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# EVALUATION OF THE TRADE INFORMATION SOURCES ACQUIRED BY THE SELECTED FARMERS FROM PODLASKIE VOIVODESHIP

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ABSTRACT

The paper includes evaluation of the sources of acquiring information in agricultural farms by farmers. The research was carried out in 2012 in the form of a direct survey of owners of 102 agricultural farms located in Podlaskie Voivodeship. A survey questionnaire, which consisted of two parts, was a research instrument. The first one concerned information on the farm owner and a farm and the second part of the questionnaire consisted of questions related to the manners of acquisition of information sources and their evaluation. The research which was carried out proves that shows and exhibitions are the weakest information sources according to the evaluation (10%). Information obtained from the Commune Offices (16%) and the Agency for Restructuring and Modernization of Agriculture (18%) were evaluated as a weak source of information. However, a direct contact with friends and neighbours (42%) and agricultural advisers (59%) seems to be a popular source of information. The Internet, as well as radio and television, each reach more than 70%. Specialist press and guides were evaluated very high (above 80%). According to the investigated group, agricultural journals are the most significant source of information in the plant and livestock production and information on agricultural machines and devices. In the evaluation of the access to various types of agricultural information as much as 58% said that it is on a very good level, 30% of respondents evaluated it as good and only 12% of the respondents claimed that the access to various types of agricultural information sources is at a fairly good level. Any of the questioned farmers did not claim that the access to information is bad.

## Introduction

Changes in the conditions of operation of agricultural farms caused that they are more open to external factors, the impact of which creates the production surrounding. Necessity of competitive advantage on the market forces farmers to increase capacity and improve farming effectiveness. Agricultural farmers must, thus, be more active in searching for information (Bernacki, 2004). According to Kocira and Lorencowicz (2011) and Kuboń (2007) farmers use information technologies in managing a farm to a low extent. Achieving

high quality products in the sustainable development conditions requires the use of modern management methods and the use of more information than before a few decades, which may be facilitated by the IT technologies. New techniques, particularly the Internet, give possibilities of acquiring information from great number of dispersed sources around the world. Thus, information sources should be complete, precise, up-to-date and affordable. Partial or invalid information, which was not obtained in a suitable time, unfavourably influences the process of managing the farm.

An agricultural farmer, in order to stay at the market, must obtain indispensable information systematically, interpret them correctly and react to them. On the other hand, efficient information and the advisory system enable agricultural producers to use knowledge which is the basis for the systems, technologies and production methods implementation which guarantee high economic efficiency of incurred expenditures (Pawlak, 1999). After Poland's accession to the European Union, farmers found themselves in a new situation of the increased competitiveness, necessity of implementing new production methods and technologies. It causes that a farmer needs various knowledge both biological, chemical, technical, technological, economic and social (Wiatrak, 2004). Lack of ability to use information or a delay in implementation of technological progress eliminates a farmer from the market (Bliźniak and Nowak, 2005). The amount of the acquired data and the manner of their acquisition considerably results from the specificity of a farm and depends on the production trend and intensity (Cupiał and Wnęk, 2008; Kuboń, 2007). Szeląg-Sikora and Cupiał (2008) stated in their research that farmers, who reached for or prefered more than one information source, better managed their farms.

## Objective of the paper and methodology of research

The objective of the paper was to evaluate the sources of information in the selected farms in Podlaskie Voivodeship. In Podlaskie Voivodeship, there are 120.1 agricultural farms (including those with the area up to 1 ha) – source the Agency for Restructuring and Modernization of Agriculture. The voivodeship's asset is the highest area of grassland (35.4%) in the country which is excellently used by farmers for the cow milk production.

The research was in the form of a survey, which was carried out directly in 102 agricultural farms, which carried out plant and animal production. Farmers, who have more than 1 ha of agricultural land constituted 100% of population among the respondents. The research was carried out in the form of a survey questionnaire, which consisted of two parts. The first one concerned information on the farm owner (sex, age, education, area and the period the farm was maintained) and the second part consisted of questions related to the manners of obtaining information sources and their evaluation.

## Research results

Men constituted a considerable participation among the questioned (86%). The biggest group consisted of people between 31-40 years of age (49%). Farmers who were more than 50 years old were the least numerous (3%). Majority (58%) had secondary education; 30% of the respondents declared that they had higher education (figure 1). Owners of farms above 10 ha prevailed (69%), farms up to 5 ha constituted 11%.

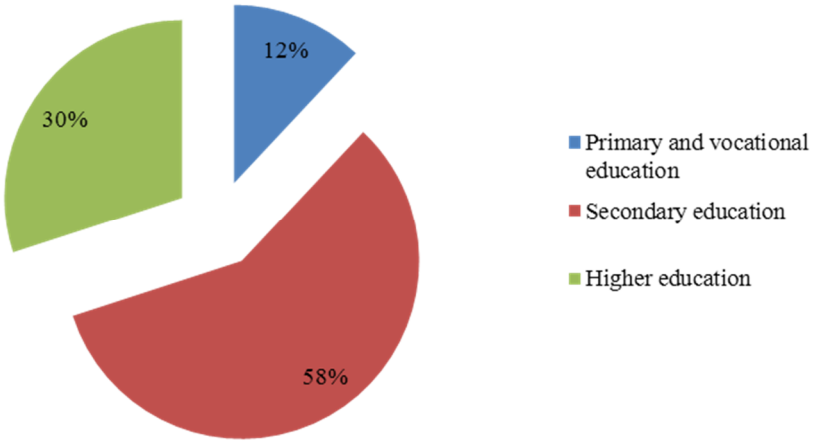


*Figure 1. The structure of education of the investigated group of farmers*

Among the investigated, the biggest group consisted of farmers, whose agricultural experience on a farm was from 1 to 5 years (32%) and from 6 to 10 years (30%). Less than 8% of the investigated have been engaged in farming for less than one year, 10% for 11-20 years and 20% more than 20 years.

The respondents were asked in the research to indicate the information source which they use. The research which was carried out proves that shows and exhibitions are the weakest information source according to the evaluation (10%). Information acquired from the Commune Offices (16%) and the Agency for Restructuring and Modernization of Agriculture (18%) were evaluated as a weak source of information. However, a direct contact with friends and neighbours (42%) and agricultural advisers (59%) seems to be a popular source of information. Professional press and guides were evaluated very high (above 80%), the Internet and radio as well as television each above 70% (fig. 2).

According to the investigated group's opinion, the most significant information source in the plant production are agricultural journals – as much as 70% of the respondents indicated them, less, because 56% indicated agricultural advisers and 52% – the Internet (fig. 3).

The livestock production enjoys similar results. trade journals (75%), agricultural advisers (68%) and the Internet (60%) are the best source of information on the production (fig. 4).

The research which was carried out proved that in case of information on agricultural machines and devices, journals are the best source, in the respondents' opinion (65%), brochures of the machinery producers (53%) and other farmers (45%). Only 32% of the questioned indicated the Internet and less than 25 % advisers, whereas only 12% indicated agricultural fairs and exhibitions (fig. 5).

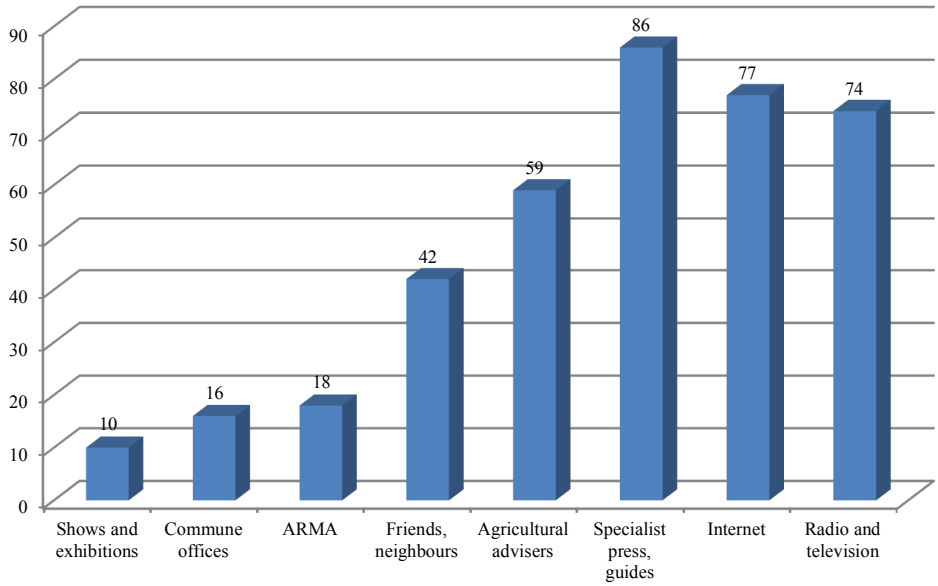


*Figure 2. The most frequently used information sources by the investigated farmers (multiple answers in percentage)*

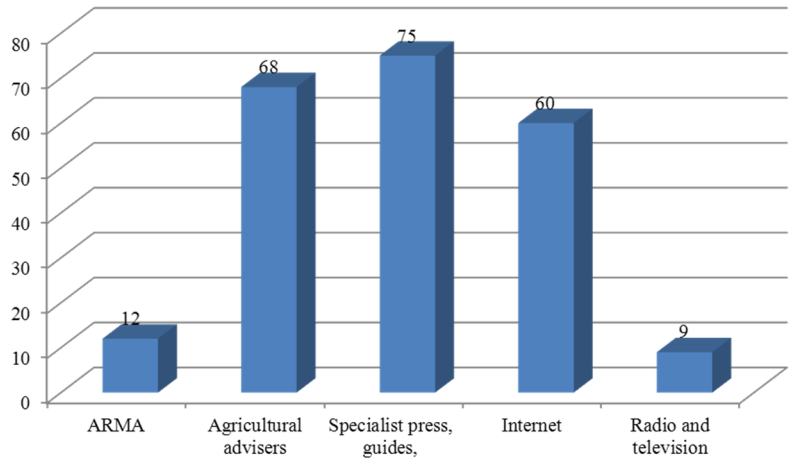


*Figure 3. The most frequently indicated information sources used in the plant production (multiple answers in percentage)*

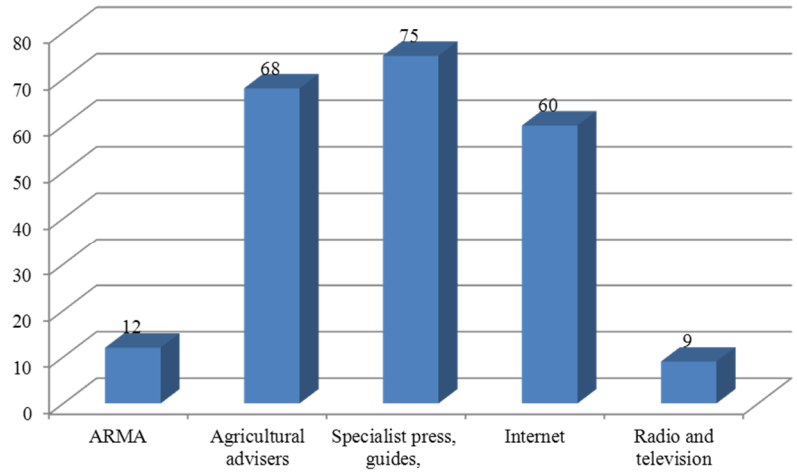


*Figure 4. The most frequently indicated information sources used in the plant production (multiple answers in percentage)*

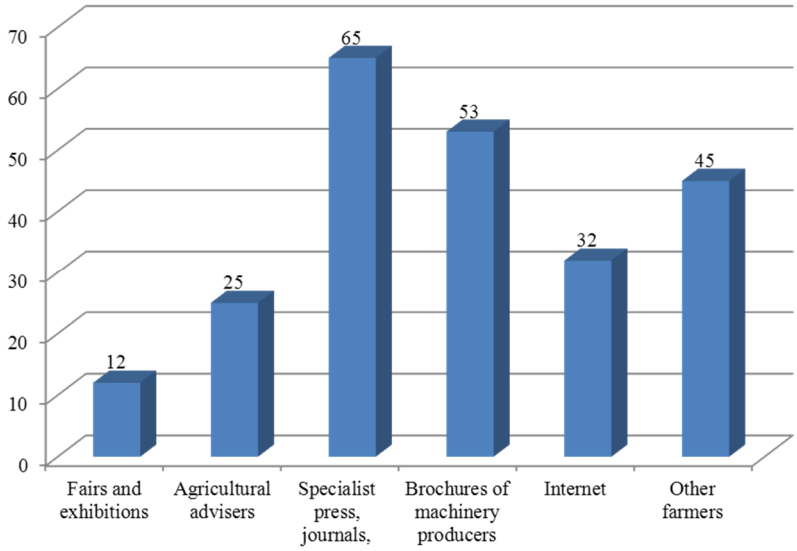


*Figure 5. The most frequently indicated information source on agricultural machines and devices (multiple answers in percentages)*

The tests prove that the surveyed farmers the most eagerly and frequently use trade journals and the Internet for obtaining agricultural information, therefore they were asked to define these sources.

The most popular among the respondents is Tygodnik Rolniczy (83%) and Top Agrar (74%). 60% respondents indicated Poradnik Rolniczy and Hodowca Bydła, 50% indicated Farmer and 42% – Agroserwis. The least popular (less than 30%) are Wieś Jutra, Rolniczy Przegląd Techniczny and Agrotechnika.

During information acquisition from the Internet, farmers the most often use various farming portals such as e.g. ppr.pl, wpr.pl, polskierolnictwo.pl (over 90%) and such pages as: Agencja Restrukturyzacji i Modernizacji Rolnictwa [Agency for Restructuring and Modernization of Agriculture], Agencja Rynku Rolnego [Agricultural Market Agency], Ośrodek Doradztwa Rolniczego [Centre for Agricultural Advise], Ministerstwo Rolnictwa i Rozwoju Wsi [The Ministry for Agriculture and Rural Development], Agencja Nieruchomości Rolnych [Agricultural Property Agency] or Kasy Rolniczego Ubezpieczenia Społecznego [The Agricultural Social Insurance Fund] (more than 70% of the investigated). According to Cupiał (2006) agricultural information is also provided by Ośrodek Przetwarzania Informacji (OPI) [National Information Processing Institute], where except for information on the current research, the portal deals with the exchange of scientific information and registration of the research works results. Less than 8% of the questioned at least once used such services. Any of the surveyed farmers did not indicate the use of libraries and academic reading rooms.

In the evaluation of the access to various types of agricultural information as much as 58% said that it is on a very good level, 30% of the respondents evaluated it as good and only 12% of the respondents claimed that the access to various types of agricultural information sources is sufficient. Any of the questioned farmers did not claim that the access to information is bad.

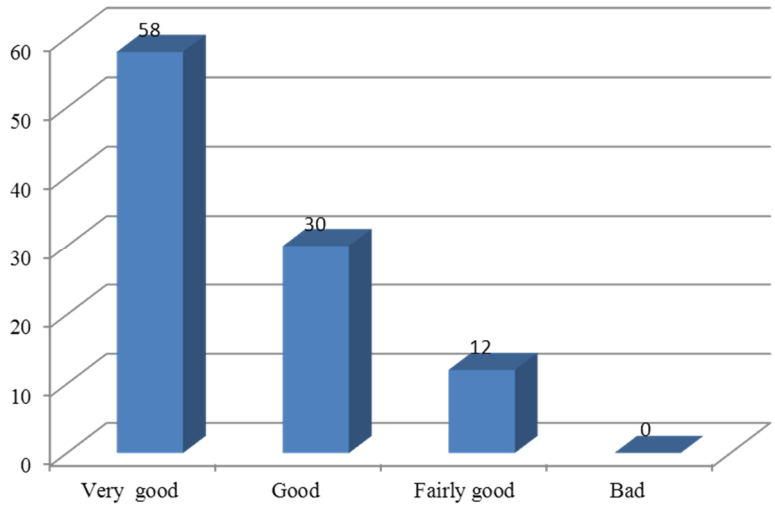


*Figure 6. Evaluation of the access to agricultural information sources*

## Conclusion

Information as a source of knowledge in the agriculture has become more significant in the recent years. According to Adamowicz (2005) acquisition of information, new knowledge and improvement of the educational level of people is a necessary condition in the realities of the global economy. The importance of the Internet as an information carrier increases (Gruziński, 2006; Zaliwski and Pietruch, 2007) which is confirmed by the research which was carried out. According to Pisarek and Tokarska (2008) the agricultural information sources in the Internet are extremely extensive and varied, therefore almost everyone may obtain access to the data on the subject in which he/she is interested. As the tests show, significance of agricultural journals has not weakened. Specialist press, brochures and guides are read in more than 80% of farms. The role of the radio and television in the information transfers is also noticeable (over 70%). General information (events), weather conditions and information on the market prices are the most frequently obtained information with the use of these sources. However, through these sources, a farmer very rarely gets professional information, which he/she may apply in the production process.

Shows and exhibitions are the weakest in the respondents' opinion. Farmers emphasised that they play a cognitive role, the role of establishing contacts rather than obtaining professional knowledge.

Despite many possibilities for information acquisition, obtaining knowledge in the direct contact with friends and neighbours as well as employees of the agricultural advisory centres enjoy great confidence. Based on the survey with farmers, it should be stated that the respondents more eagerly use the professional advisory knowledge of commercial companies, express their readiness for both complex advisory service as well as assistance in applying for aid funds from the EU and bookkeeping. The research, which was carried out, shows that farmers try to broaden the knowledge indispensable for carrying out the agricultural production. These needs result greatly from the farm specificity; to a great extent they depend on the production trend, which is confirmed by Ziętara (2010) in his research.

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## OCENA ŹRÓDEŁ POZYSKIWANIA INFORMACJI BRANŻOWYCH PRZEZ WYBRANYCH ROLNIKÓW WOJEWÓDZTWA PODLASKIEGO

**Streszczenie.** W pracy dokonano oceny źródeł pozyskiwania informacji w gospodarstwach rolnych przez rolników. Badania zostały przeprowadzone w 2012 roku poprzez bezpośrednie ankietowanie właścicieli 102 gospodarstw rolnych położonych na terenie województwa podlaskiego. Instrumentem badawczym był kwestionariusz wywiadu, który składał się z dwóch części. Pierwsza dotyczyła informacji o właścicielu gospodarstwa i gospodarstwie druga część ankiety składała się z pytań dotyczących sposobów pozyskiwania źródeł informacji oraz ich oceny. Przeprowadzone badania wskazują, że najsłabiej ocenianym źródeł informacji są pokazy i wystawy (10%). Dość nisko zostały ocenione informacje pozyskiwane z Urzędów Gmin (16%) i Agencji Restrukturyzacji i Modernizacji Rolnictwa (18%). Natomiast popularnym sposobem zdobywania informacji okazuje się bezpośredni kontakt ze znajomymi i sąsiadami (42%) oraz doradcami rolnymi (59%). Internet oraz radio i telewizja, każdy powyżej 70%. Bardzo wysoko zostały ocenione prasa fachowa i informatory (powyżej 80%). Według opinii badanej grupy najistotniejszym źródłem informacji w produkcji roślinnej, zwierzęcej oraz informacji na temat maszyn i urządzeń rolniczych są czasopisma rolnicze. W ocenie dostępu do różnego rodzaju informacji rolniczej, aż 58% stwierdziło, że jest on na bardzo dobrym poziomie, 30% respondentów oceniło go, jako dobry a tylko 12% ankietowanych uważa, że dostęp do różnego rodzaju źródeł pozyskiwania informacji rolniczych jest na niezłym poziomie. Żaden z ankietowych rolników nie ocenił, że dostęp do informacji jest na złym poziomie.

**Słowa kluczowe:** informacja, źródła informacji, produkcja rolnicza

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# PROVIDING MILK AGRICULTURAL FARMS WITH PRODUCTION MEANS

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*providing with production means*

ABSTRACT

A survey concerning provision of milk farms with production means in Warmińsko-Mazurskie Voivodeship was carried out in 2013 in the group of 80 farmers. Based on the survey, it should be stated that farmers define themselves their purchase needs and they start with planning the material needs. They search the market for possible suppliers and then place an order with a selected contractor. In the end, after they receive goods, they evaluate the quality of the service. Farmers more eagerly place orders via Internet. The research shows that farmers have high negotiating skills because they always ask for discounts when ordering. They also negotiate terms concerning orders, when they order big batches and control the received raw materials in order to evaluate the service. In milk farms maintaining the liquidity of supply in production means is significant. The research shows that more than half of farmers place orders a month before the stock depletes. Only a few farmers declared that they place orders for particular goods only when they need it. Some of them even were in favour of purchasing bigger batches in order to store the remaining part and avoid cyclic smaller orders.

## Introduction

Logistic farm management consists in performing specific activities in a specific time, for example: ordering fodder, seeds for insemination, products for hygiene and disinfection of milking devices. Information is indispensable for both agricultural producers as well as the producers and suppliers of production means and consumers of farm products. (Kuboń, 2007c). However, in order to make it possible, one should start from the stage of providing and ensuring a farm with materials for production in the moment when they are really needed. The farm size and the production type in the said region have an impact on the structure of production means purchase (Owsiak et al., 2013). Production specialization gives an opportunity to reduce the number of agricultural equipment and its better use (Kowalczyk, 2009). Execution of logistic processes requires a specific infrastructure in the form of inventory buildings, storages, technical production means and tele-informatics means (Kuboń, 2007b).

Many times, in case of placing a bigger order, materials are not used entirely at the same time and their surplus forms the so-called stock, which should be later stored, which limits the costs of raw material flow (Kuboń, 2006). Such stock may occur at the supply, production and distribution stage. In farms, which specialize in milk production a stock is created during the supply and the surplus which follows from production. Then, it is considered differently than in big production establishments, because maintaining stocks in a farm generates lower costs. For example, materials which come from a direct purchase, such as: mineral fertilizers, crop protection chemicals, fodder, spare parts for milking machines or other machines and devices, disinfectants, fuel, etc. On the other hand surplus of dry volumetric fodders, such as straw and hay, as well as grains, silage or root crops and even manure may be a stock. Rational storing of stocks allows maintaining the production rhythm, while their lack may cause stoppage and generate unnecessary expenses (Kuboń, 2008; Ficoń, 2008).

Costs of maintaining stocks incurred by farms are quite essential. Therefore in order to reduce them, the most adequate solution is a logistic method of completing stocks Just in Time (JIT). This method consists in supplying materials and raw materials for production in strictly determined amounts and precisely on time, when it is required to be used. It allows reduction of the number of employees and stoppages in production and what is the most important minimization of stocks costs and incurred damages or losses as a result of storing. Main assumptions of the just-in-time method, include minimization of the amount of stocks, short cycles of realization of orders, frequent completion of particular goods and their high quality (Sarjusz-Wolski, 2000). Kuboń stated in his research that with the increase of the size of farms and the distance from the supply markets, the storage potential of the investigated farms increases (Kuboń, 2007a).

## Methodology of research

The objective of the paper was to evaluate manners of providing milk agricultural farms from Warmińsko-Mazurskie Voivodeship with the production means. The research was carried out based on the survey carried out among 80 farm owners. Selection of people taking part in the survey was purposeful in nature and concerned the units selected with the help of an employee of the Polish Federation of Cattle Breeders and Milk Producers Branch in Olsztyn. Farms, which have not less than 25 cows and covered with the evaluation of the utility values of milk cattle constituted the criterion for selection. The survey included in total 25 questions, the first one related to the general characteristic of the respondent i.e. sex, age, education; the next 6 questions referred to the data on a farm and milk production, the next 10 related to the manner of orders, contacts with suppliers and manners of supplying agricultural farms.

## Research results

The most numerous group included farms with the area from 51 to 80 ha (48%) then 28% used the area from 31 to 50 ha. Farms below 30 ha constituted approx. 13%, and big-area farms – above 121 ha. Also, one farm with the area from 81 to 120 ha was reported.

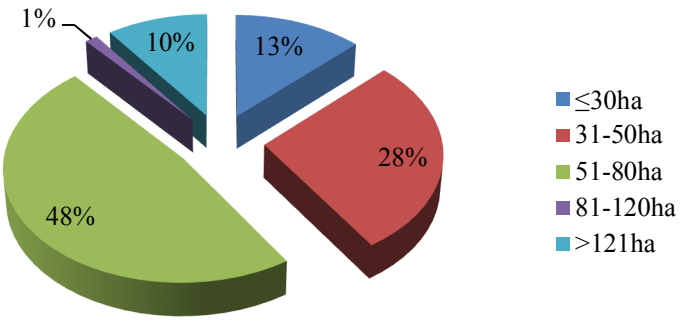


*Figure 1. The used area of agricultural land*

Among the land use structure, meadows and pastures (which are the basic juicy roughage for ruminants) covered from 50% to 100% of the area of arable land, as declared by 23 respondents. In case when meadows and pastures constituted from 60% to 100% of crops (12 respondents). Maize cultivation for silage in 8 farms covered as much as 50% of the land. Grains cultivation was similar because in any farm it did not exceed 50% of sowing. More and more farmers sow smaller areas.

In milk farms, frequency of reception of this raw material is significant. In order to eliminate this problem, milk is collected in cycles. Among the researched group, 70% of the surveyed persons have milk collected every second day whereas 30% of the questioned declares that this cycle is repeated every day.

The research shows that there are two popular cow herds sizes. 31 farms have from 36 to 45 cows and 25 farms have herds which amount from 25 to 35 cows. Further analysis shows the trend for co-dependence, namely along with the increase of the herd size, the number of such farms decreases. Five respondents declared that they have from 46 to 55 cows and 11 maintained from 56 to 65 cows. Only two farms had from 66 to 75 cows. Subsequently 3 farms with the herd of 86 to 95 cows and 3 farms with 96 cows appeared.

For a decisive number of farmers (66%) a dairy which collected milk was located in the distance up to 50 km. 125 respondents cooperates with dairies located from 51 to 100 km whereas the remaining 2% of respondents had the longest distance, because over 101 km.

Presently computer availability is no longer a problem. 98.75% of people declared that they have a computer in a farm.

Each year the number of users of the internet portals increases and the use of a computer with the internet creates more opportunities. 92% of respondents claim that having the Internet connection is as necessary as having a computer. They appreciate the number of functions and information which they may obtain from the Internet. 8% of the researched people claimed the opposite. They did not have the Internet connection.

When questioned on which source they use to follow current prices of raw materials, farmers provided two sources: the internet (26%) and the specialist press (25%); then, television (22%), radio (12%), agricultural advisers (10%) and the remaining sources – 5%. It

proves the IT development in rural areas and shows the scope of possibilities, which are provided by the Internet concerning following the newest information on animals feeding and breeding, prices of raw materials, technological solutions, placing announcements and exchange of experiences in production. Still, the specialist press is still an important source of information among farmers.

Among people who have the Internet connection, as much as 41 respondents prefer to order products via the Internet. The second group consisted of farmers, who placed orders via telephone and farmers who preferred placing direct orders that is in the point of sale. Only a few farmers considered distributor's suggestions when ordering production means.

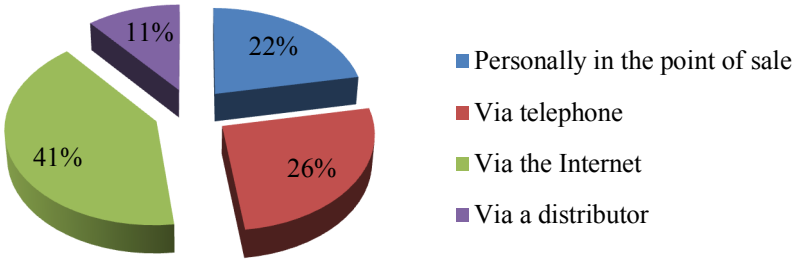


*Figure 2. Manners of placing orders by farmers*

In each production, supply is an inseparable element and its significant part is good planning. Therefore, farmers were asked how much time earlier they place orders for specific goods. The highest number of respondents (64%) admitted that they place orders with a one -month advance. Another big group (20%) orders with a 6-month advance. On the other hand, 8% prefers to purchase greater number of products to store them. The same number of farmers (8%) uses the just-in-time method, namely only when the products are really needed.

