиздавачког новчаног дела. Уговор се склапа са важношћу од једне (календарске) године, тј. односи се на два броја часописа.

Приликом враћања потписаних уговора суиздавач шаље уредништву и своју адресу, логотип, текст огласа и рукописе прилога које жели да му се штампају, као и име свог представника у Савету часописа. На његово име стижу и бесплатни примерци часописа и сва друга пошта од издавача.

Суиздавачки део за часопис у 2013. год. износи 20.000 динара. Напомињемо, на крају, да суиздавачки статус једној фирми пружа могућност да са Факултетом, односно уредништвом часописа, разговара и договара и друге послове, посебно у домену издаваштва.

Научно-стручно информативни медијум у правим рукама

Када се има на уму да часопис, са два обимна броја са информативно-стручним додатком, добија значајан број фирми и појединаца, треба веровати у велику моћ овог средства комуницирања са стручном и пословном јавношћу.

Наш часопис стиже у руке оних који познају области часописа и њима се баве, те је свака понуда коју он садржи упућена на праве особе. Већ та чињеница осмишљава бројне напоре и трајне резултате који стоје иза подухвата званог издавање часописа.

За сва подробнија обавештења о часопису, суиздаваштву, уговарању и др., обратите се на:

Уредништво часописа
ПОЉОПРИВРЕДНА ТЕХНИКА
Пољопривредни факултет,
Институт за пољопривредну технику
11080 Београд-Земун, Немањина 6, п. фах 127,
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CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

631(059)

ПОЉОПРИВРЕДНА техника : научни часопис = Agricultural engineering : scientific journal / главни и одговорни уредник Горан Тописировић. – Год. 1, бр. 1 (1963)- . - Београд; Земун : Институт за пољопривредну технику, 1963- (Београд : Штампарија ”Академска издања”) . – 25 cm

Тромесечно. – Прекид у излажењу
од 1987-1997. године
ISSN 0554-5587 = Пољопривредна техника
COBISS.SR-ID 16398594