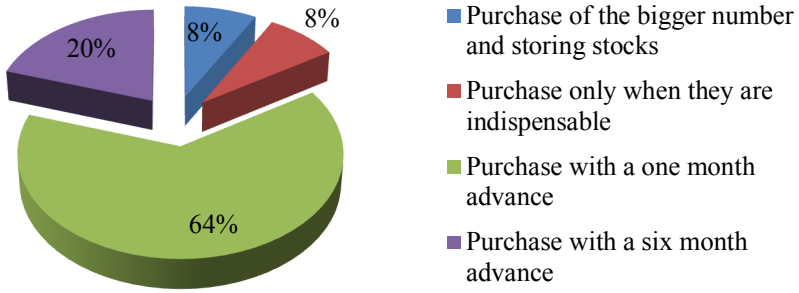


*Figure 3. The time limit for placing orders*

Among the surveyed, all buy mineral fertilizers, crop protection chemicals and disinfectants. 66 farmers buy the qualified sowing material obtained from the Seed Central Station. The next raw material, which improves the health condition of cows and influences the quality and amount of milk are fodder additives and industrial fodders, which are purchased by 64 respondents. 5 farmers buy grain from other farmers.

In the next question concerning a desire to obtain new contractors by a farmer, as much as 82% of respondents aim in their activities to settle permanent relations with potential suppliers in order to obtain discounts. Whereas, the remaining farmers (18%) prefer to change suppliers.

A supplier is related to the buyer only by the concluded contracts of sale or purchase but also with evaluation of cooperation. 725 of farmers evaluated such cooperation at the sufficient level, and 20% of the investigated persons graded suppliers as very good with regard to the quality of services rendered. 8% of respondents were not satisfied with services.

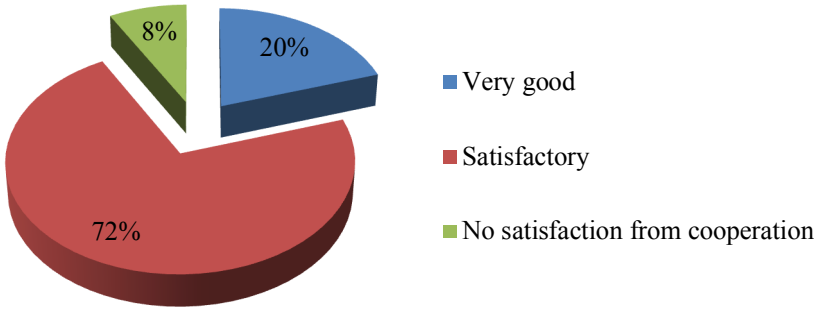


*Figure 4. Evaluation of cooperation with suppliers*

A decisive majority (66%) during placing orders asks contractors about possible discounts.

Research on the negotiating skills of respondents with regard to the conditions and prices of ordered raw materials, shows that farmers are reasonable in this issue. In 62% of cases, respondents start negotiations when they need to order often and big batches, whereas a numerous group (34%) are farmers, which always negotiate and independently from the circumstances of orders. 4% of respondents were quite the opposite. They never initialize negotiations.

Among the questioned, 68% implements one of the main objectives of the supply logistics, namely, the maximum satisfaction of material needs at the simultaneous minimization of costs of material supplies. Whereas the remaining (32%) farmers do not apply this objective during farm supply.

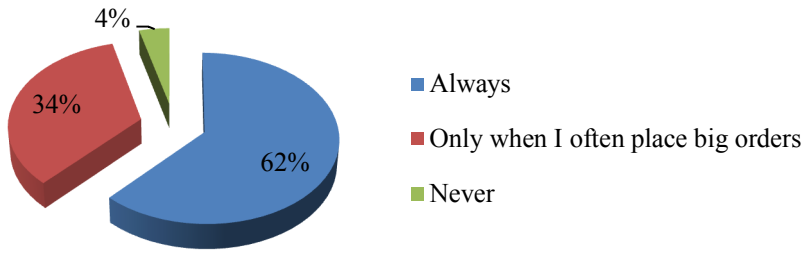


*Figure 5. Starting negotiations of conditions and prices of orders*

## Conclusions

1. A computer with the internet connection in a farm positively influences frequent on-line orders. 42% of respondents use this manner of ordering from among those who have the internet connection.
2. Planning orders by farmers takes place most frequently with a one-month advance before the stock depletes. Whereas only a few place orders for particular goods only when they need it.
3. Cooperation of contractors was evaluated by farmers as satisfactory and very good, because they always choose diligent suppliers and aim at obtaining permanent suppliers among the possible ones.
4. Farmers' negotiating skills are at a very high level, because they ask for discounts and conditions of orders.
5. Farmers implement supply logistics objectives at a high level in farms, which specialize in milk production, which results in the maximum satisfaction of material needs at the minimization of supply costs.

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## ZAOPATRZENIE W ŚRODKI PRODUKCJI GOSPODARSTW ROLNYCH SPECJALIZUJĄCYCH SIĘ W PRODUKCJI MLEKA

**Streszczenie.** Badanie ankietowe dotyczące zaopatrzenia w środki produkcji gospodarstw specjalizujących się w produkcji mleka w województwie warmińsko-mazurskim, przeprowadzono w 2013 roku w grupie rolników liczącej 80 osób. Na podstawie przeprowadzonych badań ankietowych należy stwierdzić, że rolnicy sami określają swoje potrzeby zakupowe rozpoczynając od zaplanowania potrzeb materiałowych. Śledzą rynek w poszukiwaniu potencjalnych dostawców, a później decydują się złożyć zamówienie u wybranego kontrahenta. Na zakończenie, po otrzymaniu towaru oceniają jakość wykonanej usługi. Rolnicy coraz chętniej dokonują zamówień i zleceń przez sieć internet. Z badań wynika, że na wysokim poziomie kształtują się umiejętności negocjacyjne rolników, ponieważ zawsze dopytują o rabaty i upusty cenowe podczas zamówień, negocjują również warunki zamówień, gdy zamawiają duże partie oraz kontrolują otrzymywane surowce w celu oceny wykonanej usługi. W gospodarstwach specjalizujących się w produkcji mleka istotne jest utrzymanie płynności zaopatrzenia w środki produkcji. Z badań wynika, że więcej, niż połowa rolników dokonuje zamówień z miesięcznym wyprzedzeniem, zanim zapas ulegnie wyczerpaniu. Zaledwie nieliczni oświadczyli, że dokonują zamówień na dany towar dopiero wtedy, gdy jest on potrzebny. Niektórzy nawet skłaniali się do zakupów większych partii, aby pozostałą część magazynować i uniknąć cyklicznych mniejszych zamówień.

**Słowa kluczowe:** produkcja mleka, gospodarstwa rolne, logistyka, zaopatrzenie w środki produkcji

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# THEORY OF THE PLOUGHING MECHANISM OF THE SUGAR BEET COMBINE HARVESTER

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ABSTRACT

Forces acting on the sugar beet combine plough are caused not only by physical properties of soil (e.g. its compactness) but also by physical properties of the harvested crop (i.e. sugar beets). A current theory on rooting out sugar beets has included only physical properties of soil along with physical and geometrical parameters of the ploughing mechanism. The article presents a mathematical model of mechanical influence of the soil layer together with the mass of sugar beets roots on the beets ploughing element. Mathematical formulas of the developed theory were verified with exemplary calculations for the accepted working parameters of the sugar beets harvesting combine (inter alia working speed, working depth).

## Einführung

Die Theorie der Extraktion der Hackfrüchte aus dem Boden mit dem Roderschar, die der Arbeit anderer Wirkorgane der Landmaschinen auf Grund der fundamentalen Forschungen des Dreikantkeilbewegungs im Boden zugrunde liegt, galt als erforscht und wurde bereits viele Jahre lang in der Lehrliteratur (Bosoj, 1977; Chawostov, 1995) behandelt. Beim Studium dieser Literatur wurde festgestellt, daß da nur die Frage des Zusammenwirkens der Scharoberflächen des Roders mit der Bodenschicht im Roder behandelt wird, und die Frage der Bedingungen für dessen Kompression und Zerstörung. Es wurde angenommen, daß gleiche Bedingungen auch für die Hackfrüchte in der Bodenschicht für ihre endgültige und qualitative Extraktion aus dem Boden geschaffen werden. Aber die Hackfrucht als Objekt der Analyse der Kinematik und Kraft wurde hierbei nicht betrachtet, da sein Kontakt mit den Keilkanten, die Bewegung im Raum beim Zusammenwirken mit Scharen sowie Bedingungen ihrer Nichtbeschädigungen bei der Extraktion aus dem Boden und usw. nicht untersucht wurde.

## Zweck und Umfang der Anallyse

Wir haben es sich zum Ziel gesetzt, die Theorie des Rodens der Rübenwurzeln mit dem Scharroder zu schaffen, die die Hackfrucht als Gegenstand der mechanik-mathematischen Forschung betrachtet, und ausgerechnet für das Zusammenwirken des Roders und des Rübekörpers wird das mathematische Modell geschaffen werden. Das neue Theorie wird die Anfangsergebnisse der Forschungen bezüglich der Deformation der Bodenschicht zwischen zwei Keilen des Scharroders (Bosoj, 1977) zugrunde gelegt.

Bei der Bewegung des Scharroders wird die Bodenschicht der Reihe der Hackfrüchte entlang durch die Keile zerstört, die sich samt den Wurzelkörpern zwischen den inneren Keiloberflächen des Roders verjüngt. Da die Keile unter den entsprechenden Winkeln $\alpha, \beta$ und $\gamma$ positioniert sind, so werden die Bodenschicht und die Wurzelkörper bei der Vorwärtsbewegung der Keile zusammen gepresst und deformiert. Bei der weiteren Bewegung der Schicht zwischen den sich verengenden Oberflächen werden die für die Wurzelkörper die Kräfte deren Rodens aus der Erde geschaffen.

Das Zusammenwirken der Kräfte des Scharroders und des Bodens untersucht werden. Dafür stellen wir das Kraftschema wie auch in (Bosoj, 1977) zusammen, wo wir den Scharroder mit der zwischen seinen Keilen gepressten Bodenschicht $KL$ zeigen/abbilden. In der Bodenschicht befindet sich der Rübekörper, dessen Form wir als echten Kegel (Abb. 1) darstellen. Unter der Wirkung der Bodenstützkraft, die als gleichmäßig verteilte Belastung mit einer Intensität $\overline{q}$ dargestellt wird, wird das Element $KL$ zwischen den Wirkoberflächen des Scharroders bei der Vorwärtsbewegung allmählich zusammen gepresst. Unter die Stützkraft, die unmittelbar auf den Rübekörper übertragen wird, bezeichnen wir $\overline{Q}$. Infolge der Wirkung der normalen Kräfte $\overline{N}$ und der Reibungskräfte $\overline{F}$ ensteht in den Kontaktpunkten $K$ und $L$ der Bodenschicht mit den Keiloberflächen die Spannung. Auf den Teil des Rübekörpers, der sich innerhalb der Schicht $KL$ befindet (der untere Teil des Rübekörpers befindet sich in der nicht deformierten Bodenschicht), wirkt die bereits festgesetzte Kraft $\overline{Q}$, bedingt durch die Stützkräfte $\overline{q}$. Auf diesen Teil des Rübekörpers wirken andererseits auch die Kräfte $\overline{P}'_{xi}, \overline{P}'_{yi}, \overline{P}'_{zi}$, ($i$ =1,2), die von den Keiloberflächen getragen werden, wo die Kräfte $\overline{P}_{xi}, \overline{P}_{yi}, \overline{P}_{zi}$, ($i$ =1,2) entstehen.

Jede der erwähnten Kräfte, die von den Scharoberflächen wirken, ist auf der Abb. 1 mit dem entsprechenden Koeffizient abgebildet. Die Kräfte, die von der Wirkoberfläche $A_1B_1C_1$ übertragen werden und auf die Bodenschicht im Punkt $K$ wirken, sind mit Index 1 – $\overline{P}_{x1}, \overline{P}_{y1}, \overline{P}_{z1}$, und die Kräfte, die auf den Wurzelkörper unmittelbar von dieser Oberfläche wirken, werden – $\overline{P}'_{x1}, \overline{P}'_{y1}, \overline{P}'_{z1}$ bezeichnet. Die Kräfte, die auf die Bodenschicht im Punkt $L$ von der Wirkoberfläche $A_2B_2C_2$ wirken, sind mit Index 2 – $\overline{P}_{x2}, \overline{P}_{y2}, \overline{P}_{z2}$ bezeichnet, und die Kräfte, die auf den Wurzelkörper unmittelbar von dieser Oberfläche auf den Rübekörper wirken, mit $\overline{P}'_{x2}, \overline{P}'_{y2}, \overline{P}'_{z2}$ bezeichnet. Die Wirkung der besagten Kräfte auf den Wurzelkörper hängt von ihrer Entstehung an den Keiloberflächen und vom Charakter der Übertragung in der deformierten Bodenschicht ab. Die Kraft der Bindung des Wurzelkörpers mit dem Boden bezeichnen wir als – $\overline{R}$ . Sie ist wie vereinbart an der Achse

des Wurzelkörpers angeordnet und ist üblicherweise senkrecht nach unten gerichtet. Aber bei der unmittelbaren Extraktion des Wurzelkörpers aus dem Boden kann sie entlang den entsprechenden Koordinatenachsen verlaufen. Auf Abb. 1 ist sie als Projektionen $R_x$, $R_z$ dargestellt.

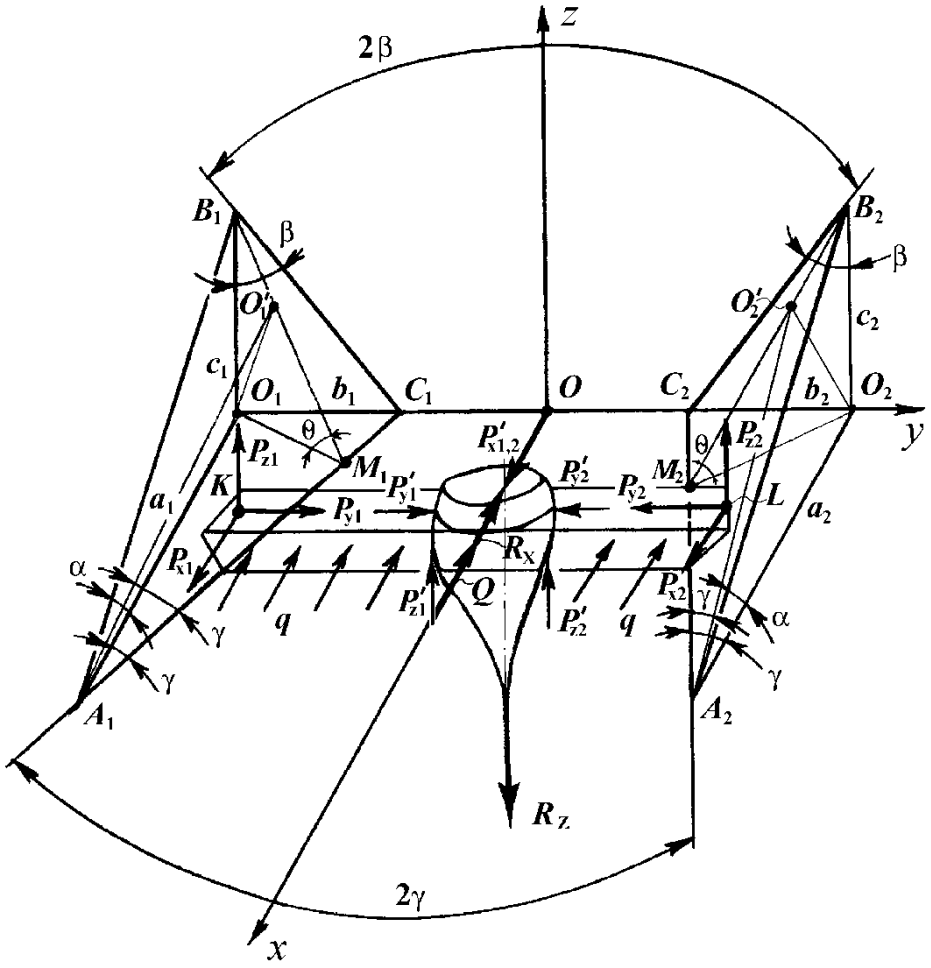



*Abbildung 1. Zusammenwirken des Scharroders mit dem Boden*

Bestimmen wir die erwähnten Kräfte. Die Kräfte $\overline{P}_{xi}, \overline{P}_{yi}, \overline{P}_{zi}$ ($i$=1,2), die auf Abb. 2 (Abb. 2 a, b, c) dargestellt sind, sind allgemein in der Vektorform für die Fläche $A_1B_1C_1$:

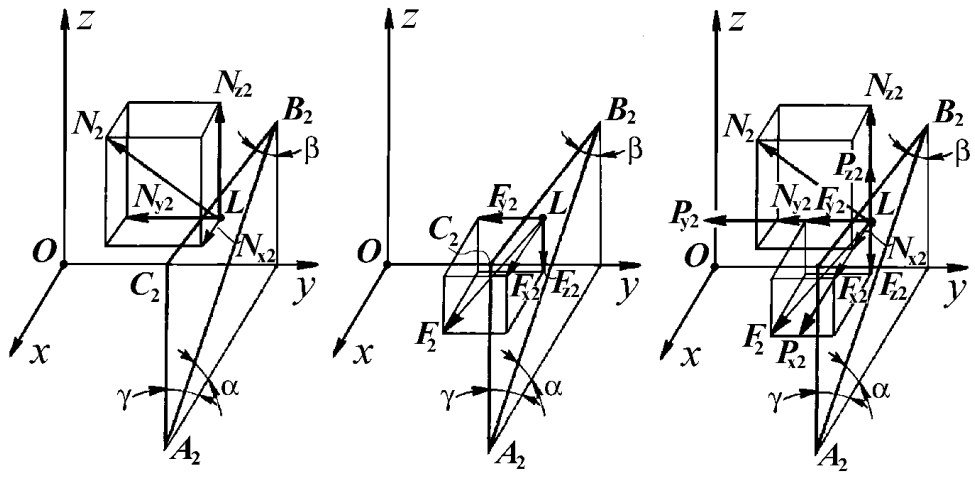
$$\left.\begin{aligned} \overline{P}_{x1} &= \overline{N}_{x1} + \overline{F}_{x1}, \\ \overline{P}_{y1} &= \overline{N}_{y1} + \overline{F}_{y1}, \\ \overline{P}_{z1} &= \overline{N}_{z1} + \overline{F}_{z1}. \end{aligned}\right\}, \tag{1}$$

gleich und

für die Fläche $A_2B_2C_2$

$$\left.\begin{aligned} \overline{P}_{x2} &= \overline{N}_{x2} + \overline{F}_{x2}, \\ \overline{P}_{y2} &= \overline{N}_{y2} + \overline{F}_{y2}, \\ \overline{P}_{z2} &= \overline{N}_{z2} + \overline{F}_{z2}. \end{aligned}\right\}, \tag{2}$$

gleich, wo $\overline{N}_{xi}, \overline{N}_{yi}, \overline{N}_{zi}$, ($i$ =1,2) – normale Reaktionen der Keiloberflächen als Projektionen an den entsprechende Achsen der Koordinaten; $\overline{F}_{xi}, \overline{F}_{yi}, \overline{F}_{zi}$, ($i$ =1,2) – Reibungskräfte der Bodenschicht an den Keiloberflächen auch in den Projektionen an entsprechenden Achsen der Koordinaten.




a b c

*Abbildung 2. Schema der Kräfte, die auf einen der Roderkeile wirken: a) normale Komponente/Kraft $\overline{N}_2$ und ihre Projektion auf die Koordinatenachse; b) reibungskraft $\overline{F}_2$ und ihre Projektion auf die Koordinatenachse;* **c)** *summarische Kräfte, die von der Keiloberfläche $P_{x2}, P_{y2}, P_{z2}$ übertragen werden.*

Analysieren wir die Wirkung jeder der Kräfte, die Bestandteile der Formel (1) und (2) sind und die die Kräfte bilden, die von den Rodekeilen auf die Hackfrucht (Wurzelkörper) übertragen werden. Senkrechte Kräfte der Keiloberflächen $\overline{P}'_{z1}, \overline{P}'_{z2}$ reißen die Hackfrucht aus der Erde (insbesondere den Teil der Hackfrucht, der im Boden eingeklemmt ist), die

waagerechten Querkräfte $\overline{P}'_{y1}, \overline{P}'_{y2}$ pressen die Hackfrucht wie einen Keilkörper aus der Erde heraus.

Die horizontalen Kräfte $\overline{P}'_{x1}, \overline{P}'_{x2}$ (auf Abb. 1 sind sie wie nur eine Kraft $\overline{P}'_{x1,2}$ abgebildet) wirken in Richtung der Bewegung des Roders und mittels der Kraft $\overline{Q}$ pressen die Wurzel aus dem Boden raus. Da die Kraft $\overline{Q}$ gegen die Bewegung des Roders gerichtet ist, ist es nicht zu vermeiden, dass die Wurzelkörpers manchmal beschädigt werden. Die Stützkraft $\overline{Q}$ kann je nach Erdbeschaffenheit und aus anderen Gründen gering sein, dann ist $P'_{x1,2} > Q$, so dass die Wurzel unter der Wirkung bestimmter horizontaler Kraft $R_t = P'_{x1,2} - Q$ nach vorne verschoben wird und dadurch zu Bruch der Wurzel im Bereich der Festklemmung in der nicht deformierter Bodenschicht führen kann. Aus diesem Grund kann die qualitative Arbeit der Rodeschare nur im Falle der Schaffung maßgeblicher Werte der Kräfte $\overline{P}_{yi}, \overline{P}_{zi}$ und umgekehrt der niedrigeren Werte der Kräfte. $\overline{P}_{xi}$ erreicht werden.

Die Werte und die Richtung der Kräfte $\overline{N}_i$, $\overline{F}_i$, die Kräfte $\overline{P}_{xi}, \overline{P}_{yi}, \overline{P}_{zi}$ ($i$=1,2) bestimmen, hängen von vielen Faktoren ab: vom Zustand und der Beschaffenheit der Erde, von der Größe der Kraft $\overline{R}$ der Bindung des Wurzelkörpers und der Erde, von geometrischen Parametern der Roderkeile und der Einstellungswinkel gegenüber der Richtung der Bewegung, der Geschwindigkeit der Vorwärtsbewegung u.ä. Weiterhin betrachten wir den Einfluß der Winkel $\alpha, \beta, \gamma$ auf die Werte der Kräfte $\overline{P}_{xi}, \overline{P}_{yi}, \overline{P}_{zi}$, ($\dot{i}$=1,2), die den Druck der Keiloberfläche auf die Bodenschicht und entsprechenderweise auf den Rübekörper erzeugen. Wie aus dem Schema Abb. 2 ersichtlich ist, wirkt im Kontaktpunkt $L$ (Abb. 2a) normale Reaktion $\overline{N}_2$, die in Form von Projektionen an die entsprechenden Achsen der Koordinaten $N_{x2}, N_{y2}, N_{z2}$) dargestellt werden kann. Nach der Errechnung der besagten Projektionen der normalen Reaktion $\overline{N}_2$ wird es möglich, auch die Reibungskraft $\overline{F}_2$ zu finden, die auch in Form von Projektionen an die gleichen Achsen der Koordinaten - $F_{x2}, F_{y2}, F_{z2}$ dargestellt werden kann (Abb. 2b).

Finden wir die Größen der Kräfte $\overline{N}_{xi}, \overline{N}_{yi}, \overline{N}_{zi}$, die entlang den Achsen der Koordinaten $x, y, z$ gerichtet sind und von der Richtung des selbigen Vektors der Kraft $\overline{N}_i$, ($i$=1,2) abhängen. Für die Ebene $A_1B_1C_1$ sind sie gleich:

$$\left.\begin{aligned} N_{x1} &= N_1 \cos\left(x, \hat{\overline{N}}_1\right), \\ N_{y1} &= N_1 \cos\left(y, \hat{\overline{N}}_1\right), \\ N_{z1} &= N_1 \cos\left(z, \hat{\overline{N}}_1\right). \end{aligned}\right\}, \tag{3}$$

für die Ebene $A_2B_2C_2$

$$\left.\begin{aligned} N_{x2} &= N_2 \cos\left(x, \hat{\overline{N}}_2\right), \\ N_{y2} &= -N_2 \cos\left(y, \hat{\overline{N}}_2\right), \\ N_{z2} &= N_2 \cos\left(z, \hat{\overline{N}}_2\right). \end{aligned}\right\}, \tag{4}$$

wo $\cos\left(x, \hat{\overline{N}}_i\right)$, $\cos\left(y, \hat{\overline{N}}_i\right)$, $\cos\left(z, \hat{\overline{N}}_i\right)$ – die richtenden Kosinuswerte des Kraftvektors $\overline{N}_i$ ($i$ =1,2 sind).

Und nun bestimmen wir die Abhängigkeit der gegebenen richtenden Kosinuswerte von den Winkeln $\alpha, \beta$, $\gamma$, die im Grunde genommen die Konstruktionsparameter des Roders bestimmen. Dazu bezeichnen wir die Abschnitte der Koordinatenachsen durch $a_i$, $b_i$, $c_i$, ($i$ =1,2), die der Arbeitskeilflächen abtrennen. Für die Fläche $A_1B_1C_1$ sind das die Abschnitte $a_1, b_1, c_1$, und für die Fläche $A_2B_2C_2$ – $a_2, b_2, c_2$. Dann sind die Koordinaten dreier Punkte an jeder Fläche ($A_1B_1C_1$; $A_2B_2C_2$) im übernommenen Koordinatensystem *Oxyz* entsprechenderweise gleich:

$$\left.\begin{aligned} &x_{A1} = a_1; \quad y_{A1} = -\frac{A_1A_2}{2}; \quad z_{A1} = 0; \\ &x_{B1} = 0; \quad y_{B1} = -\frac{A_1A_2}{2}; \quad z_{B1} = c_1; \\ &x_{C1} = 0; \quad y_{C1} = -\left[\left(\frac{A_1A_2}{2}\right) - b_1\right]; \quad z_{C1} = 0; \\ &x_{A2} = a_2; \quad y_{A2} = \frac{A_1A_2}{2}; \quad z_{A2} = 0; \\ &x_{B2} = 0; \quad y_{B2} = \frac{A_1A_2}{2}; \quad z_{B2} = c_2; \\ &x_{C2} = 0; \quad y_{C2} = \left(\frac{A_1A_2}{2}\right) - b_2; \quad z_{C2} = 0. \end{aligned}\right\} \tag{5}$$

Auf Grund der Hauptbestimmungen (Priwalov, 1960) und der Angaben (5) bilden wir eine Gleichung der Oberflächen $A_1B_1C_1$ und $A_2B_2C_2$ in Form von solchen Determinanten:

$$A_1B_1C_1: \begin{vmatrix} x_{A1}-a_1 & y_{A1}+\dfrac{A_1A_2}{2} & z_{A1} \\ -a_1 & b_1 & 0 \\ -a_1 & 0 & c_1 \end{vmatrix} = 0 \tag{6}$$

$$A_2B_2C_2: \begin{vmatrix} x_{A2}-a_2 & -y_{A2}-\dfrac{A_1A_2}{2} & z_{A2} \\ -a_2 & -b_2 & 0 \\ -a_2 & 0 & c_2 \end{vmatrix} = 0$$

Aus dem Schema auf Abb. 1 sehen wir, daß die Werte der entsprechenden Abschnitte $a_i$, $b_i$ $c_i$, ($i$ =1,2) an den Achsen gleich sind.

$$a_1 = \frac{b_1}{tg\gamma}; \quad a_2 = -\frac{b_2}{tg\gamma}; \quad c_1 = \frac{b_1}{tg\beta}; \quad c_2 = -\frac{b_2}{tg\beta}; \quad b_1 = b_2 = \frac{(A_1A_2 - C_1C_2)}{2} \tag{7}$$

Nach der Transformation der erhaltenen Determinanten bekommen wir folgende Gleichungen der Oberflächen:

$$A_1B_1C_1: \quad (x_{A1}-a_1)[b_1c_1 - 0\cdot 0] + \left(y_{A1}+\frac{A_1A_2}{2}\right)[0\cdot(-a_1) - (-a_1)\cdot c_1] + \\ + z_{A1}[(-a_1)\cdot 0 - b_1(-a_1)] = 0 \tag{8}$$

$$A_2B_2C_2: \quad (x_{A2}-a_2)[(-b_2)\cdot c_2 - 0\cdot 0] + \left(-y_{A2}-\frac{A_1A_2}{2}\right)\times \\ \times[0\cdot(-a_2) - (-a_2)\cdot c_2] + z_{A2}[(-a_2)\cdot 0 - (-b_2)(-a_2)] = 0$$

Nach der Substitution (7) in (8) und nach entsprechenden Transformationen bestimmen wir die Gleichungen der Roderscharoberflächen. Sie sehen folgenderweise aus:

$$A_1B_1C_1: \quad x_{A1}\,tg\gamma + y_{A1} + z_{A1}\,tg\beta + \frac{C_1C_2}{2} = 0 \tag{9}$$

$$A_2B_2C_2: \quad x_{A2}tg\gamma - y_{A2} + z_{A2}\,tg\beta - \frac{C_1C_2}{2} = 0 \tag{10}$$

Aus dem Abb. 3 wissen wir, dass für die Vektorwerte, die an der Normale zur Fläche angeordnet sind und den Ausdruck der Oberflächen (9) und (10) haben, die richtenden Kosinuswerte folgende Größen haben:

$$\begin{aligned}
\cos\left(x,\hat{\overline{N}}_i\right) &= \frac{tg\gamma}{\sqrt{tg^2\gamma+1+tg^2\beta}} \\
\cos\left(y,\hat{\overline{N}}_i\right) &= \frac{1}{\sqrt{tg^2\gamma+1+tg^2\beta}} \\
\cos\left(z,\hat{\overline{N}}_i\right) &= \frac{tg\beta}{\sqrt{tg^2\gamma+1+tg^2\beta}}
\end{aligned} \tag{11}$$

Nach der Substitutionformel (11) in (3) und (4) bekommen wir die Werte der Projektionen der Normal- bestandteile der Kräfte $\overline{N}_i$, ($i$ =1,2) der Oberflächen der Keile an entsprechenden Achsen der Koordinaten. Für die Fläche $A_1B_1C_1$ sind sie gleich:

$$\left.\begin{aligned}
N_{x1} &= \frac{N_1\, tg\gamma}{\sqrt{tg^2\gamma+1+tg^2\beta}}, \\
N_{y1} &= \frac{N_1}{\sqrt{tg^2\gamma+1+tg^2\beta}}, \\
N_{z1} &= \frac{N_1\, tg\beta}{\sqrt{tg^2\gamma+1+tg^2\beta}}.
\end{aligned}\right\} \tag{12}$$

für die Fläche $A_2B_2C_2$ :

$$\left.\begin{aligned}
N_{x2} &= \frac{N_2\, tg\gamma}{\sqrt{tg^2\gamma+1+tg^2\beta}}, \\
N_{y2} &= -\frac{N_2}{\sqrt{tg^2\gamma+1+tg^2\beta}}, \\
N_{z2} &= \frac{N_2\, tg\beta}{\sqrt{tg^2\gamma+1+tg^2\beta}}.
\end{aligned}\right\} \tag{13}$$

Nach der Errechnung der Werte der Projektionen der normalen Bestandteile der Keiloberflächen kann man andere Kräfte bestimmen, die von den Keilen auf die Bodenschicht und von da direkt auf den Wurzelkörper übertragen werden.

Weiterhin betrachten wir unter welchen Hauptfaktoren und Kräften beim Roden mit den Scharrodern normale Reaktionen $\overline{N}_1$ und $\overline{N}_2$ der Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ entstehen sowie die Reibungskräfte $\overline{F}_1$ und $\overline{F}_2$ der Bodenschicht samt Hackfrüchten an den bereits erwähnten Keiloberflächen, d.h. bestimmen wir das physikalische Wesen dieser Kräfte. Auf die Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ wirkt die Kraft des Gewichtes $\overline{G}$ der Bodenschicht samt der Hackfrucht. Nehmen wir an, daß die Gewichtskraft der Boden-

schicht und der Wurzelkörper an beide Roderkeile $A_1B_1C_1$ und $A_2B_2C_2$ gleich verteilt wird, d.h. $G_1 = G_2 = \frac{1}{2}G$. Die Kräfte $\overline{G_1}$ und $\overline{G_2}$ rufen statische Komponenten normaler Reaktionen seitens der Wirkoberflächen der Keile ( $\overline{N}_{G1}$, $\overline{N}_{G2}$ ) hervor. Infolge der Bewegung der Schicht an den besagten Oberflächen entstehen infolge der Gewichtskräften $\overline{G_1}$ und $\overline{G_2}$ die Komponenten der Reibungskräfte $\overline{F}_{G1}$ und $\overline{F}_{G2}$. Zum Zweiten, wirken auf die Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ entsprechenderweise die Trägheitskräfte $\bar{I}_1$ und $\bar{I}_2$ der sich bewegenden Bodenschicht. Betrachten wir die Wirkung der gegebenen Kräfte als kontinuierlichen Ablauf des Schlages der Bodenpartikeln an die Keilflächen $A_1B_1C_1$ und $A_2B_2C_2$. Infolge des ununterbrochenen Stromes der Erdschicht entsteht der Stossimpuls, der gleich ist:

$$\bar{I}_1 dt = \bar{I}_2 dt = \left(\overline{V}_a - \overline{V}_o\right) dm \tag{14}$$

wo:

$\overline{V}_a$ – absolute Geschwindigkeit der Bewegung der Bodenpartikeln mit der Masse $dm$

$\overline{V}_o$ – die Anfangsgeschwindigkeit der Partikeln vor dem Zusammenstoß mit dem Keil.

Da die Anfangsgeschwindigkeit $\overline{V}_o = 0$ ist, so bekommen wir aus der Gleichung (14)

$$\bar{I}_1 = \bar{I}_2 = \frac{dm}{dt} \cdot \overline{V}_a \tag{15}$$

Die Erdmenge, die an die Keiloberfläche in einer bestimmten Zeiteinheit gelangt, kann folgenderweise bestimmt werden:

$$\frac{dm}{dt} = ab \frac{\gamma_{об.}}{g} V \tag{16}$$

wo:

$a$ und $b$ – dicke und Breite der Bodenschicht ist, die mit jedem Keil getrennt geschnitten wird;

$\gamma_{об.}$ – das räumliche Erdgewicht;

$g$ – Beschleunigung des freien Fallens und

$V$ – Geschwindigkeit der Vorwärtsbewegung des Roders ist.

Setzen wir (16) in (15) ein, bekommen wir

$$I_1 = I_2 = ab \frac{\gamma_{об.}}{g} V \cdot V_a \tag{17}$$

Die Trägheitskräfte $\bar{I}_1$ und $\bar{I}_2$ wirken gegen die Vektorrichtung $\overline{V}_a$ der absoluten Geschwindigkeit der Bewegung der Bodenschicht.

Für die Bestimmung der Bahnkurve und der Geschwindigkeit der Bewegung der Bodenschicht an der Keiloberfläche nehmen wir laut (Saika, 2001) an, daß sich die Länge der

Bodenschicht beim Schneiden und der Bewegung an dem Keil nicht ändert, deshalb ist die Geschwindigkeit der relativen Bewegung $V_r$ der Bodenschicht an der Keiloberfläche der Geschwindigkeit deren transportablen Bewegung $V$ gleich, d.h. der Geschwindigkeit der Vorwärtsbewegung des Scharroders ). Es kann ähnlich wie in (Saika, 2001) angenommen werden, dass bei der Bewegung der Bodenschicht im Arbeitsbereich des Roders die Bahnkurve der Bewegung des Schichtbodenpunktes an der Keiloberfläche $A_1B_1C_1$, die sich vor dem Schneiden am Anfang im Punkt $O_1$ befand, ist eine gerade Linie $A_1O_1'$. Eine absolute Bahnkurve ist die gerade Linie $O_1O_1'$, wobei $O_1'M_1 = O_1M_1$ und $\angle O_1'A_1M_1 = \angle O_1A_1M_1 = \gamma$ ist.

Genauso bei der Bewegung der Bodenschicht an der Oberfläche $A_2B_2C_2$ - $O_2'M_2 = O_2M_2$ und $\angle O_2'A_2M_2 = \angle O_2A_2M_2 = \gamma$. Dabei sind die relative und absolute Bahnkurven der Bewegung des Bodenschichtpunktes entsprechend gerade Linien $A_2O_2'$ und $O_2O_2'$ ($O_2'M_2 = O_2M_2$, $\angle O_2'A_2M_2 = \angle O_2A_2M_2 = \gamma$ ).

Daraus kann man schließen, daß die Bahnkurven der relativen Bewegung unterschiedlicher Punkte der Bodenschicht, die die Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$, berühren, gerade Linien sind, die den geraden Linien $A_1O_1'$ und $A_2O_2'$ parallel sind, und die Bahnkurven der absoluten Bewegung sind gerade Linien, die den Linien $O_1O_1'$ und $O_2O_2'$ parallel sind.

Somit sind die Reibungskräfte $\overline{F}_1$ und $\overline{F}_2$ der Bodenschicht an den Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ den geraden Linien $A_1O_1'$ und $A_2O_2'$ parallel, und der Richtung der relativen Bewegung der Bodenschicht an den Keilen entgegengesetzt gerichtet. Gleiche Schlüsse kann man über die Bewegung des Rübenkörpers und die Richtung der Reibungskräfte beim unmittelbaren Kontakt des Rübenkörpers mit den Keiloberflächen ziehen, da die Bewegungsbahnkurve durch die geometrischen Parameter der Rodekeile bestimmt ist.

Die Kräfte der Trägheit $\overline{I}_1$ und $\overline{I}_2$ der sich mit dem Rübenkörper bewegenden Bodenschicht rufen dynamische Bestandteile/Komponenten der normalen Reaktionen $\overline{N}_{I1}$ und $\overline{N}_{I2}$ hervor.

Normale Bestandteile/Komponenten der Reaktionen der Keiloberflächen, die infolge der Wirkung der Gewichtskraft (G) der Bodenschicht samt Rübenkörper entstehen, sind gleich

$$N_{G1} = N_{G2} = \frac{G}{2\left(\cos\theta - f\sin\theta\sin\gamma\right)} \tag{18}$$

wo:

$\theta$ – zweiflächiger Winkel ($\angle B_1M_1O_1$) zwischen der unteren Grundfläche/Grundlinie $A_1O_1C_1$ und der Keillauffläche $A_1B_1C_1$;

$f$ – der Gleitreibungskoeffizient des Bodens an der Keillauffläche.

Beim unmittelbaren Kontakt des Rübenkörpers mit der Keillauffläche $f$ ist der Gleitreibungskoeffizient des Rübenkörpers an der Keillauffläche.

Ein Teil der Reibungskraft, die unter der Wirkung der Gewichtskraft $G$

bei der Bewegung der Bodenschicht samt Rübenkörper entstehen, ist gleich:

$$F_{G1} = F_{G2} = \frac{Gf}{2(\cos\theta - f\sin\theta\sin\gamma)} \tag{19}$$

Da die absolute Geschwindigkeit der Bewegung der Schicht samt Rübekörper $V_a$ von der Geschwindigkeit der Vorwärtsbewegung des Roders $V$

$$V_a = 2V\sin\frac{\theta}{2}\cdot\sin\gamma \tag{20}$$

abhängig ist, so ergibt sich aus (17), daß die Kräfte der Bodenschicht

$$I_1 = I_2 = \frac{2ab\cdot\gamma_{об.}}{g}\cdot V^2\sin\frac{\theta}{2}\sin\gamma \tag{21}$$

gleich sind.

Die Bestandteile der normalen dynamischen Reaktionen der Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ sind (bei der Wirkung der Trägheitskräfte $\bar{I}_1$ und $\bar{I}_2$)

$$N_{I1} = N_{I2} = I_1\frac{\cos\frac{\theta}{2}}{\cos\theta - f\sin\gamma\cdot\sin\theta}$$

gleich.

Bei Berücksichtigung (21) ergibt sich

$$N_{I1} = N_{I2} = \frac{ab\cdot\gamma_{об.}}{g}\cdot V^2\cdot\frac{\sin\theta\cdot\sin\gamma}{(\cos\theta - f\sin\gamma\cdot\sin\theta)} \tag{22}$$

Die Bestandteile der Reibungskräfte, die infolge der Wirkung der Trägheitskräfte der Bewegung der Bodenschicht samt Rübenkörper der an den Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ (Saika, 2001) entstehen, sind gleich

$$F_{I1} = F_{I2} = f\cdot\frac{ab\cdot\gamma_{об.}}{g}\cdot\frac{V^2\sin\theta\cdot\sin\gamma}{(\cos\theta - f\sin\gamma\cdot\sin\theta)} \tag{23}$$

Für gutes Funktionieren der Scharroder ist die Bodenstützkraft $\overline{Q}$ notwendig, die wie oben gezeigt horizontal der Achse entlang $Ox$ und der Bewegungsrichtung des Roder entgegengesetzt gerichtet ist . Maximale Bedeutung der Bodenstützkraft ist gleich (Saika, 2001).

$$Q_{\max.} = 2ab \cdot \sigma_{zp.} \tag{24}$$

wo:

$\sigma_{zp.}$ – zulässige Spannung der Bodenkompression; Umrechnungsfaktor 2 zeigt, daß die Kraft $\overline{Q}$ gleichzeitig an zwei Keilen entsteht/sich bildet.

Bei der weiteren Bewegung des Rübenkörpers in der Bodenschicht verringert sich im Scharroder die Bodenstützkraft $\overline{Q}$ maßgeblich wegen der Lockerung des Bodens und im hinteren Teil des Durchgangs ist die Wirkung dieser Kraft gering. In diesem Fall kann man die Stützkraft $\overline{Q}$ mit der Formel $Q = 2ab \cdot k_{y\partial.}$ bestimmen, ($k_{y\partial.}$ – der spezifische Koeffizient des Widerstandes des aufgelockerten Bodens ist).

Nehmen an, dass die Kraft des Widerstandes $\overline{R}$ (das heißt, die Haftkraft des Rübenkörpers mit dem Boden) entgegengesetzt der Richtung der Rodekraft des Rübenkörpers aus dem Boden gerichtet ist.

Wie schon erwähnt wurde, kann die Widerstandskraft $\overline{R}$ in zwei Bestandteile zerlegt werden: die Kraft des Widerstandes der senkrechten Bewegung des Rübenkörpers $\overline{R}_z$ und die Kraft des Widerstandes der horizontalen Bewegung des Rübenkörpers $\overline{R}_x$. Bei der horizontalen Bewegung des Rübenkörpers im Roder entstehen ausgerechnet unter der Kraftwirkung $\overline{R}_x$ die biegenden Deformationen bei dessen Ziehen aus der Erde. Die biegenden Deformationen bringen zur Beschädigung des Rübenkörpers meistens bei der maßgeblichen Haftkraft mit dem Boden. Das geschieht in der Regel infolge des unmittelbaren Kontaktes des Rübenkörpers mit den Keilflächen der Schare im hinteren Teil des Durchganges/Arbeitsbettes des Roders. Deshalb ist das Zusammenwirken des Rübenkörpers mit den Scharoberflächen im verjüngten Durchgang des Roders abgesondert zu untersuchen und die Differentialgleichungen der Bewegung des Rübenkörpers bei dessen unmittelbaren Roden aus dem Boden zusammenzustellen. Die Kräfte des Zusammenwirkens des Rübenkörpers mit den Keiloberflächen sollen in diesem Fall den Kräften des Zusammenwirkens der Bodenschicht mit den Keiloberflächen fast identisch sein. Deshalb können wir annehmen, daß diese Kräfte gleich sind und dass das Roden des Rübenkörpers aus dem Boden unter der Wirkung der Kräfte erfolgt, die auf Abb. 3 dargestellt sind.

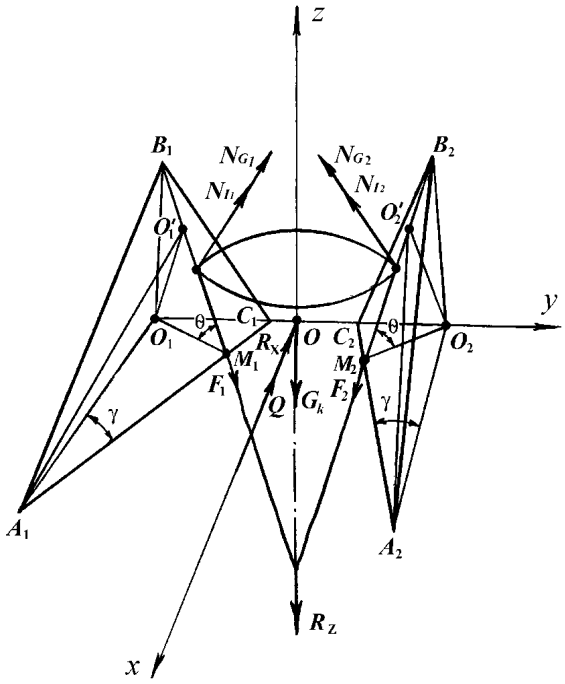



*Abbildung 3. Kraftzusammenwirken des Rübenkörpers mit den Keilen des Scharroders*

Leiten wir die Differentialgleichung der Bewegung des Rübenkörpers ab. In der Vektorform sieht diese Gleichung so aus

$$m\overline{a} = \overline{N}_{G1} + \overline{N}_{G2} + \overline{N}_{I1} + \overline{N}_{I2} + \overline{Q} + \overline{R}_x + \overline{R}_z + \overline{F}_1 + \overline{F}_2 + \overline{G}_k , \tag{25}$$

wo:

$m$ – Masse des Rübenkörpers,

$\overline{a}$ – Beschleunigung des Rodenprozesses des Rübenkörpers aus dem Boden,

$\overline{R}_x$, $\overline{R}_z$ – horizontale und senkrechte Bestandteile der Widerstandskraft $\overline{R}$ der Haftung des Rübenkörpers mit dem Boden,

$\overline{F}_1$, $\overline{F}_2$ – summarische Reibungskräfte, die bei der Bewegung des Rübenkörpers an den Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ entstehen,

$G_k$ – ist Gewicht des Rübenkörpers.

Es ist offensichtlich, dass die Reibungskräfte $F_1$ und $F_2$ in (25) sind gleich

$$F_1 = f_1\left(N_{G1} + N_{I1}\right), \quad F_2 = f_1\left(N_{G2} + N_{I2}\right), \tag{26}$$

wo:

$f_1$ – der Reibungskoeffizient der Seitenfläche des Rübenkörpers an den Keiloberflächen.

Die Differentialgleichung (25) zeichnen wir in den Projektionen an die Achse des kartesischen Koordinatensystems $xOyz$ auf. Infolgedessen, dass die Bestandteile der normalen Reaktionen an den Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ an der Achse $Oy$ der Größe nach gleich und entgegengerichtet sind (d.h., der Rübenkörper berührt zu gleicher Zeit zwei Keiloberflächen und wird im weiteren Verlauf zwischen beiden geklemmt), so findet das Roden des Rübenkörpers eigentlich im Bereich der Fläche $xOz$ statt. Deswegen wird die Differenzialgleichung der Bewegung der Rübenkörper (25) im Vektorform in das System folgender zweier Differentialgleichungen abgeleitet:

$$\left.\begin{aligned} m\ddot{x} &= N_{G1x} + N_{G2x} + N_{I1x} + N_{I2x} - Q - R_x + F_{1x} + F_{2x} \\ m\ddot{z} &= N_{G1z} + N_{G2z} + N_{I1z} + N_{I2z} - R_z - F_{1z} - F_{2z} - G_k \end{aligned}\right\} \tag{27}$$

Bestimmen wir die Projektionen der Kräfte, die zum erwähnten System der Differenzialgleichungen (27) gehören. Die Projektionen der normalen Reaktionen der Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ an der Achse $x$ und $z$ bestimmen wir nach den Formeln (12) und (13). Sie sind gleich

$$N_{G1x} = N_{G2x} = \frac{N_{G1} \cdot tg\gamma}{\sqrt{tg^2\gamma + 1 + tg^2\beta}} \tag{28}$$

oder unter Berücksichtigung von (18)

$$N_{G1x} = N_{G2x} = \frac{G \cdot tg\gamma}{2\left(\cos\theta - f\sin\theta \cdot \sin\gamma\right)\sqrt{tg^2\gamma + 1 + tg^2\beta}} \tag{29}$$

Genauso bestimmen wir aus den Formeln (12), (13) und (22)

$$N_{I1x} = N_{I2x} = \frac{ab \cdot \gamma_{об.}}{g} V^2 \cdot \frac{\sin\theta \cdot \sin\gamma \cdot tg\gamma}{\left(\cos\theta - f\sin\theta \cdot \sin\gamma\right)\sqrt{tg^2\gamma + 1 + tg^2\beta}} \tag{30}$$

$$N_{I1z} = N_{I2z} = \frac{ab \cdot \gamma_{об.}}{g} V^2 \cdot \frac{\sin\theta \cdot \sin\gamma \cdot tg\beta}{\left(\cos\theta - f\sin\theta \cdot \sin\gamma\right)\sqrt{tg^2\gamma + 1 + tg^2\beta}} \tag{31}$$

Da die Reibungskräfte entgegengesetzt der Richtung der Bahnkurve der relativen Bewegung der Bodenschicht und des Rübenkörpers an den Keiloberflächen $A_1B_1C_1$ und $A_2B_2C_2$ (das heißt parallel $A_1O_1'$ und $A_2O_2'$) sind, so sind ihre Projektionen an der Koordinatenachse gleich:

$$\left.\begin{aligned} F_{1x} &= F_1\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right) \\ F_{1y} &= -F_1\cos\gamma\cdot\sin\gamma\left(1-\cos\theta\right) \\ F_{1z} &= -F_1\sin\gamma\cdot\sin\theta\,, \\ F_{2x} &= F_2\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right) \\ F_{2y} &= F_2\cos\gamma\cdot\sin\gamma\left(1-\cos\theta\right) \\ F_{2z} &= -F_2\sin\gamma\cdot\sin\theta \end{aligned}\right\} \tag{32}$$

Fernerhin führen wir folgende Bezeichnungen ein:

$$\overline{N}_1 = \overline{N}_{G1} + \overline{N}_{I1}, \quad N_2 = \overline{N}_{G2} + \overline{N}_{I2}$$
$$\overline{F}_1 = \overline{F}_{G1} + \overline{F}_{I1}, \quad \overline{F}_2 = \overline{F}_{G2} + \overline{F}_{I2}$$

Dann erhalten wir:

$$\begin{aligned} N_{1x} &= N_{G1x} + N_{I1x} & N_{2x} &= N_{G2x} + N_{I2x} \\ F_{1x} &= F_{G1x} + F_{I1x} & F_{2x} &= F_{G2x} + F_{I2x} \\ N_{1z} &= N_{G1z} + N_{I1z} & N_{2z} &= N_{G2z} + N_{I2z} \\ F_{1z} &= F_{G1z} + F_{I1z} & F_{2z} &= F_{G2z} + F_{I2z} \end{aligned}$$

Danach sieht das System der Differentialgleichungen (27) nach der Substitution aller bekannten Größen folgenderweise aus:

$$\left.\begin{aligned} m\ddot{x} &= N_{1x} + N_{2x} - R_x + F_{1x} + F_{2x} - Q \\ m\ddot{z} &= N_{1z} + N_{2z} - R_z - F_{1z} - F_{2z} - G_k \end{aligned}\right\} \tag{33}$$

Es ist offensichtlich, dass der Vorgang des Rodens der Rübenkörper aus dem Boden möglich wäre, wenn

$$N_{1z} + N_{2z} - F_{1z} - F_{2z} - G_k > R_z \tag{34}$$

oder unter Berücksichtigung von formel (29), (31) und (26) wir folgendes erhalten:

$$\frac{tg\beta}{\sqrt{tg^2\gamma + 1 + tg^2\beta}}\left[\frac{G}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \frac{2ab\cdot\gamma_{об.}\cdot V^2\sin\theta\cdot\sin\gamma}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)}\right] -$$
$$-\frac{Gf_1\cdot\sin\theta\cdot\sin\gamma}{\cos\theta - f\sin\theta\cdot\sin\gamma} - \frac{2ab\cdot\gamma_{об.}\cdot V^2\sin^2\theta\cdot\sin^2\gamma\cdot f_1}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)} - G_k > R_z \tag{35}$$

Bei der Erfüllung der Bedingung (35) erfolgt das Roden der Rübenkörper aus der Erde. Der linke Teil der Formel (35) stellt dar die Aufzeichnung der Kraft beim Roden der Rübenkörper in Richtung der Achse $Oz$ unter der Bedingung des vorhandenen Kontaktes der Rübenkörper und den Keiloberflächen.

Wenn wir das System der Differenzialgleichungen (33) zweimal integrieren, erhalten wir den Wert der Geschwindigkeit und der Bewegung der Rübenkörper als Funktion der Zeit $t$.

Die ersten Integrale sind gleich:

$$\begin{aligned} \dot{x} &= \frac{1}{m}\left(N_{1x} + N_{2x} - R_x + F_{1x} + F_{2x} - Q\right)t + C_1 \\ \dot{z} &= \frac{1}{m}\left(N_{1z} + N_{2z} - R_z - F_{1z} - F_{2z} - G_k\right)t + L_1 \end{aligned} \tag{36}$$

und die zweiten Integrale sind gleich:

$$\begin{aligned} x &= \frac{1}{m}\left(N_{1x} + N_{2x} - R_x + F_{1x} + F_{2x} - Q\right)\frac{t^2}{2} + C_1 t + C_2 \\ z &= \frac{1}{m}\left(N_{1z} + N_{2z} - R_z - F_{1z} - F_{2z} - G_k\right)\frac{t^2}{2} + L_1 t + L_2 \end{aligned} \tag{37}$$

wo:

$C_1, C_2, L_1, L_2$ – willkürliche Konstantwerte sind.

Für das Auffinden der willkürlichen Konstantwerte geben wir Anfangs- und Grenzbedingungen vor. Bei $t_o = 0$:

$$x = x_o, \quad z = -h, \quad \dot{x} = 0, \quad \dot{z} = 0,$$

und bei $t = t_1$:

$$x = x_1, \quad z = 0, \quad \dot{x}_1 = V_1,$$

wo:

$t_o$ – Anfangszeitpunkts des Rodens;

$t_1$ – Endzeitpunkt des Rodens der Rüben aus der Erde;

$x_o$ – Abstand vom Anfang der Koordinaten bis zu der senkrechten Achse des Rübenkörpers zum Zeitpunkt $t_o$;

$x_1$ – Abstand vom Anfang der Koordinaten bis zu der senkrechten Achse des Rübenkörpers zum Endzeitpunkt des Rodens $t_1$;

$h$ – Tiefe des Sitzes des Rübenkörpers im Boden;

$V_1$ – Geschwindigkeit der Bewegung des Rübenkörpers im Endzeitpunkt des Rodens $t_1$.

Ausgehend von Ausgangsbedingungen bekommen wir die Werte der willkürlichen konstanten Größen:

$$C_1 = 0, \quad L_1 = 0, \quad C_2 = x_o, \quad L_2 = -h. \tag{38}$$

Nach der Substitutionformel (38) in (36) in (37) bekommen wir

$$\dot{x} = \frac{1}{m}\left(N_{1x} + N_{2x} - R_x + F_{1x} + F_{2x} - Q\right)t, \tag{39}$$

$$\dot{z} = \frac{1}{m}\left(N_{1z} + N_{2z} - R_z - F_{1z} - F_{2z} - G_k\right)t, \tag{40}$$

$$x = \frac{1}{m}\left(N_{1x} + N_{2x} - R_x + F_{1x} + F_{2x} - Q\right)\frac{t^2}{2} + x_o, \tag{41}$$

$$z = \frac{1}{m}\left(N_{1z} + N_{2z} - R_z - F_{1z} - F_{2z} - G_k\right)\frac{t^2}{2} - h. \tag{42}$$

Die oben erhaltenen Werte für die Kräfte (28) – (32) setzen wir in die Formeln (39) – (42) ein. Nach all den nötigen Transformationen bekommen wir:

$$\dot{x} = \frac{1}{m}\left\{\frac{tg\gamma}{\sqrt{tg^2\gamma + 1 + tg^2\beta}}\left[\frac{G}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \frac{2ab\cdot\gamma_{об.}\cdot V^2\cdot\sin\theta\cdot\sin\gamma}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)}\right] + \right.$$
$$+ \frac{G\cdot f_1\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right)}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \tag{43}$$
$$\left. + \frac{2f_1\cdot ab\cdot\gamma_{об.}\cdot V^2\sin\theta\cdot\sin\gamma\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right)}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)} - 2ab\cdot k_{уд.} - R_x\right\}t,$$

$$\dot{z} = \frac{1}{m}\left\{\frac{tg\beta}{\sqrt{tg^2\gamma + 1 + tg^2\beta}}\left[\frac{G}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \frac{2ab\cdot\gamma_{об.}\cdot V^2\cdot\sin\theta\cdot\sin\gamma}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)}\right] - \right.$$
$$\tag{44}$$
$$\left. - \frac{G\cdot f_1\cdot\sin\theta\cdot\sin\gamma}{\cos\theta - f\sin\theta\cdot\sin\gamma} - \frac{2f_1\cdot ab\cdot\gamma_{об.}\cdot V^2\sin^2\theta\cdot\sin^2\gamma}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)} - G_k - R_z\right\}t,$$

$$x = \frac{1}{m}\left\{\frac{tg\gamma}{\sqrt{tg^2\gamma + 1 + tg^2\beta}}\left[\frac{G}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \frac{2ab\cdot\gamma_{об.}\cdot V^2\cdot\sin\theta\cdot\sin\gamma}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)}\right] + \right.$$
$$+ \frac{Gf_1\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right)}{\cos\theta - f\sin\theta\cdot\sin\gamma} + \tag{45}$$
$$\left. + \frac{2f_1\cdot ab\cdot\gamma_{об.}\cdot V^2\sin\theta\cdot\sin\gamma\left(\cos^2\gamma + \sin^2\gamma\cdot\cos\theta\right)}{g\left(\cos\theta - f\sin\theta\cdot\sin\gamma\right)} - 2ab\cdot k_{уд.} - R_x\right\}\frac{t^2}{2} + x_o,$$

$$z=\frac{1}{m}\left\{\frac{tg\beta}{\sqrt{tg^2\gamma+1+tg^2\beta}}\left[\frac{G}{\cos\theta-f\sin\theta\cdot\sin\gamma}+\frac{2ab\cdot\gamma_{об.}\cdot V^2\cdot\sin\theta\cdot\sin\gamma}{g\left(\cos\theta-f\sin\theta\cdot\sin\gamma\right)}\right]-\right.$$

$$\left.-\frac{G\cdot f_1\cdot\sin\theta\cdot\sin\gamma}{\cos\theta-f\sin\theta\cdot\sin\gamma}-\frac{2f_1\cdot ab\cdot\gamma_{об.}\cdot V^2\sin^2\theta\cdot\sin^2\gamma}{g\left(\cos\theta-f\sin\theta\cdot\sin\gamma\right)}-G_k-R_z\right\}\frac{t^2}{2}-h,. \tag{46}$$

Aus der Formel (42) kann man die Zeit des Rodens der Rübenkörper aus dem Boden $t_1$ bestimmen. Sie ist gleich:

$$t_1=\sqrt{\frac{2mh}{N_{1z}+N_{2z}-F_{1z}-F_{2z}-R_z-G_k}} \tag{47}$$

Wenn wir in die Formel (47) die oben erhaltenen Werte der Kräfte einsetzen und sie entsprechenderweise transformieren, bekommen wir die Endformel der Zeit $t_1$ :

$$t_1=\sqrt{\frac{2mgh\left(\cos\theta-f\sin\theta\cdot\sin\gamma\right)\sqrt{tg^2\gamma+1+tg^2\beta}}{\left(Gg+2ab\cdot\gamma_{об.}\cdot V^2\sin\theta\sin\gamma\right)\left(tg\beta-\sin\gamma\cdot\sin\theta\cdot f_1\times\right.}} \tag{48}$$

$$\left.\cdot\overline{\times\sqrt{tg^2\gamma+1+tg^2\beta}}\right)-\left(R_z+G_k\right)\mathrm{g}\left(\cos\theta-f\sin\theta\cdot\sin\gamma\right)\sqrt{tg^2\gamma+1+tg^2\beta}}$$

Da $t_1$ die Rodenzeit der Rübenkörper mit Roderscharen ist, so kann die Formel (48) für die Bestimmung der Leistung des Zuckerrübenerntegerätes, ausgerüstet mit diesen Werksorganen, verwendet werden.

Wird die Bedingung (35) nicht erfüllt, d.h. es besteht gegensätzliche Ungleichheit, der Rübenkörper haftet mit dem Boden, so dass seine Bewegung der Achse $Oz$ entlang ausbleibt. Und trotzdem erfolgt unter der Wirkung der Kräfte, die in der ersten Gleichung des Systems (33) enthalten sind, nämlich die Kraft

$$P_x=N_{1x}+N_{2x}+F_{1x}+F_{2x}-Q \tag{49}$$

die die Widerstandskraft $R_x$ (die Haftung des Rübenkörpers mit der Erde) überwindet, verhält sich die Hackfrucht wie ein Krafträger und biegt sich, weil der obere Teil des Rübens sich in Richtung der Kraftwirkung $P_x$ um Einiges verschiebt, infolgessen die Wurzel brechen kann.

Deswegen gibt es eine bestimmte zulässige Kraft $\left[P_x\right]$, bei der keine Beschädigung des Rübenkörpers stattfindet. Wenn man in die Formel (49) anstatt der Kraft $\left[P_x\right]$ deren zulässigen Wert einsetzt, bekommen man:

$$\left[P_x\right]=N_{1x}+N_{2x}+F_{1x}+F_{2x}-Q \tag{50}$$

oder unter Berücksichtigung der Bedeutungen der Kräfte aus dem rechten Teil dieser Formel

$$[P_x] = N_{G1x} + N_{G2x} + N_{I1x} + N_{I2x} + F_{G1x} + F_{G2x} + F_{I1x} + F_{I2x} - Q \tag{51}$$

Wenn wir also die symmetrische Anordnung der Roderkeile berücksichtigen, bekommen wir:

$$[P_x] = 2N_{G1x} + 2N_{I1x} + 2F_{G1x} + 2F_{I1x} - Q \tag{52}$$

Die Formel (52) wird dann so aussehen:

$$2N_{I1x} + 2F_{I1x} = [P_x] - 2N_{G1x} - 2F_{G1x} - Q \tag{53}$$

Ersetzen wir die Kräfte in der Formel (53) durch ihre oben erhaltenen Werte. Dann bekommen wir:

$$\begin{aligned} &\frac{2ab\cdot\gamma_{об.}}{g}\cdot\frac{V^2\sin\theta\cdot\sin\gamma\cdot tg\gamma}{(\cos\theta - f\sin\theta\cdot\sin\gamma)\sqrt{tg^2\gamma+1+tg^2\beta}} + \\ &+2f_1\frac{ab\cdot\gamma_{об.}\cdot V^2\sin\theta\cdot\sin\gamma(\cos^2\gamma+\sin^2\gamma\cdot\cos\theta)}{g(\cos\theta - f\sin\theta\cdot\sin\gamma)} = \\ &=[P_x] - \frac{G\cdot tg\gamma}{(\cos\theta - f\sin\theta\cdot\sin\gamma)\sqrt{tg^2\gamma+1+tg^2\beta}} - \\ &-\frac{f_1G(\cos^2\gamma+\sin^2\gamma\cdot\cos\theta)}{(\cos\theta - f\sin\theta\cdot\sin\gamma)} + 2ab\cdot k_{уд.} \end{aligned} \tag{54}$$

Auf Grund der Formel (54) errechnen wir die Geschwindigkeit $V$ der Vorwärtsbewegung des Scharroders, bei der die Wurzelkörper nicht beschädigt werden:

$$\begin{aligned} V = \sqrt{\frac{g([P_x]+2ab\cdot k_{уд.})(\cos\theta - f\sin\theta\cdot\sin\gamma)\sqrt{tg^2\gamma+1+tg^2\beta} - gG\cdot tg\gamma -}{2ab\cdot\gamma_{об.}\cdot\sin\theta\cdot\sin\gamma\left[tg\gamma + f_1(\cos^2\gamma+\sin^2\gamma\cdot\cos\theta)\times\right.}} \\ \left.\frac{-f_1gG(\cos^2\gamma+\sin^2\gamma\cdot\cos\theta)\sqrt{tg^2\gamma+1+tg^2\beta}}{\times\sqrt{tg^2\gamma+1+tg^2\beta}}\right] \end{aligned} \tag{55}$$

Somit sind endgültig kinematische Parameter des Rodens der Rüber aus dem Boden mit Scharrodern, die durch geometrische Parameter ausgedrückt sind, gefunden und die die Bedingungen für die qualitative Ausführung des gegebenen technologischen Prozesses berücksichtigen.

Für die praktische Nutzung der Formel (55) muss man das Verhältnis bestimmen zwischen dem Zweikeilwinkel $\theta$ und den Winkeln $\beta$ und $\gamma$, die eigentlich alle Winkelpara-

meter der Keile bestimmen, weil der dritte Winkel $\alpha$ durch die Winkel $\beta$ und $\gamma$ ausgedrückt werden kann. Wie aus dem Schema (Abb. 1) zu ersehen ist:

$$tg\alpha = \frac{c_1}{a_1} \tag{56},$$

können wir unter Berücksichtigung (7) bekommen:

$$tg\alpha = \frac{tg\gamma}{tg\beta} \tag{57}$$

Somit kann der Winkel $\theta$ durch die Winkel $\beta$ und $\gamma$ bestimmt werden. Mittels des Schemas (Abb. 1) kann man folgende Relationen feststellen:

$$tg\theta = \frac{O_1B_1}{O_1M_1} \tag{58}$$

und

$$O_1M_1 = O_1A_1 \cdot \sin\gamma \tag{59}$$

Wenn man berücksichtigt, dass $O_1B_1 = c_1$ und $O_1A_1 = a_1$ gleich ist, bekommen wir

$$tg\theta = \frac{c_1}{a_1 \sin\gamma} \tag{60}$$

Nach der Substitution (7) in (60) bekommen wir

$$tg\theta = \frac{1}{\cos\gamma \cdot tg\beta} \tag{61}$$

oder

$$tg\theta = \frac{\cos\beta}{\sin\beta \cdot \cos\gamma} \tag{62}$$

infolgedessen wir endgültig die Größe des Winkels $\theta$ erhalten:

$$\theta = arctg\frac{\cos\beta}{\sin\beta \cdot \cos\gamma} \tag{63}$$

Indem wir geometrische Parameter der Scharroderkeile (Winkel $\beta$ und $\gamma$) ändern, können wir auf Grund der oben erhaltenen analytischen Abhängigkeiten benötigte kinematische Parameter des Roderwerkzeuges unter der Bedingung der Unbeschädigkeit der Hackfrüchte bestimmen. Mit Hilfe der Formel (55) kann die Abhängigkeit der zulässigen Geschwindigkeit $V$ der Vorwärtsbewegung des Roders von seinen Winkeln $\beta$ und $\gamma$ feststellen ohne seine anderen Kostruktionsparameter zu ändern.

Entsprechend dem zusammengesetzten EDV-Programm wurde die zulässige Geschwindigkeit $V$ der Bewegung des Scharroders bei unterschiedlichen Winkelgrößen $\gamma$ und eini-

gen fixierten Winkelgrößen $\beta$ (unter der Bediedung der Unbeschädigkeit des Rübekörpers) errechnen.

Die Ausgangswerte für die Kalkulationen (Pogorelij, 1983 und andere Quellen), wo die Ergebnisse der Versuchsforschungen herausgegeben wurden, sind in der folgenden Tabelle angeführt:

*Tabelle 1*

| Parameter | $a$ (m) | $[P_x]$ (N) | $\gamma_{об.}$ (N/m$^3$) | $f$ | $f_1$ | $g$ ($m \cdot s^{-2}$) |
|---|---|---|---|---|---|---|
| Werte/Größen/ Mengen | 0,12 | 200 | 11000 | 0,6 | 0,5 | 9,81 |

Einige Kostruktionsparameter des Scharroders und des ausgeführten technologischen Prozesses des Roders sind untereinander durch folgende Abhängigkeiten verbunden:
die Breite der deformierten Bodenschicht

$$b = a \cdot tg\beta = 0{,}12 tg\beta \tag{64}$$

das Gewicht der Bodenschicht

$$G = \gamma_{об.} \cdot a^2 \left(2a \cdot tg\beta + 0{,}05\right) \frac{tg\beta}{\sin\gamma} \tag{65}$$

Auf Grund der Zahlenrechnungen werden die graphischen Darstellungen der Veränderung der Geschwindigkeit bei der Vorwärtsbewegung des Scharroders $V$ je nach der Winkelgröße $\gamma$ (Abb. 4).

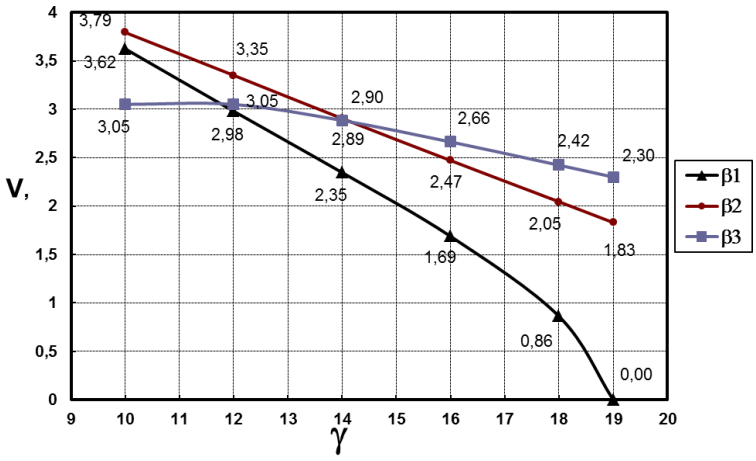



*Abbildung 4. Abhängigkeit der zulässigen Geschwindigkeit der Vorwärtsbewegung $V$ vom Winkel $\gamma$ bei $\beta_1 = 15^o$, $\beta_2 = 20^o$, $\beta_3 = 30^o$.*

## Zusammenfassung

Die Analyse der Kennlinien ergibt, daß die Abhängigkeit dieser Parameter dem linearen Parameter näht. Bei der Vergrößerung des Anstellwinkels $\gamma$ des Scharroders sinkt die Größe der Geschwindigkeit der Vorwärtsbewegung $V$, was beim Roden die Nichtbeschädigung der Wurzelkörper ermöglicht. Die Benutzung der größeren Werte des Schrägwinkels ermöglicht es, die höhere Geschwindigkeiten der Vorwärtsbewegung zu erreichen. Berücksichtigend, daß die Statistikwert der Konizität des Zuckerrübekörpers $\gamma_k$ = 20...28º laut (Pogorelij, 1983) ausmacht, kann die Steigerung der Geschwindigkeit der Vorwärtsbewegung beim Schrägewinkel $\beta$ des Scharroders bei ca. 30º erreicht werden. Die gewonnenen Forschungsergebnisse zeigen somit, dass die optimalsten Winkelwerte $\gamma$ und $\beta$, bei denen eine hohe Geschwindigkeit $V$ der Vorwärtsbewegung des Scharroders und des Rodens der Zuckerrüben aus der Erde ohne Beschädigung gesichert wird, $\gamma = 13...16^o$ und $\beta = 20...30^o$ gleich sind.

Die Ergebnisse der Berechnungen bestätigen somit laut den gewonnenen analytischen Abhängigkeiten deren Richtigkeit und schaffen die Basis für die praktische Anwendung beim Entwurf und Kalkulation neuer ausgereifterer Wirkorgane der Rübenerntemaschinen.

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### TEORIA MECHANIZMU WYORUJĄCEGO KOMBAJNU DO ZBIORU BURAKÓW CUKROWYCH

**Streszczenie.** Siły oddziałujące na wyorywacz kombajnu do zbioru buraków cukrowych wymuszane są nie tylko fizycznymi właściwościami gleby (np. jej zwięzłością), ale także fizycznymi właściwościami zbieranego plonu (tj. buraków cukrowych). Dotychczasowa teoria wyrywania buraków cukrowych uwzględniała tylko właściwości fizyczne gleby, w powiązaniu z fizycznymi i geometrycznymi parametrami mechanizmu wyorującego. Artykuł prezentuje matematyczny model mechanicznego oddziaływania warstwy gleby, łącznie z masą korzeni buraków cukrowych na element wyorujący buraki. Formuły matematyczne opracowanej teorii zostały weryfikowane przykładowymi obliczeniami, dla przyjętych parametrów roboczych kombajnu do zbioru buraków cukrowych (m.in. prędkością roboczą, głębokością roboczą).

**Słowa kluczowe**: wyorywacz buraków, teoria mechanizmów, model matematyczny

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# QUALITY ASSESSMENT OF THE OPERATION PROCESS OF HEID TECHNOLOGICAL LINE THRESHING UNIT FOR CORN COBS

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ABSTRACT

The article presents the quality assessment of the operation of HEID technological line threshing unit in SAATBAU Sp. z o.o. company in Środa Śląska. Evaluation of the CIMBRIA abrasive machine was made based on the macro and micro damages of seeds, which were made after threshing and through determination of seeds germination capacity and energy. Tests were carried out for five corn varieties: *Bosman, Sl Normo, Odilo, Okato, Wikana*. The calorymetric method was applied for determination of mechanical damages to seeds. The biggest macro-damages were reported at the level of 4.2% and micro-damages at the level of 14.5%. The increased values of damages occurred after threshing. The highest germination capacity was 96%. On this basis it was stated that the quality of the operation of the threshing unit was within the norm.

## Introduction and the objective of the paper

Three cultivation plants: wheat, corn and rice have the fundamental meaning in the global agriculture. Corn is a grain on account of the obtained crops. For 20 years the area of its cultivation as well as crops in the world increased by 1/3 (Dragańska, 2010). It is one of the most productive cultivation plants. Corn is cultivated for seeds, silage and sometimes for green forage. The main reason, for which corn is significant in fodder production, is including it to the main component of food for cattle and monogastric animals (Dubas, 2004; Radzyńska and Szymańczak, 2010). In case of seeds, costs of production of one energy unit are lower than for other grains. From one hectare of a corn plantation 7-10 tonnes of dry seeds may be obtained. It should be mentioned that also price of energy included in the corn silage is one of the cheapest among the volumetric fodders. In Poland, cultivation of corn is strictly related to the zoning. Therefore, particular climatic regions are referred to a relevant variety. Corn cultivation is the highest in the following voivodeships: Dolnośląskie, Opolskie and Wielkopolskie (Księżak, 2008).

The symptom of full maturity of a seed is the so-called black spot stage, namely, a small black spot at the base of the caryopsis next to a germ. Early variety reach full maturity in September whereas middle-late varieties in October. Corn for seeds may be harvested when the water content in seeds, in relation to a variety is within 31-37%. A two-stage method is used at the harvesting of corn for seeds where the smallest damage to seeds occurs. Then, a full-value sowing material is obtained. The first stage consists in harvesting cobs and their barking. Cobs after teh removal of covering leaves are dried in the temperature that does not exceed 42ºC (Sęk and Przybył, 1998; Grundas et al., 2002; Kowalik, 2011; Szymanek and Dreszer, 2011; Bieniek, 2013). Threshing takes place when the water content in seeds drops below 15%, sometimes threshing is carried out at the moisture of approx. 18% with later additional drying of seeds. The sowing material, which must be of a high class is prepared and stored by Seed Central Station. The objective of the research was to carry out the quality assessment of the operation process of the HEID technological line threshing unit for corn cobs.

**Place and subject matter of the research**

The research was carried out in SAATBAUS POLSKA Sp. z o.o. in Środa Śląska. The object of the research consisted of the threshing and abrasive unit CIMBRIA HEID (figure 1), which is included in the HEID technological line for after-crop treatment of corn cobs. Before threshing, cobs were dried. After drying, corn cobs are transported to an abrasive machine, where cobs are threshed with the force produced by an engine and due to rubbing of cobs against each other and with smooth, rounded rotor ribs. Separated seeds fall down through slits between the cage bars towards the outlet, whereas rachises are transported to the end part of the machine, where the outlet channel is placed. In the next stage, the corn seed is transported to the separator and cobs rachises are transported with belt conveyors outside the building (The Manual of the abrasive machine MR20 PNr 609038).

Five corn varieties were selected for the research: *Bosman*, *Odilo, Okato, SL Enormo, Wikana*. Corn cobs were harvested in the physiological maturity stage after approx. 2 weeks after the so-called black spot appeared. Bourgoin JDL 410D and Bourgoin GX 406A were used for harvesting (Molendowski, 2006).

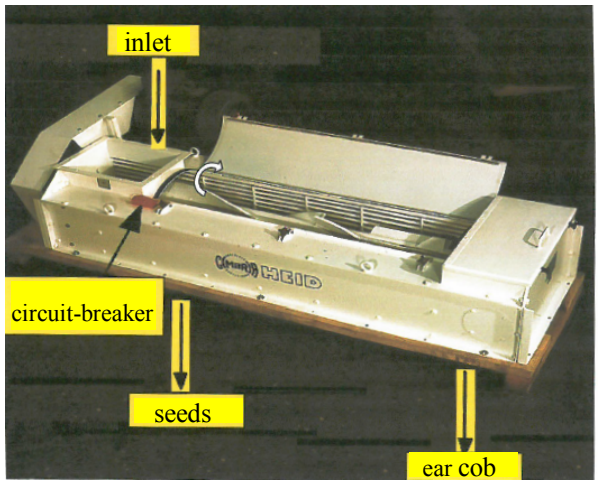
*Bosman* is a mixture of the Semi Flint caryopses type. The variety is characterized with big cylindrical cobs. This plant is high, well leaved, and resistant to lodging with high content of starch in a seed. It is a variety of an intensive nature, showing a very high potential of cropping on better soil test stands. The second researched variety was *Sl Normo.* It is a variety which is lodging resistant and has a high crop of dry and fresh mass. It belongs to middle-early single mixtures with the Semi Flint caryopses type.

*Odilo* variety is a single mixture of corn with an early time of maturity and the Semi Flint caryopses type. When cultivating *Odilo* variety, very high crops of silage with high starch content may be obtained. This variety is characterized with a perfect early vigour and high yield of dry mass.

*Okato* is a middle-early seed variety, of a single mixture of Saatbau Linz variety. It is characterized with Semi Flint caryopses, high mass of thousand seeds, wholesomeness and mainly with lodging resistance.

*Wikana* is the fifth investigated variety. It is a three-line mixture characterized by high crop of fresh and dry mass of silage. Moreover, it has wholesome cobs and low susceptibility to lumpy smut, stem and root lodging.

a)




b)

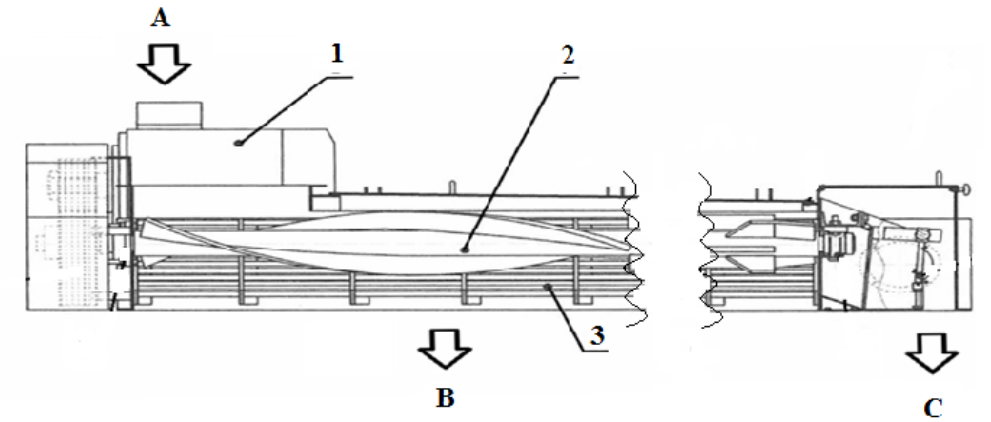



*Figure 1. Huller MR 20: a – view, b– scheme: 1 – motor, 2 – rotor, 3 – wire screen, A – ear cob inlet, B – grain falling through the bars of the cage, C – outlet corn cobs (Source: Manual huller MR20)*

## Methodology of research

Assessment of the quality of the exploitation process of CIMBRIA HEID MR20 threshing unit was carried out through analysis. The most important factors were macro and micro damages of seed and the seed germination capacity and energy after threshing. Tests were carried out in two stages. In the first one, corn material was obtained before transferring it to the threshing unit. In the second one, material samples were obtained after the material left the abrasive machine. Each time after the first and the second stage, moisture of the material was determined. All tests were carried out in 15 repeats for each variety. Output mass of each sample was 15 g. Seeds before and after threshing were subjected to the visual control and those, where damages were reported were weighed. Whereas, in order to determine damages in the remaining mass, it was bathed in Lugol's iodine. After 40 minutes a dye was filtered with a sieve. With the use of a magnifying glass, micro-damages to caryopses in the form of dark spots on the seed were determined. All seed samples were weighed with a precision up to 0.1 g. Tests with regard to the germination capacity and energy were carried out in the laboratory of SAATBAU POLSKA Sp. z o. o. company.

## Research results and their analysis

According to the norm PN-94/R-74015, which defines the quality requirements for corn, the maximum number of seeds may not exceed 10%. The results, which were obtained, show that only one variety exceeded this border. Analysing of the number of micro-damages in the seeds, showed that the biggest damages before threshing occurred at *Okato* variety (4.2%), then *Bosman* (1.3%), *Wikana and Sl Enormo* ( 0.5% each) and *Odilo* (0.1%). After threshing the following macro-damages occurred: *Okato* (13.3%), *Bosman* (2.8%), *Odilo* (1%), *Wikana* (0.5%) and *Sl Enormo* (0.35%). Whereas the biggest micro-damages before threshing occurred for: *Okato* (1.17%), *Bosman and Odilo* varieties (0.67%). In case of *Wikana* and *Sl Enormo* varieties no damages were reported. After threshing, the biggest micro-damages occurred for the following varieties: *Okato* (14.5%), *Bosman* (7.2%), *Sl Enormo* (0.83%) and in case of *Wikana and Odilo* (0.5%). A variety with the biggest macro- and micro-damages before and after threshing is *Okato*variety. *Wikana* and *Sl Enormo* varieties had the same number of damages, they differed only with a percentage content of micro-damages after threshing. Before threshing, the percentage content of micro-damages of *Odilo* variety was 0.67% and was higher than after threshing (0.5%). The research proved that the biggest macro- and micro-damages occurred in case of *Okato and Bosman*. These varieties had the moistest seeds.

Moisture of the tested varieties before drying was within 37.6-42.1%. According to the norm PN-R-74104 the seed moisture after drying should not exceed 14.5%. It was found out that any of the investigated varieties after threshing did not exceed this border (table 1). Moisture was within 11.2-12.8%. Varieties *Okato and Bosman*had the highest moisture of corn cobs before drying and after drying the moisture was higher in comparison to other

varieties. It can be justified by the fact that these varieties have thick and big cobs, which influences the prolongation of the drying time. The lowest moisture before drying was in case of *Wikana variety* (37.6%), which after drying had 11.4% of moisture. *Sl Enormo* variety before drying had moisture of 37.8% and after drying the lowest from all the investigated varieties (11.2%). Both varieties had the lowest moisture of seeds both before as well as after drying.

Table 1
*Moisture of corn ear cobs*

| Corn variety | Moisture (%) | |
|---|---|---|
| | Before drying | After drying |
| *Okato* | 41.8 | 12.8 |
| *Bosman* | 44.1 | 12.3 |
| *Odilo* | 39.3 | 11.9 |
| *Wikana* | 37.6 | 11.4 |
| *Sl Enormo* | 37.8 | 11.2 |

Seeds viability, which may be determined with the germination capacity and energy is one of the significant quality properties of seeds. Table 2 presents a percentage participation of the germination size of the investigated varieties. Each variety was characterized with greater germination capacity and energy. *Okato*had the lowest germination capacity and energy, then *Bosman, Odilo, Sl Enormo and Wikana*. *Wikana and Odilo* had the same germination capacity which was 95%. However, the first one had 3% higher germination capacity. Germination capacity and energy depended on the investigated variety.

Table 2
*The capacity and energy of germination of the tested sub-species*

| Corn variety | Germination (%) | |
|---|---|---|
| | Germination energy | Germination capacity |
| *Okato* | 79 | 82 |
| *Bosman* | 82 | 85 |
| *Odilo* | 89 | 95 |
| *Wikana* | 92 | 95 |
| *Sl Enormo* | 92 | 96 |

In the final stage of research, a statistical analysis of the obtained results was carried out. When comparing results of macro-damages after threshing, it was reported, that the highest average and the standard deviation as well as the median was in case of *Okato* variety (table 3). While, the lowest statistical figures were for *Sl Enormo* variety. Whereas, when discussing macro-damages of seeds after threshing, it was reported that *Okato*variety had the biggest arithmetic mean, median and standard deviation. In case of micro-damages before threshing, the lowest mean, median and standard deviation appeared for *Wikana and Sl Enormo* (table 3).

Table 3
*Statistical analysis of macro- and micro-damages before and after threshing*

| Variety of corn | Type of damages (%) | | | | | |
|---|---|---|---|---|---|---|
| | Macro-damages | | | | | |
| | Before threshing | | | After threshing | | |
| | Arithmetic mean | Median | Standard deviation | Arithmetic mean | Median | Standard deviation |
| *Okato* | 4.17 | 3.33 | 1.67 | 13.33 | 12.33 | 3.84 |
| *Bosman* | 1.33 | 2.33 | 1.89 | 2.83 | 2.33 | 0.75 |
| *Odilo* | 1.1 | 1.33 | 0.47 | 1 | 0.33 | 0.59 |
| *Wikana* | 0.5 | 0.33 | 0.23 | 0.5 | 0.33 | 0.24 |
| *Sl Enormo* | 0.5 | 0.67 | 0.21 | 0.34 | 0.33 | 0.11 |
| | Micro-damages | | | | | |
| *Okato* | 1.17 | 0.67 | 0.48 | 14.5 | 12.33 | 6.58 |
| *Bosman* | 0.67 | 0.67 | 0.24 | 7.2 | 7.67 | 2.95 |
| *Odilo* | 0.67 | 0.67 | 0.22 | 0.5 | 0.33 | 0.23 |
| *Wikana* | 0.0 | 0.0 | 0.0 | 0.5 | 0.43 | 0.21 |
| *Sl Enormo* | 0.0 | 0.0 | 0.0 | 0.67 | 0.43 | 0.36 |

According to the statistical analysis, in each case the standard deviation did not exceed 40% of the mean, which in case of a non-uniform biological material is an acceptable value and proves the repeatability of results.

The obtained results of relative values of macro- and micro-damages of seeds were presented in figures 2 and 3. Both in the first as well as the second case, according to presumptions, their increased values occurred after threshing. In case of macro-damages, their relative value in border cases increased by approx. 330% and in case of micro-damages even by 500%, which does not mean that these are non-acceptable values.

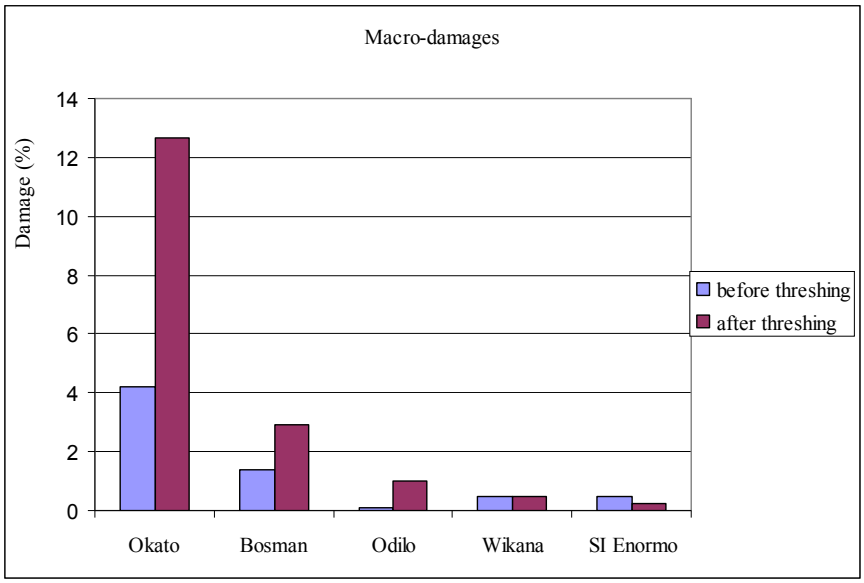



*Figure 2. Macro-damages before and after threshing*

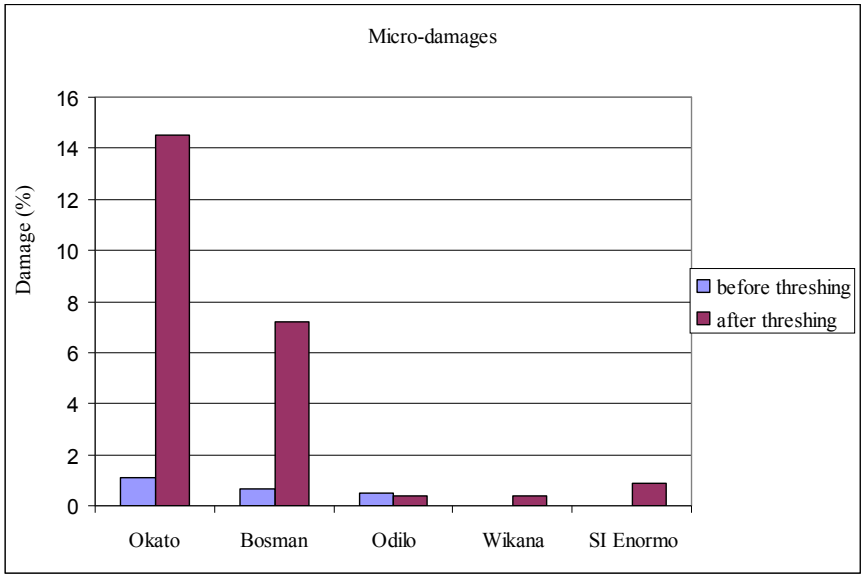



*Figure 3. Micro-damages before and after threshing*

## Conclusions

1. *Bosman (44.1%)* and *Okato* (41.8%) varieties had the highest moisture of corn cobs before drying. The lowest moisture before drying was in case of *Wikana variety* (37.6%), which after drying had 11.4% of moisture. For the investigated corn varieties the cobs moisture after drying did not exceed the admissible norm.
2. Number of damages, capacity and energy of germination of seeds is strictly related to a variety. The biggest macro- and micro-damages before and after threshing were in case of *Okato* variety. This variety had also the lowest capacity (82%) and energy of germination (79%). Whereas the smallest damages before and after threshing were reported for *Wikana* and *SI Normo,* varieties, they also had the biggest capacity (95-96%) and energy of germination (92%).
3. When assessing the quality of operation of HEID line threshing unit, it may be stated that the technological process performed by it guarantees obtaining the sowing seed quality of corn with parameters pursuant to applicable norms.

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## OCENA JAKOŚCI PROCESU EKSPLOATACJI ZESPOŁU OMŁOTOWEGO KOLB KUKURYDZY LINII TECHNOLOGICZNEJ HEID

**Streszczenie**. W artykule przedstawiono ocenę jakości pracy zespołu omłotowego linii technologicznej HEID w firmie SAATBAU Sp. z o. o. w Środzie Śląskiej. Oceny łuszczarki CIMBRIA dokonano na podstawie powstałych po omłocie makro i mikrouszkodzeń ziarna oraz poprzez określenie jego siły i energii kiełkowania ziarna. Badania przeprowadzono dla pięciu odmian kukurydzy: *Bosman, Sl Normo, Odilo, Okato, Wikana.* Do wyznaczenia uszkodzeń mechanicznych ziarna wykorzystano metodę kolorymetrii. Największe makro- uszkodzenia ziarna stwierdzono na poziomie 4,2%, a mikrouszkodzenia na poziomie 14,5%. Zwiększone wartości uszkodzeń występowały po jego omłocie. Największa siła kiełkowania wynosiła 96%. Na tej podstawie stwierdzono, że jakość procesu eksploatacji zespołu omłotowego odpowiadała normie.

**Słowa kluczowe:** łuszczarka, uszkodzenia mechaniczne, odmiana, ziarno kukurydzy

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# RESULTS OF OPERATIONAL AND FUNCTIONAL RESEARCH OF THE SLOT DISPENSING ASSEMBLY

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ABSTRACT

The concept of construction and testing the slot dispensing assembly for pneumatic and mechanical drills appeared during implementation of the development project No. N R003 0021 06/2009 at Poznań University of Technology. The paper contains the results of laboratory studies aimed at clarifying the impact of such factors as the type of grain, use of mixers, pressure in the seed tank to the seed rate of wheat and oats in the slot dispensing assembly. Laboratory tests were performed on the prototype of the pneumatic drill constructed at the Department of Working Machines with a built-in slot-dispensing assembly. For the same width of the slot opening, the dispensed amount of wheat seeds is dosed almost twice than the oats seed grain. The tests proved that the dosage in the unit dispensing slot would be impossible without the use of a mixer. Further research is planned for the slot dispensing assembly for other types of grains, small grains such as rape, in order to verify the usability and scaling the amount of sowing the seeds for a given slot opening.

## Introduction

Precise sowing is one of the factors which ensure good quality and high yields of plants. Due to many advantages, pneumatic drills with central dispensing assemblies and pneumatic transport of seeds to drill openers are eagerly bought and frequently used.

The basic source of uneven sowing is a sowing unit (which dispenses seeds). Many scientists debated over the question how to eliminate unfavourable pulsations in shaft dispensers. During implementation of the development design at the Poznań University of Technology (Kęska et al., 2012) the concept of construction and testing an innovative slot dispensing assembly occurred.

During the analysis of available solutions of dispensing assemblies, a popular patented pin sowing unit (patent specification PL 200965B1), which was described (Markowski and Rawa, 2009) and tested on account of regularity of dispensing (Rawa and Markowski, 2001); (Markowski et al., 2008) was found out. Previously, a pin sowing unit was used in mineral fertilizers spreaders, for example spreaders produced by the Polish producer Unia Brzeg (http://www.uniagroup.com/ug/site/offer/items-for-category?categoryId=78 or

a foreign producer (http://www.amazone.pl/6.asp). Here the problem of suspension of the sowed material and irregular dispensing appears.

The objective of the research was the initial operational and functional verification of the sowing unit and scaling the norm of sowing in relation to opening of the dispensing valve. The paper includes the laboratory tests results of the impact of such factors as:

– type of grain,
– mixer / without mixer,
– overpressure in the seed container / area pressure to the standard of sowing for a prototype slot dispensing assembly incorporated in a seed drill.

## Methodology of research

Laboratory tests were performed on the prototype of the pneumatic drill constructed at the Department of Working Machines with a built-in slot-dispensing assembly. Seeds sowing took place on the stand for testing transverse irregularity of sowing, where tensometric scale was mounted (Feder et al., 2012). Tests were carried out on the wheat and oat seeds purchased in Poznańska Centrala Nasienna (Poznań Seed Central Office). Before the tests were initiated, measurements of basic parameters of the used material were taken, in particular the mass of 1000 seeds, dimensions, moisture of seeds according to the PN-79/R-65950 standard, which could influence the results of taken measurements (Gierz and Kęska, 2011; Gierz et al., 2012).

As a result of measurementscarried out, table 1 presents the following characteristics of wheat and oats.

Table 3
*Basic parameters of wheat and oats*

| Type of grain | TSW (g) | Length a (mm) | Width b (mm) | Thickness c (mm) | Moisture (%) |
|---|---|---|---|---|---|
| Wheat | 42 ± 2 | 6.80±0.5 | 3.70±0.38 | 3.50±0.37 | 13.5 |
| Oats | 33 ± 1 | 10.96±0.71 | 3.08±0.4 | 3.05±0.39 | 12.5 |

During the tests, the velocity of transporting air was assumed to be at the same level. In the seed container there was an overpressure. The initial research proved that when the container is opened, that is, when the container has the pressure of thearea, the seed flow is irregular. Moreover, it was also proved that a mixer played a great role, without which the process of dispensing for seeds with higher internal friction coefficient was practically impossible, which results from the research carried out on oat seeds. Figure 1 presents a slot dispensing assembly designed and constructed in the Department of Working Machines of the Poznań University of Technology, whereas figure 2 presents a dispensing valve with basic dimensions.

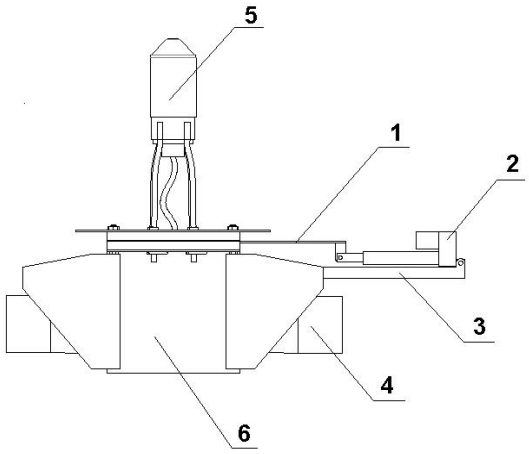


*Figure 1. Slot dispensing assembly 1 – dosing valve, 2 – electric actuator, 3 – arm, 4 – injector, 5 – mixer, 6 – support structure*

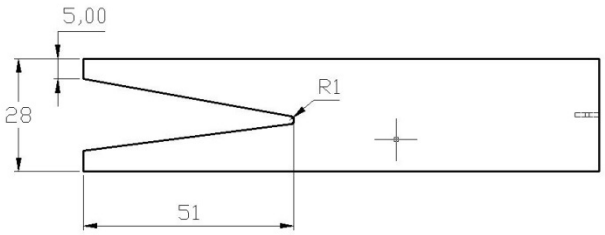


*Figure 2. Dispensing valve with the basic dimensions*

## Research results

As a result of implementation of laboratory tests, a wide set of data was obtained, based on which a characteristic of valve capacity both for wheat and oat seeds could be determined. During initial research without a mixer, for the oat seeds, dispensing could not have been performed. Subsequent research was carried out with the use of a mixer.

Laboratory tests confirmed a considerable influence of the seed type on the standard of sowing for a prototype slot dispensing unit of a pneumatic drill. This assembly is built-in on the test stand and properly reflects real conditions of sowing (dispensing) of seeds. The obtained results gave an initial view of using a slot dispensing assembly.

Figure 3 presents the relation of sowed wheat seeds to the slot width, whereas figure 4 presents relation of the amount of sowed oat seeds to the slot width. As it can be seen, characteristic of capacity for both wheat and oat seeds is almost linear.

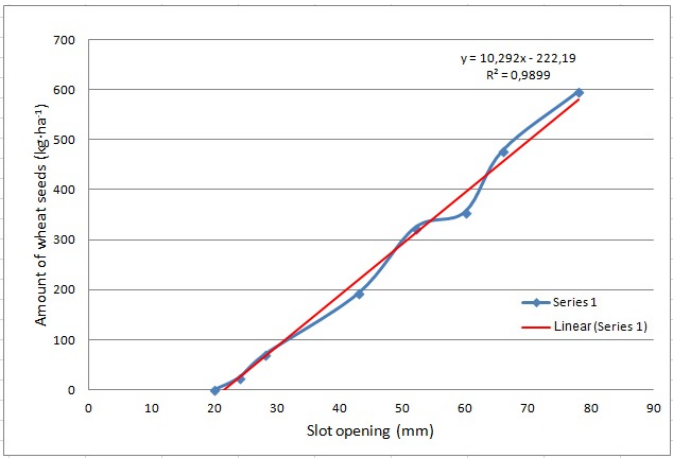


*Figure 3. Relation of the quantity of the dispensed wheat seeds to the width of the slot*

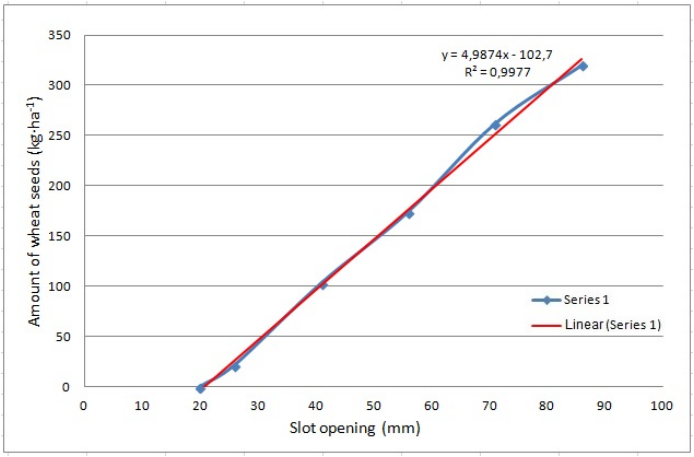


*Figure 4. Relation of the quantity of the dispensed oat seeds to the width of the slot*

## Conclusions

Laboratory tests which were carried out allow for the following conclusions:

1. Relation of the amount of sowed seeds to the slot width is practically linear for both wheat and oat seeds. Slight fluctuations of research results were related to inertia and measurement error of the used tensometric weight.

– For the same width of the slot opening, the dispensed amount of wheat seeds is almost twice than the dispensed oat seed grain.
– The process of dosing in the slot dosing assembly would be impossible without the use of a mixer, which became clear during the initial tests.

– Tests for other shapes of slots in the dispensing valve should be carried out;
– Further tests for other types of seeds should be carried out, e.g. small seeds such as rape in order to verify the usefulness and scaling the amount of sowing of these seeds for the set slot opening.

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# WYNIKI BADAŃ EKSPLOATACYJNO-FUNKCJONALNYCH SZCZELINOWEGO ZESPOŁU DOZUJĄCEGO

**Streszczenie.** Podczas realizacji na Politechnice Poznańskiej projektu rozwojowego nr N R003 0021 06/2009 powstała koncepcja zbudowania i przebadania szczelinowego zespołu dozującego dla siewników pneumatycznych i mechaniczno-pneumatycznych. W pracy przedstawiono wyniki badań laboratoryjnych mające na celu wyjaśnienie wpływu takich czynników, jak: rodzaj ziarna, zastosowanie mieszadła, zastosowanie ciśnienia w zbiorniku materiału siewnego na ilość wysiewanych nasion ziarna pszenicy i owsa szczelinowym zespołem dozującym. Badania laboratoryjne przeprowadzono na zbudowanym w Zakładzie Maszyn Roboczych prototypowym siewniku pneumatycznym z wbudowanym szczelinowym zespołem dozującym. Dla tych samych szerokości szczeliny, ilość dozowanych nasion ziarna pszenicy jest prawie dwukrotnie większa od dozowanych nasion ziarna owsa. W trakcie badań dowiedziono, że dozowania w szczelinowym zespole dozującym byłoby niemożliwe bez zastosowania mieszadła. Planowane są dalsze badania szczelinowego zespołu dozującego dla innych rodzajów ziaren np. ziaren drobnych jak rzepak celem weryfikacji użyteczności i wyskalowania ilości wysiewu tych nasion dla zadanego otwarcia szczeliny.

**Słowa kluczowe:** zespół dozujący, ziarna pszenicy i owsa, ilość wysiewu, siewnik pneumatyczny

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# ANALYSIS OF THE VENTILATION AIR STREAM SIZE IN CATTLE BUILDINGS[1]

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ABSTRACT

The analysis concerns the size of the ventilation air stream, which is variable in time, in a cowshed with natural ventilation. The research was carried out in two buildings designed for dairy cattle, one has ventilation ducts, the other an air vent. The research covered measurement of internal and external air temperature, which is variable in time, air flow temperatures and velocity in air vents and the wind velocity. Temperature and velocity of air flow in particular ducts differed between each other. In the winter season, average air temperature in ducts was lower than the air temperature in the zone where animals stayed. The ventilation air stream size resulting from the measured flow velocities in ventilation ducts was compared to the theoretical size.

## Introduction

Microclimate in the animal hall, and in particular, temperature, moisture and the air movement velocity are main factors, which influence the animal welfare and in consequence the milking capacity of cows (Daniel, 2008). One of the elements of the welfare is meeting the requirements concerning living in good environmental conditions. Such conditions are ensured by a well designed and constructed building and efficient ventilation system.

The ventilation air stream size is calculated based on the amount of carbon dioxide, water vapour or total heat produced by animals (Gaziński, 2012). The stream size, determined for the accepted conditions, is the basis for designing elements of natural ventilation. In the presently applied designing practice, dimensioning of elements of the natural ventilation system is based on the temperatures assumed for calculations:

– calculation temperature of external air, which depends on the climatic zone, where the designed building is located (PN-82/B-02403) or the designed external air temperature (PN-EN ISO 12831:2006),

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– calculation internal air temperature which depends on the animal species and the growth group (Journal of Laws, No 167, Item 1629).

Thermal dimensioning of inventory buildings is carried out based on the balance of profits and losses of sensible heat and total heat, formulated in the classic method of thermal dimensioning, in which heat losses for ventilation are calculated according to the water vapour or carbon dioxide criterion. Heat balance is also the basis for the simplified thermal conductivity coefficient method developed by Wolski and the method of thermal shaping of inventory buildings (Wolski, 2001). In these methods, established conditions are assumed, namely, only one calculation internal air temperature, which depends on the animal type and one external air temperature, which is related to the climatic zone. In real conditions, the inventory building is located in the constantly variable conditions of the surrounding. Temperatures and relative humidity of internal and external air are subject to dynamic changes and the heat exchange by transfer through partitions takes place according to the undetermined conditions (Głuski, 2013). The ventilation air stream is also variable in time because its size depends on the temperature difference between internal and external air and the wind speed.

Elements of the natural ventilation system influencing the air stream size may be divided into three groups:

– permanent elements, which do not change during the ventilation process; difference in the height between the roof ridge gap or the outlet of the ventilation duct and air vents,
– elements which can be regulated; width of the roof ridge gap, cross sectional area of ventilation ducts or air vents,
– factors variable in time depending on the weather; temperature and humidity of external air and the wind speed and direction.

Assessment of the real size of the ventilation air stream is very difficult to carry out on account of complexity of this process and great number of factors, which are variable in time, which influence it. There are several methods which enable determination of the ventilation air stream size:

1. Gas leaks detection method (PN-EN ISO 12569:2013). There are three methods of investigating the size of air stream exchanged in the building as a result of ventilation and infiltration which use tracer gas:
   – tracer gas failure method,
   – permanent injection method,
   – permanent concentration method.
2. Method of air flow velocity measurement in ventilation ducts.
3. A method which uses carbon dioxide concentration measurement in the animal hall and inventory of a herd (Głuski, 2011).
4. A method which uses equation of air movement in natural ventilation.

Kiwan et al. (2012) carried out research on the ventilation air stream size, using the tracer gas method with the use of radioisotope Krypton-85, measurement of the air flow velocity in air vents and the method which uses equations of air movement in the natural ventilation. Research was carried out in two various cowsheds and two weather periods. The determined values of air stream with those three methods resulted in the Pearson coefficient of correlation 0.59-0.86.

## The objective and the scope of the study

The objective of the study is to carry out analysis of the dynamic ventilation air stream and variables in the daily cycle of factors, which influence it. The basis of analysis consisted in measurements carried out in two buildings for the dairy cattle equipped with various systems of gravity ventilation.

## Methodology of research

Research was carried out in two buildings for dairy cattle on the territory of Lubelskie Voivodeship. The building was located in Glinnik locality (measurement carried out on 26th January 2013); the building has a utility attic. The animal hall consists of two rows with a central feeding passage. It includes a barn rearing system, stands for cows – individual and tied, single coops and group coops. The building has four vent ducts with a round cross-section $\Phi$ 57 cm and is 630 cm high.

The second building is located in Przegaliny locality (measurement carried out on 14th January 2014); it is a hall type building without a utility attic, ground-floor with a non-symmetric flat roof, in which a transparent hinged roof ridge gap is located, which serves as lighting and ventilation of the building. Cows are maintained in a free-stall system and they are fed from the feeding passage. On both sides of the ridge there is a roof ridge gap, which is 25 cm wide and 49.4 m long. Air vents, which are 25 cm wide, are located in the side walls of the building under the eaves. Difference in height between the air vent and the roof ridge gap is 3.50 m. In the described buildings, research included measurements of temperature and humidity of internal and external air as well as temperature and air flow velocity at the inlet to the ventilation ducts or in the ventilation gap. Measurements of temperature and air flow velocity in trunks were carried out with thermoanemometers AVM-07 (the scope of operation 0.0-45.0 $m \cdot s^{-1}$, accuracy 3%), whereas measurements of air temperature in the animal hall and outside with COMARK sensors (the scope of operation from -40.0 to +70.0ºC, accuracy 0.1ºC). Sensors and recorders of temperature and air flow velocity were programmed to carry out the readout and the record of measurement results in 300 second intervals. One day was assumed as a basic period of time, when analyses were carried out.

A formula, which describes the air velocity in ventilation ducts provided by Hellickson and Walker (1983) was accepted for calculation of the theoretical size of the ventilation air stream:

$$V_d = \Theta \sqrt{\frac{2gH(T_i - T_o)}{T_i}} \quad (m \cdot s^{-1}) \tag{1}$$

where:

- $V_d$ – air flow velocity in the dunct, ($m \cdot s^{-1}$),
- $\Theta$ – coefficient, which includes frictional resistance of air on the internal surface of the duct,
- $g$ – gravitational acceleration, ($m^2 \cdot s^{-1}$),
- $H$ – difference between the inlet and outlet of the duct, (m),
- $T_i$ – internal air temperature, (K),
- $T_o$ – external air temperature, (K).

The following values of the coefficient $\Theta$ are accepted for calculations:
- ventilation with a roof ridge gap 0.80(0.86)
- single ventilation trunks 0.73(0.79)
- composite well 0.68(0.74)

The brackets include the values of the coefficient $\Theta$ V for air vents without a cover.

The ventilation air stream depends on the cross sectional area of the ventilation duct or a ventilation gap and the air flow velocity.

$$L = \sum_{i=1}^{n} A_i \cdot V_i \tag{2}$$

where:
$L$ – ventilation air stream variable in time, ($m^3 \cdot s^{-1}$)
$A_i$ – cross-sectional area of i-duckt, ($m^2$)
$V_i$ – the air flow velocity variable in time in i-trunk, ($m \cdot s^{-1}$)
$n$ – number of trunks

## Results

Each ventilation trunk (Glinnik) is made of 7 identical metal elements which results in their identical dimensions and air frictional resistance. Despite this, differences in the air flow velocity in particular trunks occurred. The measurement results were presented in figure 1 (trunks no 1 and 3) and figure 2 (trunks 2 and 4).

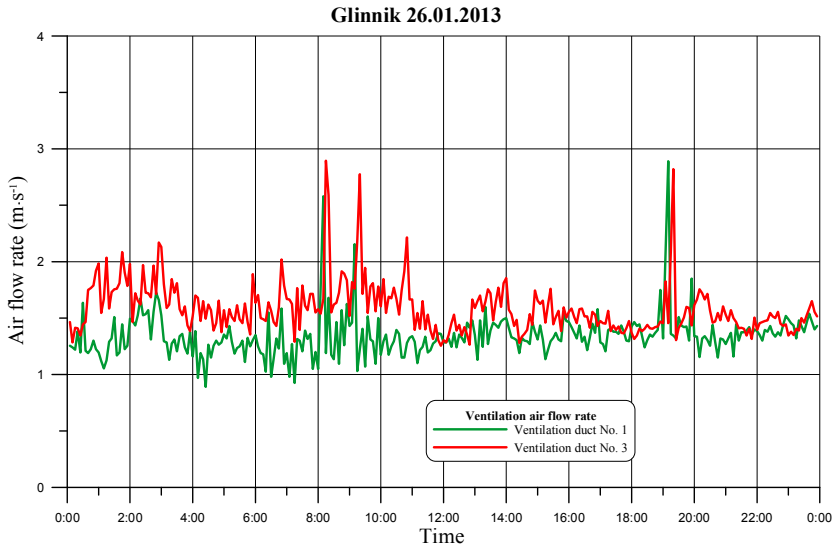


*Figure 1. Air flow velocity in ventilation ducts no 1 and 3*

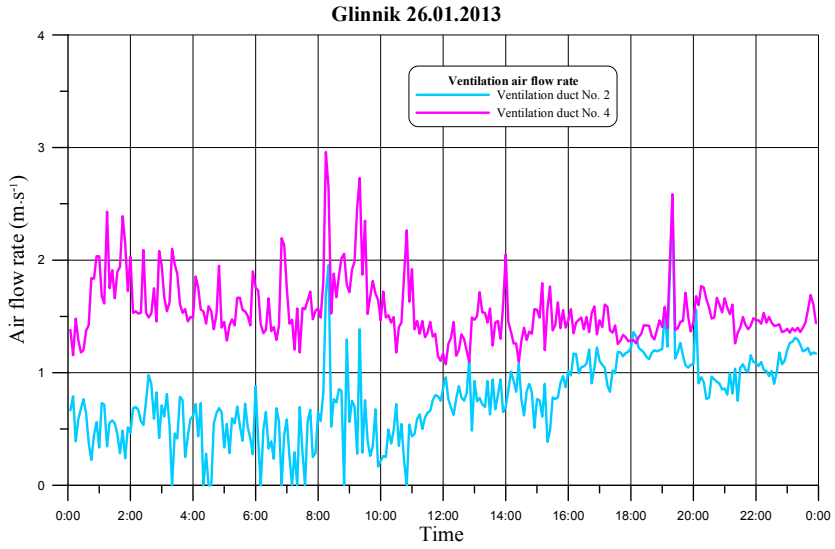


*Figure 2. Air flow velocity in ventilation trunks no 2 and 4*

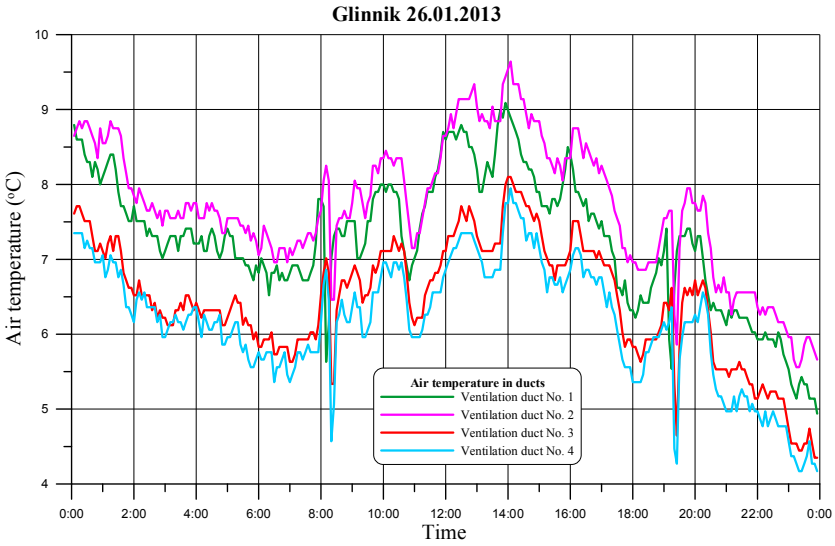


*Figure 3. Air temperature at the inlet to particular trunks*

Differences in the air flow velocity in ventilation trunks result from air temperature distribution in the animal hall. Daily changes of air temperature in ducts are presented in figure 3. Despite the fact, the inlets to ventilation trunks are at the height of the ceiling over the animal hall, the average air temperature in all trunks was lower than the average air temperature in the animal hall (fig. 4).

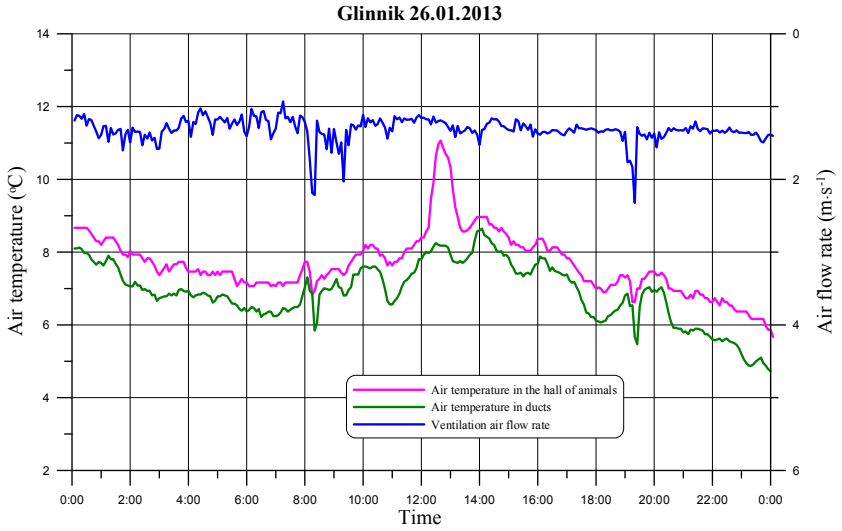


*Figure 4. Average temperature in ventilation ducts, in the animal hall and the average air flow velocity in four ducts*

Figure 5 presents results of measurements and calculations of the ventilation air stream size and the difference of the internal and external air temperatures.

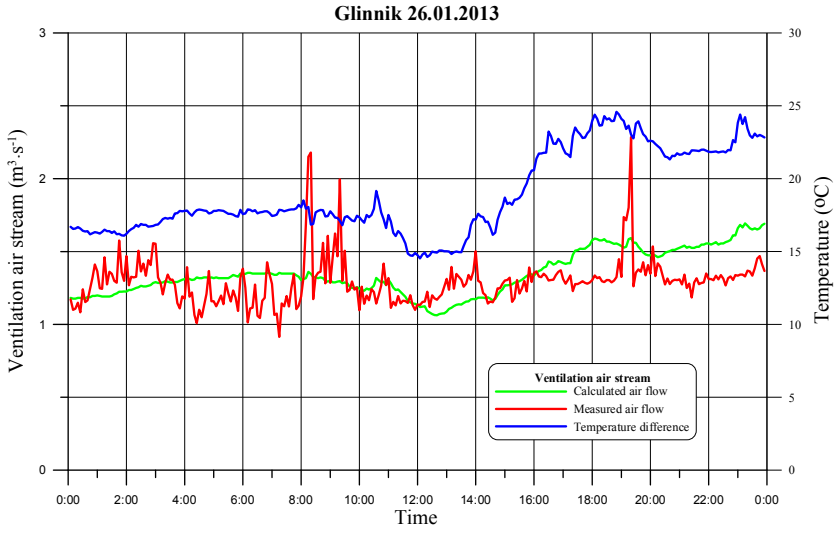


*Figure 5. Ventilation air stream measured and calculated and the difference between internal and external air temperature*

The building for the dairy cattle located in Przegaliny locality has a natural ventilation system with a roof ridge gap, which is 25 cm wide on both sides of a ridge. Anemometers for measurement of the ventilation air flow velocity were placed in the air vent.

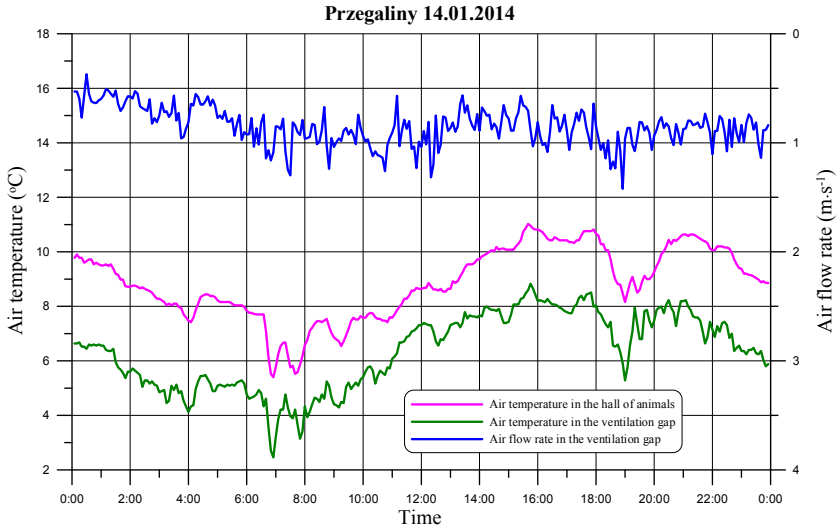


*Figure 6. Air temperature in the ventilation gap, ventilation ducts and the average air flow velocity in the air vent*

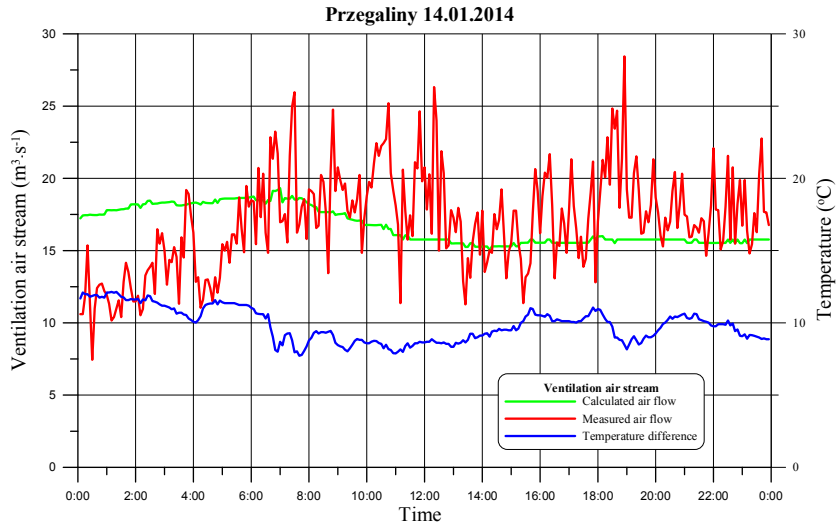


*Figure 7. Measured and calculated ventilation air stream and the difference between internal and external air temperature*

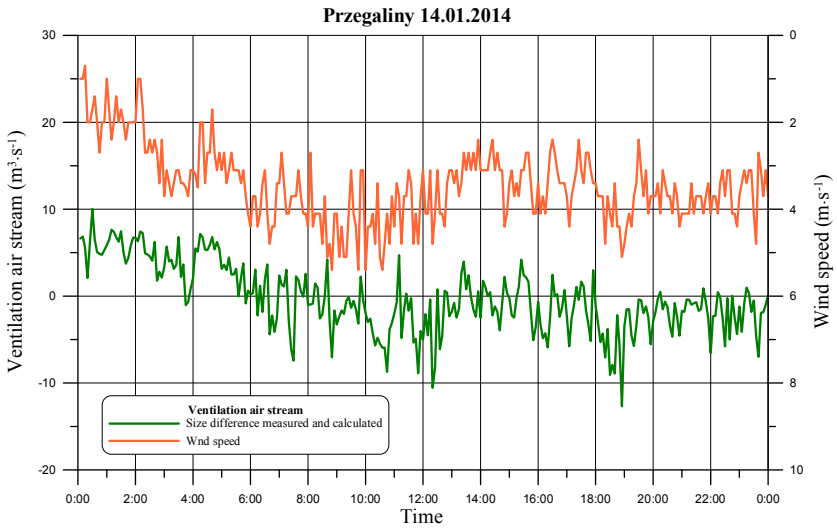


*Figure 8. Size difference measured and calculated of the ventilation air stream and the wind speed*

Figure 7 presents measured and calculated values of ventilation air stream, which are variable in time and the difference between internal and external air temperature. Difference in the measured and calculated size of the ventilation air stream results from the wind impact on the efficiency of the ventilation system but the relation is inversely proportional (fig. 8).

## Conclusion

Real values of the ventilation air stream, which is variable in time, in the inventory building are subject to frequent fluctuations and differ from the calculation values. It follows from the great number of difficult to predict and describe factors which influence the size of this stream. For example the wind impact or opening the door and gates related to the performed technological processes. Based on the research and analyses one may make the following conclusions:

1. The size of the ventilation air stream, variable in time, depends on the variable internal and external air temperatures and the temperature distribution in the animal hall.
2. In the building with chimney ventilation, although all ventilation ducts have the same cross sectional area and the same height, the air flow velocity was varied. These differences result from various air temperatures at the inlet to the duct, but high temperature corresponds to lower air flow velocity.
3. In the investigated winter season, average air temperature in ducts was lower than the temperature in the zone where animals stayed.

4. Difference in the measured and calculated size of the ventilation air stream results from the wind impact on the efficiency of the ventilation system but the relation is inversely proportional.
5. The ventilation air stream is dynamic in nature. Therefore, designing the natural ventilation system should use the simulation of the system operation based on the surrounding conditions, which are variable in time.

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# ANALIZA WIELKOŚCI STRUMIENIA POWIETRZA WENTYLACYJNEGO W BUDYNKACH DLA BYDŁA

**Streszczenie.** Analiza dotyczy wielkości zmiennego w czasie strumienia powietrza wentylacyjnego w oborach z wentylacją naturalną. Badania przeprowadzono w dwóch budynkach dla bydła mlecznego, jeden posiada kominowe kanały wywiewne drugi kalenicową szczelinę wentylacyjną. Badania obejmowały pomiary zmiennych w czasie temperatur powietrza wewnętrznego i zewnętrznego, temperatur i prędkości przepływu powietrza w wywiewnych otworach wentylacyjnych oraz prędkość wiatru. Temperatura oraz prędkość przepływu powietrza w poszczególnych kanałach różniły się między sobą. W okresie zimowym średnia temperatura powietrza w kanałach była niższa niż temperatura powietrza w strefie przebywania zwierząt. Wielkość strumienia powietrza wentylacyjnego wynikająca z pomierzonych prędkości przepływu w kanałach wentylacyjnych porównano z wielkością teoretyczną.

**Słowa kluczowe:** obora, wentylacja naturalna, strumień powietrza wentylacyjnego, mikroklimat

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# THE INFLUENCE OF NOZZLE CONFIGURATION IN ORCHARD SPRAYERS ON THE VERTICAL DISTRIBUTION OF SPRAY

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ABSTRACT

The aim of the study was to determine the effect of the selected operating parameters of the two types of orchard sprayers on vertical distribution (expressed as spray percentage share in 50-cm segments) and quantitative changes in vertical distribution of spray measured on a vertical separator of drops. The study included measurements of vertical distribution of spray for two different settings of nozzles, two types of nozzles and two fan rotational speeds. Vertical distribution of spray depended significantly on the spray emission system, the configuration and the type of nozzles and in the slightest degree on the fan rotational speed. The smallest share of liquid fell on the edge segments (≤ 5.22%) and the largest on the middle ones – 29.33%. The change in the configuration of nozzles significantly affected the change in the spray vertical distribution (by the spray displacement between the 50-cm segments). The greatest changes in vertical distribution of spray – as affected by the nozzle configuration change – was observed for the sprayer with the horizontal spray emission with a maximum change in one segment of 14.0% (an average of 7 segments: 5.38%).

## Introduction

Plant protection is effective when the appropriate quantity and uniformity of the plant protection product is deposited on the sprayed objects. The deposit is influenced by the type of a sprayer and its working parameters, characteristic of the sprayed plants (size, shape and density) and weather conditions. Among the parameters associated with a sprayer, the most important are: the sprayer type, spray volume, driving speed, the droplet size and the distance between the nozzles and the sprayed trees and their configuration and fitting to the shape of a tree (Byers et al., 1984; Ferree and Hall, 1980; Godyń et al. 2006). The impact of the majority of factors mentioned above was studied and the results of that studies and their analyses are available in numerous scientific publications. Only some trials related to the angle of nozzle orientation were carried out, among others, by Farooq and Landers (2004). These authors showed the relationship between the uniformity of the spray deposit in a tree and the nozzles direction. Furthermore, they pointed to the need to perform such regulation separately for each side of a sprayer, linking this to the asymmetric distribution of air flow.

Asymmetry in distribution of the air flow has been also confirmed by Godyń et al. (2009b). Research carried out in the Research Institute of Horticulture concerned the measurements of spray vertical distribution as well as individual nozzles distribution (Godyń et al., 2009a). The authors showed differences in vertical distribution of spray depending on the place of mounting nozzles in the air-stream.

During studies carried out on vertical distribution of spray for orchard sprayers performed outside the orchard, vertical patternators were used (devices measuring by volume vertical distribution of spray). The vertical patternators separate droplets from air on the wall a specific construction designed for this purpose (eg. HERBST patternators – Internet 2) or capture the spray, segment by segment, by means of tray collectors disposed vertically at some intervals to allow the air flow pass through the trays (eg. AAMS- Salvarani patternators - Internet 1). The first publications on vertical patternators come from the 80's of the 20th century (Pergher, 2004). There are still some research carried out on new methods of droplets separation or a different arrangements of collectors (Biocca et al., 2005; Balsari et al., 2007; Gil and Badiola, 2007; Landers, 2008).

The main practical aim of performing the measurements of vertical distribution of spray outside the orchard is related to calibration of a sprayer, including the nozzle setting in order to obtain spray distribution best suited for the sprayed plants. A change in direction of nozzle settings, which gives the changes in the spray discharge direction, is possible in most orchard sprayers offered on the market. For deflector sprayers the air deflectors may be adjustable. A few sprayers have also a limited ability to change the vertical position of the nozzles. The nozzle configuration may influence the biological efficacy of the plant protection carried out with such sprayers. Therefore, when the relationship between sprayer operating parameters together with nozzle configuration and obtained vertical distribution of spray is known, it will be possible to make recommendations for the users of orchard sprayers.

Pergher (2004) made trials on fitting the spray emission to the hedgerow vineyard by proper selection and angling of nozzles of a radial emission sprayer. He investigated three nozzle settings: factory settings with no regulation, visual adjustment in the orchard performed as matching the nozzles settings to the shape of sprayed plants and adjustment with the use of a patternator aiming to obtain the vertical distribution of spray closest to the shape of the outer contour of the sprayed plants. He achieved the best results for the factory settings or for adjustment in the orchard depending on the nozzles configuration and the adjustment method. The worst fit has been obtained for adjustment performed on a patternator. In that case the greatest discrepancies at corresponding heights between the amount of liquid collected at various heights of a patternator and spray deposit on plants were observed.

## Objectives and scope

No studies on the effects of different adjustments on the spray quantitative displacement and changes in vertical distribution of spray in orchard sprayers have been carried out yet. Therefore, the studies were undertaken to determine the effects of different regulations of orchard sprayers on spray displacement and quantitative changes in its vertical distribution measured on the vertical separator of drops. The work included measurements of vertical

distribution of spray for two different nozzle settings in orchard sprayers with a horizontal and air directed spray emission system, working with two rotational fan speeds and outfitted with two types of nozzles.

## Materials and Methods

The tests were carried out in the Agroengineering Department of Research Institute of Horticulture in Skierniewice in 2013 year. In the study two sprayers with different air emission systems and different number of installed nozzles were used. The deflector sprayer with a horizontal spray emission system and an axial fan (100v Turbo AGROLA) had on each side 8 nozzles mounted on. A sprayer with a directed air emission system (Tifone 1000) had five individually adjustable air outlets on each side with one nozzle by each outlet (fig. 1).


*Figure 1. Sprayers used at the test rigs at the vertical droplet separator (patternator): horizontal emission system sprayer AGROLA Turbo 100v (left hand) and air directed emission system sprayer Tifone 1000 (right hand)*

The factory installed nozzles were adjusted in two ways. For the sprayer with horizontal emission it was assumed to spray 3.0 m high trees. Nozzles and air directing blades were set either horizontally – without matching the emission of spray and air to the shape and height of a tree canopy ("Horizontal setting") – or were redirected to match the shape of a tree (Godyń et al., 2014) ("Matched setting"). The matching adjustment was achieved by angling the selected nozzles or air directing blades upwards by an angle of approx. 20º. The setting of nozzles No: 1, 3 and 4 (from the bottom) was changed. For the sprayer with directed air emission system it was assumed to spray 3.5 m high trees. The air outlets were set in a vertical plane, perpendicular to the direction of the travel/sprayer longitudinal axis

(Table. 1). Matching sprayers to the tree shape adjustment was achieved by varying the direction of the air outlets and their location and, in addition to changing the nozzles position (see Tab. 1), nozzles 1 and 2 were directed upwards.

Table 1
*Locations of nozzles (height from the ground/distance from the patternator) for sprayers with horizontal and air directed emission systems (cm)*

| Nozzle no. (from the bottom) | Horizontal emission system | Air directed emission system | |
|---|---|---|---|
| | Nozzles locations | | |
| | Horizontal and matched | Horizontal | Matched |
| 1. | 67.0 / 104.5 | 86.0 / 100 | 84.0 / 119 |
| 2. | 94.0 / 106.0 | 135.0 / 100 | 133.5 / 118 |
| 3. | 118.0 / 107.0 | 181.5 / 100 | 183.0 / 109 |
| 4. | 140.0 / 108.3 | 231.0 / 100 | 231.0 / 108 |
| 5. | 161.0 / 109.8 | 282.0 / 100 | 283.0 / 100 |
| 6. | 182.0 / 110.5 | X | X |
| 7. | 204.0 / 111.0 | X | X |
| 8. | 233.0 / 100.0 | X | X |

LECHLER nozzles were used in the tests: a standard hollow cone (TR 80-015) or flat fan air injector compact ones (IDK 90-015) with the nozzle flow rate of 0.83 $l \cdot min^{-1}$ at 0.6 MPa for a horizontal emission sprayer and 1.18 $l \cdot min^{-1}$ at 1.2 MPa for the air directed emission sprayer. The measurements were done at two fan rotational speeds: 1,400 or 1,800 $rpm \cdot min^{-1}$. In such conditions, the approximate air flow was 29.0 or 37.0 thous. $m^3 \cdot h^{-1}$ for the horizontal emission sprayer and 13.0 or 16.5 thous. $m^3 \cdot h^{-1}$ for the other one.

The measurements of the spray distribution were made on a vertical separator of drops (patternator) from Pessl (Austria), with a 10 cm resolution and the range of vertical measurement 20-350 cm. The measuring time of each measurement ranged 20-30 s and was chosen to collect spray volume not exceeding graduated capacity of measuring cylinders of a patternator (170 ml). The absolute values in ml read out from each of 33 cylinders scale corresponded to the quantity of liquid in the 10-centimeter vertical segments. That values were normalized and expressed as a percentage share of all the liquid collected on a patternator during a single measurement. For further calculations, the values read in five consecutive 10-centimeter segments, were combined to give the liquid share in 50-centimeter segments. Percentage share of the lowest segment (0-50 cm) was calculated by summing up the liquid shares in the three lowest segments (20-50 cm) because the measuring zone started only at 20 cm height. This gave seven 50-centimeter segments, from 0-50 cm to 300-350 cm. For each experimental combination three repetitions were made. A total of 48 measurements of vertical distribution of spray were carried out.

The vertical distribution of spray liquid was evaluated in order to find the influence of the experimental factors (nozzle setting, nozzle type and rotational speed of a fan) on the collected spray share (CSS) and the collected volume change (CVC) in the 50-centimeter segments, as well as the repeatability of the spray share measurements. For the spray share collected (CSS) in individual 50-centimeter segments the analysis of variance has been done and significance of differences between the mean (Duncan test) were rated. Two analyzes were done – for each of the fan rotational speeds separately (results – Table 2 and 3). Such a method of analysis was taken due to the possibilities of the statistical software. Further analyzes were performed for the parameter "collected volume change" (CVC) due to difficult assessment of the impact of nozzle configuration and other sprayer parameters on the magnitude of the collected spray share (CSS) changes in a 50-centimeter segments. The collected volume change (CVC) was calculated as the absolute value of the difference between the values of spray share collected (CSS) for "Matched setting" and "Horizontal setting" (with no change in other parameters). This was followed by statistical evaluation of the effects of the sprayer parameters (emission system, nozzle type, fan rotational speed and the segment) on the collected volume change (CVC) in the 50-centimeter segment (results - Table 4). Since the study did not assume any "optimal distribution", there was no basis for evaluating the "direction" of changes (getting closer or further from the optimum) due to regulations made. Repeatability of the measurements of the spray share collected (CSS) in 50-centimeter segments was assessed by calculating the coefficients of variation for replicates (Formula 1).

$$CV\% = \frac{\sqrt{\frac{\sum\left(x-\bar{x}\right)^2}{n}}}{\bar{x}} \cdot 100\% \quad (1)$$

The statistical analyzes were done using Statistica 7.1. software.

## Results

The smallest spray share (CSS) was collected in the extreme segments No. 1 and 7 (≤5.22%) and the biggest in the middle ones (No. 3-5) – up to 29.33% (tab. 2 and 3). Despite the relatively large divergence of the results obtained in the outer segments 1 and 7 (0.00-5.22%), no statically significant differences were observed there, only some trends. In many middle segments (No. 3-5), the spray share (CSS) exceeded 20% (38 of 48 observations).

The collected volume change (CVC) depended on the evaluated segment. The biggest changes were observed in segments 2 and 5 (average: 5.84-5.99%) and the lowest ones in segments 7 and 1 (respectively 1.23 and 2.42%). Statistical analysis showed a significant influence of the evaluated parameters of the sprayer on the average collected volume change. The average values were calculated for 7 segments. The nozzles configuration had the biggest impact on the magnitude of these changes. When the nozzles configuration has been changed, on average 3.56% of the total spray volume collected on a patternator was displaced for each 50-centimeter segment. When the nozzle type has been changed, leaving other settings unchanged, the average changes were only of 1.81 and as low as 0.88% for fan rotational speed changes.

Table 2
*Spray share (by volume) collected on PESSL vertical patternator at different heights from the ground (50-centimeter segments), during the spraying simulation with horizontal and directed air emission system sprayers depending on nozzle type and configuration at fan rotational speed: 1400 r·min$^{-1}$.*

| Segment no. / Height above ground | Spray emission system | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Horizontal (AGROLA Turbo 100v) | | | | Air directed (Tifone 1000) | | | |
| | Nozzle type and size | | | | | | | |
| | TR 80-015 | | IDK 90-015 | | TR 80-015 | | IDK 90-015 | |
| | Matching of nozzles configuration to the tree shape | | | | | | | |
| | Yes | No | Yes | No | Yes | No | Yes | No |
| 1/0÷50 cm | 0.0 a | 2.1 a-c | 0.00 a | 1.42 ab | 2.89 a-c | 0.93 ab | 5.22 a-e | 1.28 ab |
| 2/50÷100 cm | 7.77 b-f | 20.8 l-u | 3.77 a-d | 13.59 f-l | 11.19 e-h | 13.47 f-l | 12.72 f-j | 12.88 f-k |
| 3/100÷150 cm | 21.52 m-u | 25.22 r-w | 11.60 e-i | 25.58 s-w | 22.03 o-u | 24.79 r-w | 22.72 o-w | 21.82 o-u |
| 4/150÷200 cm | 29.33 w | 25.81 s-w | 21.60 n-u | 27.42 uw | 23.35 p-w | 19.89 j-u | 21.51 m-u | 21.68 n-u |
| 5/200÷250 cm | 26.24 t-w | 14.18 f-m | 18.34 h-s | 17.77 h-r | 20.17 k-u | 22.04 o-u | 20.04 j-u | 20.78 l-u |
| 6/250÷300 cm | 14.3 f-n | 10.09 d-g | 9.14 c-g | 10.21 d-g | 15.51 g-o | 16.43 h-p | 14.09 f-l | 18.71 i-t |
| 7/300÷350 cm | 0.84 ab | 1.8 a-c | 2.21 a-c | 4.01 a-d | 4.86 a-e | 2.45 a-c | 3.69 a-d | 2.85 a-c |

Means in table followed by the same letter do not differ significantly Duncan Multiple Range Test (α=0.05)

Table 3
*Spray share (by volume) (%) collected on PESSL vertical patternator at different heights from the ground (50-centimeter segments), during the spraying simulation with horizontal and directed air emission system sprayers depending on nozzle type and configuration at fan rotational speed: 1800 r·min$^{-1}$.*

| Segment no. / Height above ground | Spray emission system | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Horizontal (AGROLA Turbo 100v) | | | | Air directed (Tifone 1000) | | | |
| | Nozzle type and size | | | | | | | |
| | TR 80-015 | | IDK 90-015 | | TR 80-015 | | IDK 90-015 | |
| | Matching of nozzles configuration to the tree shape | | | | | | | |
| | Yes | No | Yes | No | Yes | No | Yes | No |
| 1/0÷50 cm | 0.00 a | 2.10 a-c | 0.00 a | 1.42 ab | 2.89 a-c | 0.93 ab | 5.22 a-e | 0.99 ab |
| 2/50÷100 cm | 7.77 b-f | 20.80 l-u | 3.77 a-d | 13.59 fl | 11.19 e-h | 14.47 f-l | 12.72 f-j | 12.88 f-k |
| 3/100÷150 cm | 21.52 m-u | 25.22 r-w | 11.60 e-i | 25.58 s-w | 22.03 o-u | 24.79 r-w | 22.72 o-w | 21.82 o-u |
| 4/150÷200 cm | 29.33 w | 25.81 s-w | 21.61 n-u | 27.42 u-w | 23.35 p-w | 19.89 j-u | 21.51 m-u | 21.68 n-u |
| 5/200÷250 cm | 26.24 t-w | 14.18 f-m | 18.34 h-s | 17.77 h-r | 20.17 k-u | 20.04 o-u | 20.04 j-u | 20.78 l-u |
| 6/250÷300 cm | 14.30 f-n | 10.09 d-g | 9.14 c-g | 10.21 d-g | 15.51 g-o | 16.43 g-p | 14.09 f-l | 18.71 i-t |
| 7/300÷350 cm | 0.84 ab | 1.80 a-c | 2.21 a-c | 4.01 ad | 4.86 a-e | 2.45 a-c | 3.69 a-d | 2.85 a-c |

Means in table followed by the same letter do not differ significantly, Duncan Multiple Range Test (α=0.05)

The significant influence of the spray emission system (sprayer) on the magnitude of spray vertical distribution changes has been shown. The nozzle configuration and the type of nozzles significantly influenced the vertical distribution changes with varying intensity, depending on the type of the spray emission system. The fan rotational speed affected that at low level for both emission systems, without significant differences between them (tab. 4).

Table 4 presents the mean and maximum values of the collected volume change in 50-centimeter segments depending on the sprayer type and its working parameters that were changed. Significantly greater changes in the spray vertical distribution due to nozzle configuration changes were observed for the sprayer with a horizontal emission system (on average 5.38, maximum 14.00%) than for the air directed one (on average 1.88, maximum 4.76%).

The nozzle type also influenced the vertical distribution of spray. That means that replacing the nozzles to get droplets of different size produced (eg. coarse vs. fine), even without any change in their arrangement and fan rotational speed, the different vertical distribution of spray may be obtained. For the horizontal emission sprayer there were observed bigger changes (on average 2.24%, maximum 7.57%) than for the air directed one (on average of 1.41%, maximum 3.75%). This could mean that the additional adjustment of nozzles settings could be needed in case of nozzle replacement e.g. in windy weather condition.

Table 4
*Mean and maximum values of collected volume change (%) in 50-centimeter segments depending on sprayer emission system and its working parameters that were changed.*

| Emission system | Changed parameter | CVC in 50-centimeter segment (%) | |
|---|---|---|---|
| | | Mean* | Maximum** |
| Air directed | Fan rotational speed | 0.93 a | 3.17 |
| | Nozzle type | 1.41 b | 3.75 |
| | Nozzle configuration | 1.88 c | 4.76 |
| Horizontal | Fan rotational speed | 0.83 a | 3.16 |
| | Nozzle type | 2.24 c | 7.57 |
| | Nozzle configuration | 5.38 d | 14.00 |

* Average of 7 segments. Means in columns do not differ significantly, Duncan Multiple Range Test ($\alpha$ =0.05)
** Maximum change observed in individual 50-centimeter segment.

The minor changes of spray vertical distribution for the air directed sprayer than for the horizontal emission are related to the method and the range of the air flow regulation. In the first sprayer the position in the space of nozzles and air outlets and angling of nozzles were changed (see tab. 1). The angling of air outlets in both variants was horizontal. In the horizontal emission sprayer the angling of air directing blades was changed together with the control of nozzles angling (horizontally or 20º upward). The nozzle position in relation to the sprayer remained unchanged – which was a constructional limitation. The above mentioned observation indicates – but indirectly - that there is a greater effect of changes in the air flow direction than the spray flow direction on the vertical distribution of spray in

orchard sprayers. This thesis needs to be confirmed by research specifically scheduled for this purpose.

By adjusting the nozzles settings (matched arrangement) the spray displacement between the vertical segments has been achieved. In the experiment it was assumed to spray 3.50 m high trees for a horizontal emission sprayer or 3.0 m high trees for the air directed one. The nozzles were adjusted to fit that dimensions. By adjusting the lower nozzles to the assumed tree shape it was possible to limit the amount of spray directed to the lowest 0-50 cm segment ("under the crown"), or – in case of a horizontal emission sprayer – to the upper zone above 300 cm ("above the tree"). Such spray "redirection" should always be consistent with the tree height and the shape of the sprayed zones.

Statistical analysis showed no effect of the estimated parameters on the variation between repetitions. Average coefficients of variation (of 7 segments) did not exceed 5.80% with maximum variation in the middle segments (50-300 cm) 7.66%. Balsari et al. (2007), by formulating a criterion for assessing the suitability of patternators to measure the vertical distribution of spray, proposed that the variability between the measurements should not exceed 10% (coefficient of variation). This means that the measuring method used in the present studies meets the mentioned requirements. Another issue is to evaluate the usefulness of methods using vertical patternators for calibration of the orchard sprayer. The quality of the fit and the convergence of the vertical distribution of the spray measured on a patternator with the spray distribution in the sprayed trees was the subject of further analysis. Its results are presented in a separate publication (Godyń et al., 2014).

## Conclusions

1. The vertical distribution of spray depended significantly on the applied spray emission system, nozzles configuration and the type and in the slightest degree on the sprayers fan rotational speed.
2. The largest spray share (CSS) was collected in the middle segments of a patternator – up to 29.33%, and the smallest one in the extreme segments (0.0-5.22%).
3. The change of nozzles configuration significantly affected the change in the spray vertical distribution by the vertical displacement of spray between the 50-centimeter segments. The biggest collected volume changes (CVC) were observed in segments no. 2 and 5 (5.84-5.99%) and the lowest ones in the extreme segments no. 7 and 1 (respectively 1.23 and 2.42%).
4. The biggest change in the spray vertical distribution due to nozzles configuration changes were observed for the horizontal emission sprayer (average: 5.38%, maximum in single segment: 14.0%).
5. The average coefficients of variation between repetitions did not exceed 5.80% with maximum variation in the middle segments (50-300 cm) 7.66%. This means that the method meets the criteria of usefulness of patternators to measure the spray vertical distribution, formulated by Balsari.

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# WPŁYW KONFIGURACJI ROZPYLACZY W OPRYSKIWACZACH SADOWNICZYCH NA PIONOWY ROZKŁAD CIECZY UŻYTKOWEJ

**Streszczenie.** Celem pracy było określenie wpływu wybranych parametrów roboczych dwóch typów opryskiwaczy sadowniczych na pionowy rozkład i ilościowe zmiany rozkładu pionowego cieczy – wyrażanego jako procentowy udział cieczy w 50-centymetrowych segmentach. Pomiary prowadzono na pionowym separatorze kropel. Zakres pracy obejmował pomiary rozkładu pionowego cieczy dla dwóch różnych sposobów ustawienia rozpylaczy, dwóch typów rozpylaczy i dwóch prędkości obrotowych wentylatora. Pionowy rozkład cieczy zależał istotnie od zastosowanego systemu emisji cieczy, konfiguracji rozpylaczy i typu rozpylaczy, a w najmniejszym stopniu od prędkości obrotowej wentylatorów opryskiwaczy. Najmniejszy udział cieczy przypadał na dwa skrajne segmenty (≤5,22%), a największy na segmenty środkowe – 29,33%. Zmiana konfiguracji rozpylaczy istotnie wpływała na zmiany pionowego rozkładu cieczy poprzez przemieszczenie cieczy między pionowymi 50-centymetrowymi segmentami. Największe zmiany pionowego rozkładu cieczy w wyniku zmiany konfiguracji rozpylaczy obserwowano dla opryskiwacza o poziomej emisji cieczy – średnio: 5,38%, maksymalnie w jednym segmencie: 14,0%.

**Słowa kluczowe:** opryskiwacz sadowniczy, pionowy rozkład cieczy, udział cieczy, pionowy separator kropel, paternator

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# COMPARATIVE ANALYSIS OF WIND SPEED SHORT TERM FORECASTS FOR WIND FARMS

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ABSTRACT

The purpose of study was verification regarding quality of wind speed forecasts used during designing the wind farm capacity, with AAN [artificial neural network] methods and Brown, Holt, Winters and ARIMA time models. Analysis included results of forecasts for December, namely a month with the biggest wind speed amplitude changes, considering data for period of 2008-2009. Analysis of results confirmed that appropriate linear models and artificial neural methods for the period of wind speed forecast may ensure good results regarding forecasts of wind power output generated by wind farms.

## Introduction

Wind power industry in Poland is more and more popular, and technology used for wind power generation undergoes quick development. Wind power is environmentally friendly, and features easy operation, small costs and relatively small negative impact, although lately lively public debates have followed regarding this last issue. Areas which until now were considered unfavourable for wind farms due to wind conditions, at present have been purposed for operation. Well designed wind farms at present technology development enable to achieve many economical benefits. Yet forecast regarding energy generated by wind farms actually constitutes a big problem, and therefore more interest is focused on the methods for wind farm capacity forecast preparation. The wind speed is the main parameter that has impact on the wind farm capacity. Any error during wind speed assessment in consequence results in discrepancy of forecasted and actual energy generated by a wind farm. Actually, it results from the fact that the wind farm power is proportional to the cubed wind speed. The Energy Law Act determines the framework for the electric energy market differently than for other energy sources and the precise principles regarding reporting the wind farm operation plan, laid down in the Transmission System Operation and Maintenance, the balancing mechanism for electric energy sources, enables the correction for planned electric energy delivery to the grid, not later than 2 hours before hourly period of generation thereof. Therefore, ultra-short time forecasts covering the period of few hours are the most crucial for the electricity system operation (Karkoszka, 2010).

## The objective and scope of research

The characteristic feature of a wind farm relates to varied operation conditions, resulting from wind speed variations. Highly variable electricity generated by a single wind farm may pose a threat to the electricity system. Therefore, owners of wind farms were obliged to prepare estimates regarding generated energy. Thus, the purpose of the study was to verify whether artificial neural networks, and selected linear mathematical models may provide an effective tool for wind speed forecasting.

### Characteristics of measuring data

Data used for preparation of forecasts included measuring data of wind speed, air temperature and atmospheric pressure, recorded every hour, as of 2008-2009, at weather station close to Żelazna near Skierniewice, collected by Electricity Management Plant SGGW. Wind speed, $V$, measurements were made with the $h_{data}$=12 m high mast. Speed readings were converted into values corresponding to height where wind farm generators were installed, and these values were specified later on, in the paper, namely $h$=73 m, with application of formula (Scire et al., 2000; Szczygłowski, 2007):

$$V_h = V_{h_{data}} \left(\frac{h}{h_{data}}\right)^{0.26} \tag{1}$$

The power factor (of area roughness) was determined empirically for the location where the measuring data were collected. Figure 1 presents diagram regarding daily distribution of mean wind speed values recorded every hour, specified for the analyzed period. The distribution was similar to the normal one, with displacement by vector 5.8 m·s$^{-1}$ and of the mean value obtained during midday.

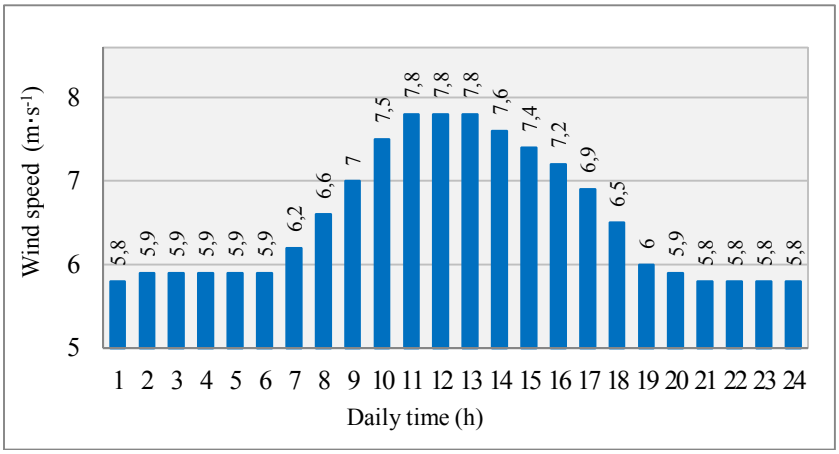


*Figure 1. Distribution of average hourly wind speeds, in the period 2008 and 2009*

Wind speeds at particular months of different years that may differ significantly, which was the case in 2008 and 2009, and Figure 2 presents their daily mean values for subsequent months of these years.

Diagram in Figure 2 confirms the strongest wind identified in the late autumn and winter. The average annual wind speed determined for the data obtained at the weather station at Żelazna, at height 73m was 6.52 $m \cdot s^{-1}$.

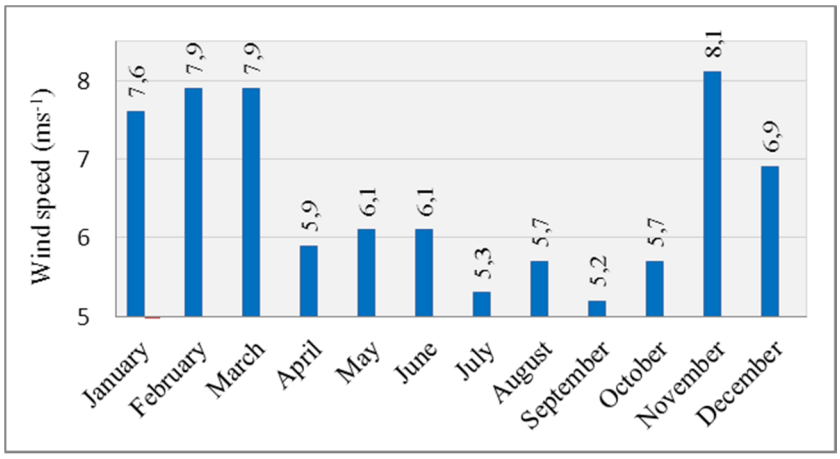


*Figure 2. Distribution of mean monthly wind speeds, on the basis of accumulated data from the period of 2008 and 2009*

For more precise assessment regarding usefulness of forecasting models, results of forecasts were considered for December, a moth that features biggest sudden amplitudes, which made forecasting more difficult.

All forecasts have been prepared with Statistica software.

**Forecasts based on the artificial neural networks (AAN)**

Assessment regarding fitness of SSN for preparing wind speed forecasts was based on the basis of comparative analysis of forecasts in advance of 1, 3, 6, 12 and 24 hours. Forecasts were prepared with use of MLP multi-layer perception. Input data set included:

– information on the date of measurement, namely year, month, hour,
– wind speed according to historical data, and its 24 preceding values,
– air temperature according to historical data, and its 24 preceding values,
– atmospheric pressure according to historical data, and its 24 preceding values,
– information on sudden changes of pressure and temperature within a single hour.

Hidden neurons of forecast taking into account pressure and temperature were activated on the basis of exponential function, whereas an output neuron was activated by sine function. In case of a forecast that was not based on other input data except of wind speed, hidden neurons action was based on logistics function whereas output neuron was activated with exponential function.

Verification confirmed that the historical data on the wind speed is crucial for the quality of a forecast, whereas other information namely on temperature and pressure had little impact on the forecast quality. Table 1 presents reference historical data for two neural models that provided best forecasts 1 hour in advance.

Table 1
*Assessment of neuron models providing forecasts 1 hour in advance*

| Model | Output data | | MAE | RMSE | Coefficient factor |
|---|---|---|---|---|---|
| MLP 111-8-1 | Speed, Pressure, Temperature | Learning | 1.14 | 1.52 | 0.90 |
| | | Validation | 1.16 | 1.57 | 0.87 |
| | | Test | 1.31 | 1.71 | 0.89 |
| MLP 60-18-1 | Speed | Learning | 1.16 | 1.55 | 0.90 |
| | | Validation | 1.18 | 1.58 | 0.86 |
| | | Test | 1.34 | 1.76 | 0.88 |

Diagrams regarding wind speed included in the following drawings relate to the period of 12 days, whereas the horizontal axis determines the beginning of each next day (0h) and afternoon (12h). Figure 3 includes a comparative analysis regarding results of forecasts for 3, 6 and 12 hours in advance against actual values of wind speed.

According to neuron calculations, for forecasts specified on 3 Figure, increase of time resulted in bigger errors of forecasts. Additionally to deviations' increase from measured values, it was evident that values of wind speed forecasts were close to mean value of this speed.

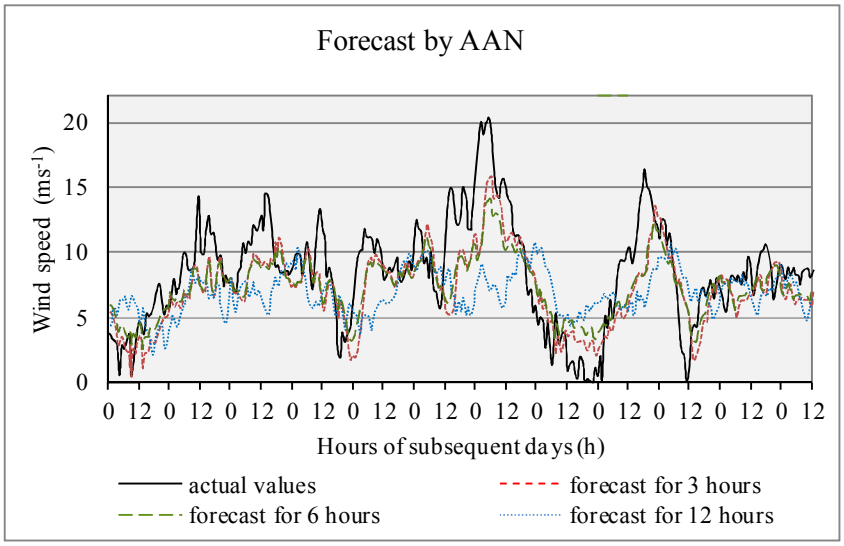


*Figure 3. Diagrams of neuron model forecasts 3, 6 and 12 hours in advance, based on input data including historical data of wind speed, atmospheric pressure, air temperature and date of measurement*

**Forecasts based on time models**

The typical models forecasting the value changing depending on variations, were the models of time series. The study verified application of Brown's, Holt's, Winters' and ARIMA models for wind speed forecasting:

**Brown's model** finds application, when variability of the forecasted variable is almost constant, no development follows within time series, and fluctuations of value resulted from impact of random factors (Cieślak, 2011). The forecast was determined on basis of the following formula (2):

$$y_t^* = \propto y_{t-1} + (1-\propto) y_{t-1}^* \quad (2)$$

where:

$y_{t-1}^*$ – value forecasted at a given value of the smoothing factor,
$y_t^*$ – forecast of Y variable value determined for $t$ time,
$\propto$ – smoothing factor, of values from range (0,1],

According to Brown's model, the forecast for 1 period in advance was the combination of model actual past value, and forecast past value. The smoothing factor was determined on the level of 0.95. Figure 4 presents Brown's model diagram forecasting wind speed 1 hour in advance:

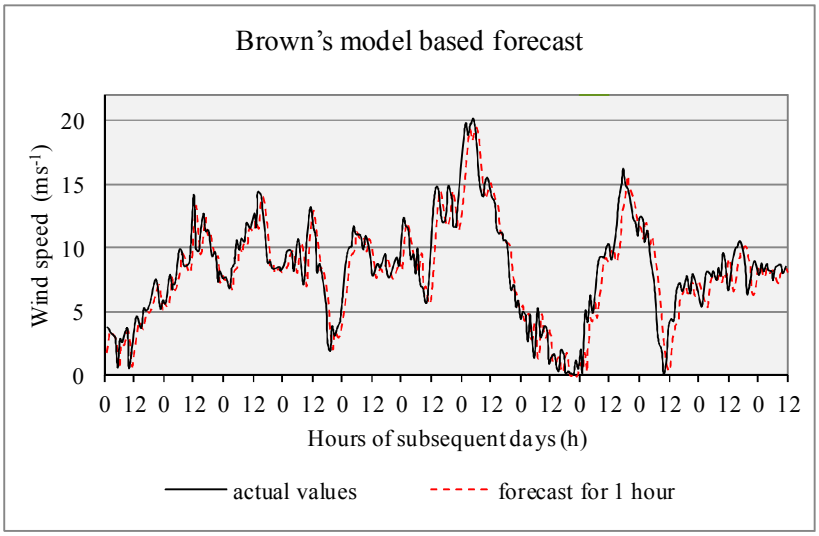


*Figure 4. Brown's model based forecast, 1 hour in advance*

Although simple, Brown's model works better than artificial neural networks. Table 2 presents the errors of models that help to assess the quality of forecasts.

**Holt's model** has been applied for forecasting phenomenon when accidental fluctuations follow and evident development trend (Halicka and Winkowski, 2013). In theory, this model featured more flexibility comparing to Brown's model, as it had two smoothing factors. Holt's linear model based on (3) and (4) equations and forecast (Cieślak, 2011) was determined with the following formula (5):

$$F_{t-1} = \propto \cdot y_{t-1} + (1-\alpha)(F_{t-2} + S_{t-2}) \tag{3}$$

$$S_{t-1} = \beta(F_{t-1} - F_{t-2}) + (1-\beta)S_{t-2} \tag{4}$$

$$y_t^* = F_n + (t-n)S_n \ , \tag{5}$$

where:

$F_{t-1}$, $(F_n)$ – smoothed variable value forecasted for time $t$-1, $(n)$,
$S_{t-1}$, $(S_n)$ – smoothed value corresponding to trend gain for time $t$-1, $(n)$,
$n$ – number of value within time series,
$\alpha$, $\beta$ – smoothing parameters within range (0,1].

Smoothing parameters determined in the work: $\alpha$=0.95, $\beta$=0.05 provided better results. Forecast based on Holt's model 1 hour in advance provided forecasts comparable to ones based on Brown's model. Observing wind speeds hour after hour, development tendency was evident that followed most often from 3 to 4 hours. Figure 5 presents forecast diagram 3 hours in advance.

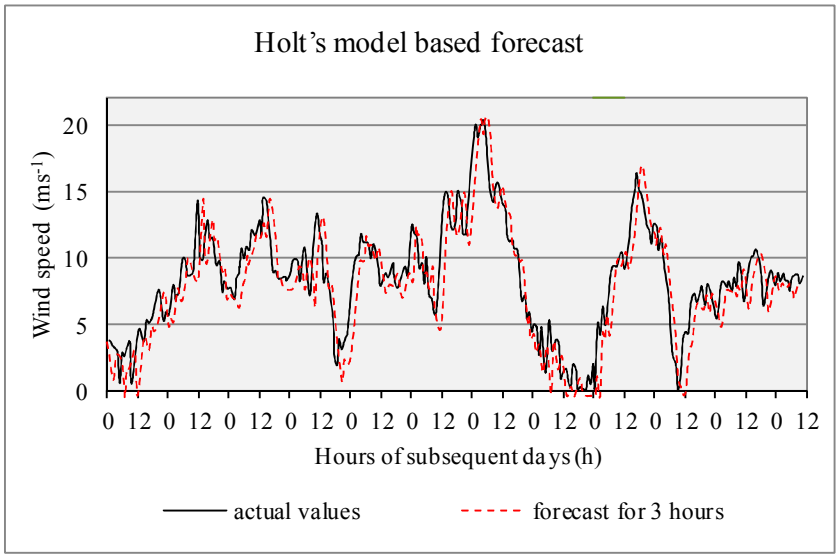


*Figure 5. Holt's model based forecast, 3 hours in advance*

The diagram demonstrated evident displacement with reference to actual values, so delay of forecast was evident. Comparative analysis of Holt's models and artificial neural networks, 3 hours in advance or more indicated that neural based model was more precise.

**Winters' additive model** is preferred, when the seasonal variations, development trend and accidental variations follow through the series time. Winters' additive model (Karkoszka, 2010) was based on (6)-(8) formulas and forecast computation was based on (9) formula.

$$F_{t-1} = \propto (y_{t-1} - C_{t-1-r}) + (1-\propto) * (F_{t-2} + S_{t-2}) \quad (6)$$

$$S_{t-1} = \beta(F_{t-1} - F_{t-2}) + (1-\beta) * S_{t-2} \quad (7)$$

$$C_{t-1} = \gamma(y_{t-1} - F_{t-1}) + (1-\gamma)C_{t-1-r} \quad (8)$$

$$y_t^* = F_n + S_n(t-n) + C_{t-r} \quad (9)$$

where:

$F_{t-1}$ – smoothed variable value forecasted for time $t$-1,
$C_{t-1}$ – smoothed seasonality value for time $t$-1,
$S_{t-1}$ – smoothed value corresponding to trend gain for time $t$-1,
$r$ – total seasonal cycle length,
$\alpha, \beta, \gamma$ – smoothing parameters within range (0,1].

For the needs of Winters' additive model and purpose of this forecast, the following parameters: $\alpha = 0.95$, $\beta = 0.05$, $\gamma = 0.05$ were applied. For example, Figure 6 presents the results of forecast 1 in advance. The forecast results were similar to the results obtained with Holt's model. Winters' model demonstrated slightly more advantageous MAE average absolute error and average-square error elements for these models were almost the same. Almost identical relation follows when comparing errors of forecast 3 hour in advance. It testified to similar limited usefulness of both Winters' and Holt's model for the wind speed forecasts a few hours in advance.

Results of forecasts were similar to those based on Holt's model. Winters' model demonstrated slightly more advantageous MAE average absolute error and average-square error elements for these models were almost the same. Almost the same dependency was evident when comparing errors of forecasts 3 hours in advance. It proves similar limited usefulness of both Winters' and Holt's model for the wind speed forecasts a few hours in advance.

As Brown's model worked better comparing to Holt's model, verification also followed regarding Winters' model excluding development trend, by applying appropriate corrections to equations – smoothed trend gain calculation was excluded. Forecast 1, 3 and 6 hour in advance underwent verification. The model excluding development trend provided better forecast 1 and 3 hours in advance, whereas time over 3 hours in case of Winters' model indicated its poor quality comparing to the neural method, what was also confirmed with error comparative analysis included in table 2.

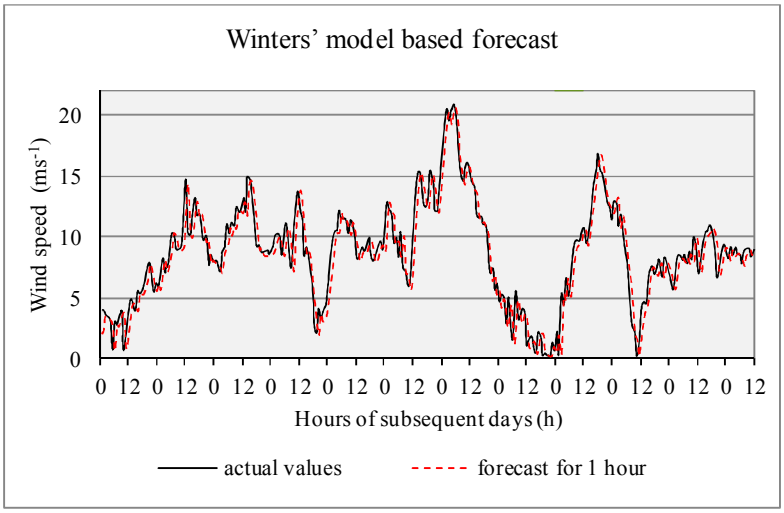


*Figure 6. Winters' additive model based forecast 1 hour in advance*

**ARMA/ARIMA models** considered as ones of the best methods for forecasting of time series. Application thereof for forecasting includes use at least 60 observations, what in this case was not a problem, due to a large set of the possessed data. ARIMA model was a combination of auto-regression and moving average structure models. Forecast was prepared (*ARMA and ARIMA models in*: Econometrics. Forecasting and simulations; StatSoft, 2006) using the following formula:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + \ldots + \Phi_p y_{t-p} + e_t - \Theta_1 e_{t-1} - \ldots - \Theta_q e_{t-q} \quad (10)$$

where:

$\Phi_0, \Phi_1, \ldots \Phi_p, \Theta_0, \Theta_1, \ldots \Theta_q$ – model factors,
p, q – delay;
$e_t, e_{t-1}, e_{t-2}$ – model remaining for time t, t-1, t-q.

ARIMA model (p,d,q)(P,D,Q), taking into account seasonality demonstrated the smallest errors when forecasting wind speed 1 hour in advance, and Table No. 3 includes errors of this forecast. The obtained model including seasonality of wind forecast 1 hour in advance was as follows: ARIMA(2,0,1)(2,0,1), which in brief was ARMA(2,1)(2,1). The analyzed study the model was applied with $p$=2 two auto-regression parameters and $q$=1 moving average one parameter, as well as, in this case, model did not require differentiation, $d$=0. Forecasting precision with this method in case of long time, similarly to neural networks resulted in large errors also.

## Summary and conclusions

The purpose for application of data regarding December, namely a month that features big speeds and sudden wind speed variations was verification regarding quality of forecasts at the most unstable conditions. In case of summer months, the analyzed forecasts demonstrated smaller errors than correlation coefficient, and bigger for models generated with the neural methods. The Table 3 includes summary namely values of errors for all tested forecasting methods.

Table 3
*Statement of mean errors for considered forecast models*

| ANN (MLP) | | | | | | |
|---|---|---|---|---|---|---|
| Forecast time | 1h (wind only) | 1h | 3h | 6h | 12h | 24h |
| MAE | 1.34 | 1.31 | 1.68 | 1.97 | 2.28 | 2.54 |
| RMSE | 1.76 | 1.71 | 2.18 | 2.56 | 3.05 | 3.28 |

| Time series models (linear) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Forecast time | Brown's | Holt's | | Winters' | | | | ARIMA |
| | | | | With trend | Without trend | | | |
| | 1h | 1h | 3h | 1h | 1h | 3h | 6h | 1h |
| MAE | 0.9 | 0.92 | 1.69 | 0.91 | 0.90 | 1.59 | 2.22 | 0.87 |
| RMSE | 1.23 | 1.25 | 2.28 | 1.25 | 1.23 | 2.14 | 2.93 | 1.19 |

The results of research provided grounds for the following conclusions:

1. The best results for forecast 1 hour in advance, with smallest MAE absolute mean error and RMSA average-square error obtained ARIMA model, good results obtained also Winters' model without trend and Brown's model, whereas poor results below the mentioned ones obtained neural models.
2. Brown's model was ineffective for longer periods.
3. In case of forecasts 3 hours in advance, ARIMA or Winters' models without trend may be used also.
4. Linear models described in this paper demonstrated big errors when forecasting wind speed 6 hours in advance and more.
5. Applying wind speed data as input data on wind speed neural models from preceding periods and additionally current air temperature and atmospheric pressure provides for quality improvement of forecast prepared with this method.

According to this study, the general recommendation is evident that a combined model can be an effective way to provide a reliable wind speed forecast prepared 24h in advance or more.

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## PORÓWNANIE MODELI KRÓTKOOKRESOWYCH PROGNOZ PRĘDKOŚCI WIATRU DLA SIŁOWNI WIATROWYCH

**Streszczenie.** Celem pracy było sprawdzenie jakości prognozy prędkości wiatru, wykorzystywanej w planowaniu mocy siłowni wiatrowej, metodami SSN i modelami szeregów czasowych Browna, Holta, Wintersa i ARIMA. Porównano wyniki prognoz sporządzonych dla grudnia, miesiąca o największych zmianach amplitudy prędkości wiatru, sprawdzając je dla danych z lat 2008-2009. Analiza wyników wskazuje, że odpowiedni dobór modeli liniowych i sztucznych sieci neuronowych do horyzontu czasowego prognozy prędkości wiatru, może pozwolić na osiągnięcie dobrych wyników prognozowania energii, wytworzonej przez siłownie wiatrowe.

**Słowa kluczowe**: prognozowanie, prędkość wiatru, siłownia wiatrowa

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# IMPACT OF THERMAL BRIDGES ON THERMAL PROPERTIES OF THE NEW-TYPE PIGGERIES STRUCTURES

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ABSTRACT

Pig production has high energy consumption thus the energy efficiency of a building is very important. The objective of this paper is a qualitative and quantitative evaluation of thermal properties and thermal bridges in the structure of a newly constructed piggery. The results prove unsuitable thermal properties of the majority of structures. Characteristic thermal properties: external walls (UT=0.470 $W \cdot m^{-2} \cdot K^{-1}$), flooring (UT=1.356 $W \cdot m^{-2} \cdot K^{-1}$), ceiling (UT=0.229 $W \cdot m^{-2} \cdot K^{-1}$), windows and doors (UT=1.70 $W \cdot m^{-2} \cdot K^{-1}$). Qualitative detection of thermal defects with utilization of infrared thermography claimed the most significant thermal bridges on uninsulated socle and flooring, steel concrete straining band of the wall, bearing steel roof frames and window and door frames. The energy efficiency of buildings is significantly affected by the built structure properties and some structures of the measured buildings had low thermal insulation and caused high heat losses.

## Introduction

Pig production highly depends on the ambient conditions inside environment of the piggery. For regulation of the inside environment conditions, thermal insulation of external envelope elements and technical equipment for heating and ventilation are used. This is one of the reasons of high energy consumption of pig production. (Theodosiou and Papadopoulos, 2008) state that the European Directive 2002/91/EC on the Energy Performance of buildings (EPBD) is probably the most important single action towards the improvement of energy efficiency in the building sector throughout Europe since 1970s when, in the aftermath of the energy crisis, most national building regulations introduced mandatory thermal insulation requirements. The implementation of the European Directive 2002/91/EC in the form of national laws by each Member State, gradually leads to the need to adopt advanced standards, techniques and technologies while designing and constructing new buildings, but also to apply energy renovation measures in existing ones, in order to comply with the updated energy efficiency requirements. (Déqué et. al., 2001) state that insulating walls

represent one of the simplest solutions for decreasing heat losses of the building. However, although quite obvious in the energy balance, the ever improving insulation implies that the relative proportion of heat losses by cold bridges in the wall has relative influenced thermal bridges in the overall heat losses. The other major improvement in the study of thermal bridges is this recent possibility for engineers to use infrared thermography instruments. This technique allows visualization of heat losses in situ, at a distance (without contact) at the scale of the building and without intrusion in the building walls as non-destructive technique (Zalewski et al., 2010).

Bucklin et al. (1992) states that livestock buildings housing young animals need addition of heat during cold weather periods. The most significantly heated livestock building, housing early-weaned piglets is a swine nursery. Autonomic and behavioral thermoregulatory mechanisms play important role in the adaptation of the pig to its environment (Ingram, 1976). Piglets are homeothermic animals and continuously try to keep their body temperature at 39ºC through the thermal exchanges with the surrounding air. (McCracken, 1984) states that for early-weaned piglets, 3-4 weeks old when weaned, housed under real farm conditions, growth parameters are optimized when temperatures vary between 21ºC and 29ºC. For pigs especially in the weaning phase, a critical parameter is room temperature, which must be maintained around 26ºC (Whittemore, 1993). The thermal equilibrium in the body is achieved through a balance between the metabolic heat production and heat loss from the body. Pigs heat production has a diurnal rhythm depending on the feed intake and activity level, and is influenced by the ambient temperature (Henken at al., 1993). Climatic conditions in pig housing, primarily ambient temperature are monitored and automatically adjusted based on the set point temperature. However, the thermal environment is not only determined by the dry-bulb temperature, but is also influenced by the wet-bulb temperature, radiant temperature and air velocity (Sällvik and Walberg, 1984). If the thermal environment does not satisfy the current thermal need of the pigs, it can lead to hygiene (Aarnink et al., 2006) and welfare problems (Hillmann at al., 2004). (Gálik and Karas, 2004) claimed that the difference between the average air temperature in the house and that of interior wall surfaces is 3.44ºC and resulted in the bedewing of circumferential construction.

The objective of this paper is a qualitative and quantitative characterization of thermal bridges on the walls of a new -built piggery. In the first step, the proposed methodology involves an infrared camera employed to locate the thermal bridges on the walls. Experimental part of the paper consists of thermograms of the envelope with their interpretation. The next step is calculation of the thermal characteristics and heat losses caused by thermal bridges.

## Material and methods

The analyzed piggery is located at Suchohrdly u Miroslavi (lat 48º56´50´´N, long 16º22´26´´E) Znojmo region, Czech Republic. This new-building piggery is a part of facilities for livestock production and was built in 2008. Capacity of piggery is designed for 350 sows and 1300 piglets. Piggery has forced ventilation with the electronic system of measurement and regulation, warm-water heating. A continuous winter duct pit ventilation centrifugal fan is integrated with variable speed axial fan to cover the summer ventilation rates.

The floor is slatted and the slurry collected in the pit underneath is continuously removed into a farm biogas station. The interior air temperature is maintained between 20-30ºC. The piggery consists of two integrated parts. The building is overall 25.0 m wide, 95.0 m long and 6.0 m high (exterior sizes). The external walls of the piggery are 40 cm thick (including plasters) and are made of light clay brick block plastered on both sides. The roof structure is made of prefabricated steel beams, with a ceiling in large trapezial galvanized steel plates layered with rock wool (about 16 cm thick). The roof sheeting is made of fibrous concrete. The inner rooms are divided by brick block walls (30 cm and 12.5 cm in thickness including plasters) plastered on both sides. The doors, gates and windows are made of plastic (PVC) profile with thermal double glazing. The parameters of the doors and gates are – width 1.10 m, height 2.10 m and width 2.10 m, height 2.10 m. The parameters of the windows are – width 1.00 m, height 1.00 m and 1.50 m.

For this study FLIR E320 thermal infrared camera was used. For thermal imaging measurement purposes the air temperature, air humidity, distance from the monitored walls and material emissivity were measured. Determination of material emissivity was performed by creation of measuring points on the materials for thermal analyses. On these points temperature with using OMEGA HH11 contact thermometer (accuracy of temperature measurement: ±0.1ºC) was measured. The most significant prerequisite was to prevent fluctuation of temperature in the course of time. The afore-mentioned point was also monitored using FLIR E320 thermal camera. In case the temperature values proved to be different, the temperature in the thermal camera was calibrated by means of setting up the emissivity value in the user interface of this device. The final emissivity value was determined at the time when the temperature values on both devices were balanced.

The air temperature and humidity were measured using OMEGA RH81 thermo-hygrometer featuring the temperature measurement accuracy of ±1ºC and humidity measurement accuracy of ±4% (at the temperature of 25ºC and relative humidity within the range of 10-90%). The temperature and humidity were measured in the close vicinity of the thermal camera and measured equipment, and the arithmetic mean was subsequently calculated on the basis of these values. The reflected temperature was not measured because no heat sources were in the surroundings, which could influence the measurement. The measurement was performed in cloudy conditions.

The measurement was conducted at a constant distance from the measured objects. The distance of the camera from the measured objects was determined using Leica DISTO$^{tm}$ A5 laser EDM device (measurement accuracy: ± 1.5 mm at a distance between 0.2 and 200 m). The thermal imaging measurement as such was conducted using FLIR ThermaCAM E320 thermal camera (FOV: 25º). The average temperature of the surface was calculated using ThermaCAM QuickReport software in which each pixel of the video recording was allocated to one temperature value. An arithmetic mean was subsequently created on the basis of all values.

The Standard EN ISO 10211:2007 describes the calculation method for linear thermal bridges and superficial temperatures.

If we consider a multi layered construction with a simplified index to represent the total heat-transfer processes, the total thermal transmittance $U_T$ is given by (EN ISO 6946) according to the following equation:

$$U_T = \frac{1}{R_T} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{1}$$

where:

$R_T$ – the total thermal resistance ($\mathrm{m^{-2} \cdot K^{-1} \cdot W^{-1}}$)

The total thermal resistance is given by (EN ISO 6946) according to the following equation:

$$R_T = R_{si} + R_1 + R_2 + \ldots + R_n + R_{se} \quad (\mathrm{m^{-2} \cdot K^{-1} \cdot W^{-1}}) \tag{2}$$

where:

$R_{si}$ – the internal surface resistance ($\mathrm{m^{-2} \cdot K^{-1} \cdot W^{-1}}$),

$R_1, R_2 \ldots R_n$ – the thermal resistance of each layer,

$R_{se}$ – the external surface resistance ($\mathrm{m^2 \cdot K \cdot W^{-1}}$).

Thermal resistance R for multilayer homogenous building elements is calculated according to the following equation (EN ISO 6946:2008)

$$R = \frac{d}{\lambda} \quad (\mathrm{m^{-2} \cdot K \cdot W^{-1}}) \tag{3}$$

where:

$d$ – the thickness of layer (m),

$\lambda$ – the thermal conductivity ($\mathrm{W \cdot m^{-1} \cdot K^{-1}}$).

Total heat losses of object Q were calculated according to the following equation

$$Q = S \cdot \left(I + q_t\right) \ (\mathrm{W}) \tag{4}$$

where:

$I$ – the intensity of grey-body radiation ($\mathrm{W \cdot m^{-2}}$),

$q_t$ – the heat losses due to convection ($\mathrm{W \cdot m^{-2}}$),

$S$ – the outer surface of construction ($\mathrm{m^{-2}}$).

Heat losses due to convection were calculated with the use of the convective heat transfer coefficient. This coefficient was determined according to the following equations (Bašta 2000): Cihelka

$$\alpha_k = 0.48\left(t_1 - t_2\right)^{0.33} \ (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{5}$$

McAdams

$$\alpha_k = 1.78 \cdot \Delta t^{0.12} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{6}$$

Hencky-Hottinger

$$\alpha_k = 1.67 \cdot \Delta t^{0.27} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{7}$$

where:

$t_1$ – the temperature of atmosphere out of thermokinetic layer (°C, K),

$\Delta t$ – the difference of air temperature and surface temperature (°C, K).

Then specific heat fluxes were calculated according to the equation

$$q_t = \alpha_k (t_1 - t_2) \quad (\mathrm{W \cdot m^{-2}}) \tag{8}$$

where:

$\alpha_k$ – the convective heat transfer coefficient ($\mathrm{W \cdot m^{-2} \cdot K^{-1}}$),
$t_1$ – the temperature of air ($^o$C, K),
$t_2$ – the temperature of surface ($^o$C, K).

Heat losses due to radiation are calculated with the help of Stefan–Boltzmann law. At first total intensity of a grey body radiation is calculated. Then the total intensity of an environment radiation was subtracted from the total intensity of a grey body radiation.
The equation for calculation of specific heat fluxes due to radiation is following

$$I = \left(\sigma \cdot \varepsilon_s \cdot T_s^4\right) - \left(\sigma \cdot \varepsilon_t \cdot T_t^4\right) \ (\mathrm{W \cdot m^{-2}}) \tag{9}$$

where:

$\varepsilon_s$ – the emissivity of grey-body,
$\varepsilon_t$ – the emissivity of environment
$T_s$ – the thermodynamic temperature of grey-body (K),
$T_t$ – the thermodynamic temperature of environment (K),
$\sigma$ – the Stefan-Boltzmann constant ($\mathrm{W \cdot m^{-2} \cdot K^{-4}}$).

The boundary conditions for calculation hypotheses are given in Table 1.

Table 1
*Boundary conditions used to calculate thermal resistance and thermal transmittance of the construction*

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| External surface thermal resistance | $R_{se}$ | 0.04 | $\mathrm{m^2 \cdot K \cdot W^{-1}}$ |
| Internal surface thermal resistance | $R_{si}$ | 0.13 | $\mathrm{m^2 \cdot K \cdot W^{-1}}$ |
| Indoor temperature | $\Theta_i$ | +22 | ºC |
| Outdoor temperature | $\Theta_e$ | -15 | ºC |

## Results and discussion

This survey aims at thermal defect detection of new-building piggery structures with the use of the IR thermography system. Boundary conditions of infrared thermography measurement are presented in table 2.

Next part of the paper consist in calculation of the thermal characteristics of the envelope construction (presented in Table 3 and 4) and heat losses caused by thermal bridges (presented in table 5). Piggery is heated at temperature 20-30ºC. Interior relative air humidity is about 75%. Temperature depends on the age group category of animals. First thermogram represents first part of the south façade of piggery. Construction of the wall is from light clay brick with external and internal plaster. This construction has only average thermal properties ($U_T$=0.470 $\mathrm{W \cdot m^{-2} \cdot K^{-1}}$) but it is not the most problematic part of the construction.

Table 2
*The boundary conditions for evaluation of the infrared thermography survey*

| No. | Object | Emissivity (-) | Atm. temperature (°C) | Relative humidity (%) | Distance from measuring point (m) | Measured surface ($m^2$) | Average temperature of the surface (°C) |
|---|---|---|---|---|---|---|---|
| 1 | Steel concrete straining band of the wall | 0.92 | - 8.8 | 83 | 28 | 40 | - 2.8 |
| 2 | Bearing steel roof frame | 0.86 | - 8.7 | 82 | 32 | 215 | - 4.9 |
| 3 | Frame of the window | 0.88 | - 8.8 | 83 | 13 | 0.4 | 0.8 |
| 4 | Frame of the door | 0.88 | - 8.8 | 83 | 12 | 0.8 | 1.2 |
| 5 | Uninsulated socle | 0.95 | - 8.7 | 83 | 24 | 43 | 0.5 |

Table 3
*Characteristic thermal properties of the new-building piggery constructions*

| Specification of the structure | Material of the structure layer | Thickness (m) | Thermal conductivity λ ($W \cdot m^{-1} \cdot K^{-1}$) | Density ($kg \cdot m^{-3}$) | Calculation of the total thermal resistance $R_T$ ($m^2 \cdot K \cdot W^{-1}$) | Calculation of the total thermal transmittance $U_T$ ($W \cdot m^{-2} \cdot K^{-1}$) |
|---|---|---|---|---|---|---|
| Outside wall | Internal plaster | 0.015 | 0.99 | 2000 | 0.015 | 66.66 |
| | Light clay brick | 0.365 | 0.19 | 720 | 1.921 | 0.52 |
| | External plaster | 0.020 | 0.99 | 2000 | 0.020 | 50 |
| | Total thermal properties of the structure | | | | 2.126 | 0.47 |
| | Required value according to standard CSN 73 0540-2:2011 | | | | - | 0.30 |
| Flooring | Concrete | 0.100 | 1.36 | 2300 | 0.074 | 13.51 |
| | Bitumen sheet | 0.07 | 0.21 | 1400 | 0.033 | 30.30 |
| | Steel concrete | 0.100 | 1.58 | 2400 | 0.063 | 15.87 |
| | Gravel | 0.150 | 0.58 | 1650 | 0.259 | 3.86 |
| | Total thermal properties of the structure | | | | 0.796 | 1.356 |
| | Required value according to standard CSN 73 0540-2:2011 | | | | - | 0.45 |

Surface temperature of the brick wall is about -5.2ºC. As we can see in Figure 1 there is increased heat flow in socle parts (height 0.7 m) of the structure because socle and foundations are from uninsulated steel concrete and also flooring has no thermal insulation. A comparable problem with heat transfer over uninsulated foundations is presented in (Al-Anzi and Krarti, 2004). The warm water floor heating system without thermal insulation of flooring is an unsuitable solution for this structure. The average surface temperature of the socle is about 0.5ºC. Significant detail there is steel concrete straining band of the wall. It is bearing structure with poor thermal insulation.

This layer (height 0.25 m) is placed under steel roof frame. Next thermal bridge related to the straining band is the bearing roof frame with external brickwork with insufficient thermal resistance. This thermal defect of the envelope caused by the bearing steel frames is similar to the results of (Höglund and Burstrand, 1998; Juárez et al., 2012; Al-Sanea and Zedan, 2012). How we can see that there is a layer in the top part of the wall (height 0.5 m), where apparent heat fluxes are visible. The average surface temperature of the brickwork is about -4.9ºC. The next problematic detail there are the door and window frames mainly at the pass between the frame and the wall. Probably it is caused by poor thermal parameters of the frames and unsuitable construction design of this detail. The surface temperature at the door frame is about 1.2ºC. The surface temperature at the window frame is about 0.8ºC. A similar case study of thermal bridges by window framework is presented in (Ben-Nakhi, 2002; Cappelletti et al., 2011). Thermal bridges caused by steel reinforcement of the wall are presented in (Fukuyo, 2003). Figure 2 and figure 3 represent the second part and the third part of the south façade of the piggery. As we can see the same situation is with the existence of thermal bridges in critical structure details. Figure 4 and Figure 5 represent a west façade (gable wall). Most problematic there is the straining band again. The surface temperature at the straining band is about – 5.2ºC. A socle part of the wall has only 0.2 m height but has not thermal insulation. Figure 6 and figure 7 (east façade of piggery) and figure 8 (north façade of piggery) represent thermograms with similar situation which confirm unsuitable solution of structure details.

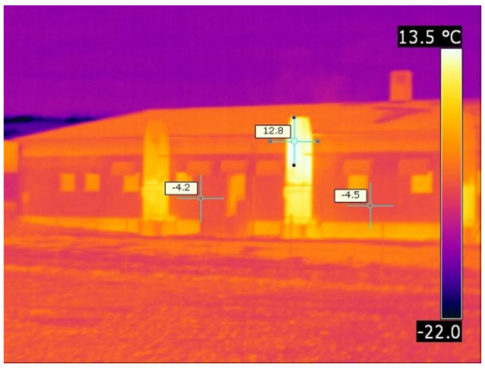


*Figure 1. South façade of piggery (part 1)*

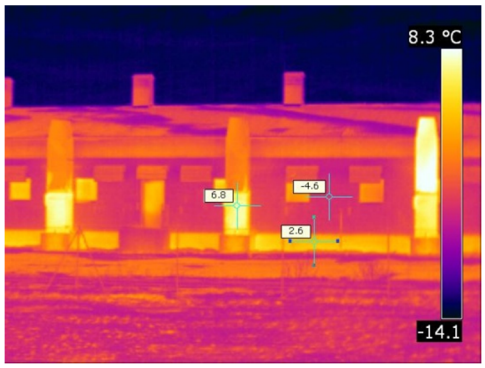


*Figure 2. South façade of piggery (part 2)*

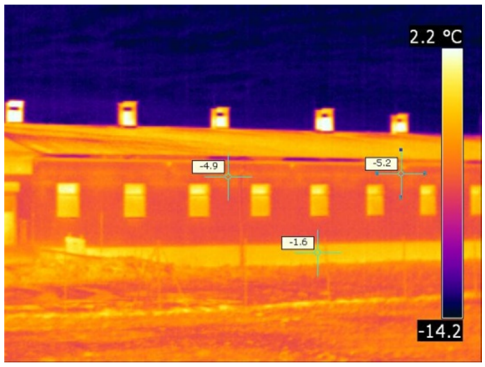


*Figure 3. South façade of piggery (part 3)*

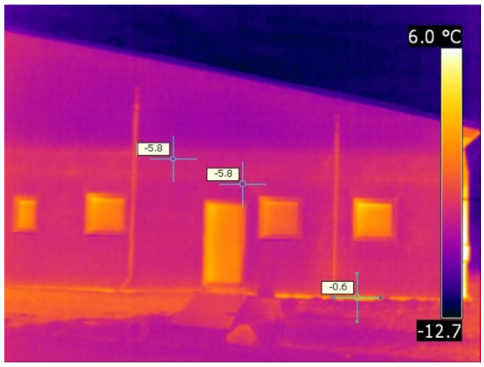


*Figure 4. West façade of piggery (part 1)*


*Figure 5. West façade of piggery (part 2)*


*Figure 6. East façade of piggery (part 1)*

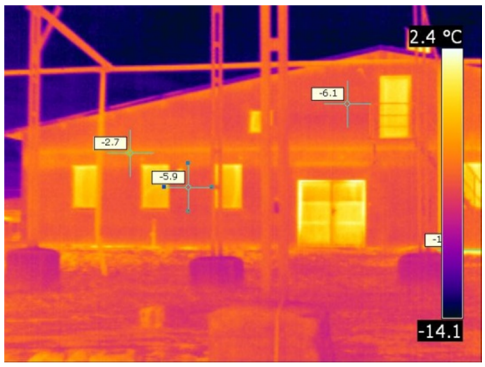


*Figure 7. East façade of piggery (part 2)*

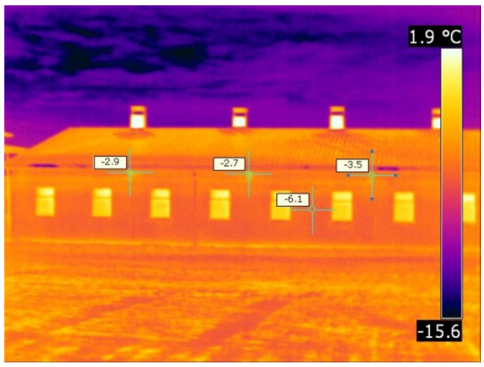


*Figure 8. North façade of piggery*

Table 4
*Characteristic properties of the new-building piggery structures*

| Specification of the structure | Material of the structure layer | Thickness (m) | Thermal conductivity λ ($W \cdot m^{-1} \cdot K^{-1}$) | Density ($kg \cdot m^{-3}$) | Calculation of the total thermal resistance $R_T$ ($m^2 \cdot K \cdot W^{-1}$) | Calculation of the total thermal transmittance $U_T$ ($W \cdot m^{-2} \cdot K^{-1}$) |
|---|---|---|---|---|---|---|
| Ceiling | Fiber-cement roofing | 0.007 | 0.45 | 1800 | 0.016 | 62.5 |
| | Aeration space | 0.040 | 0.250 | 1.275 | 0.160 | 6.25 |
| | PES sheet | 0.002 | 0.16 | 1400 | 0.013 | 76.92 |
| | Rock wool integrated with bearing steel frame | 0.160 | 0.0040 | 100 | 4.0 | 0.25 |
| | PE vapor barrier | 0.001 | 0.35 | 1470 | 0.003 | 333.33 |
| | PVC board | 0.005 | 0.16 | 1400 | 0.031 | 32.25 |
| | Total thermal properties of the structure | | | | 4.363 | 0.229 |
| | Required value according to standard CSN 73 0540-2:2011 | | | | - | 0.24 |
| Original door | PVC frame | 0.075 | 0.16 | 1400 | - | - |
| | Total thermal properties of the structure | | | | - | 1.70 |
| | Required value according to standard CSN 73 0540-2:2011 | | | | - | 1.50 |
| Original window | PVC frame (+ heat insulating glazing) | 0.075 (0.001) | 0.16 (0.71) | 1400 (2500) | - | - |
| | Total thermal properties of the structure | | | | - | 1.70 |
| | Required value according to standard CSN 73 0540-2:2011 | | | | - | 1.50 |

Calculation of heat fluxes and heat power of all thermal bridges is presented in the Table 5. Coefficient of free convection along vertical walling was calculated according to the equations developed by three different authors. Coefficient of free convection calculated by Hencky-Hottinger equation presented the maximal value of the total heat power. Next is the result of calculation by McAdams and the last is calculation by Cihelka. The calculation of heat fluxes and heat thermal bridges is approximate. The difference between calculated values is given by boundary conditions under which equations were determined.

Table 5.
*The calculated values of heat fluxes and heat losses*

| No. | Object | McAdams | | Hencky-Hottinger | | Cihelka | |
|---|---|---|---|---|---|---|---|
| | | Heat Fluxes ($W \cdot m^{-2}$) | Heat Losses (W) | Heat Fluxes ($W \cdot m^{-2}$) | Heat Losses (W) | Heat Fluxes ($W \cdot m^{-2}$) | Heat Losses (W) |
| 1 | Steel concrete straining band of the brickwork | 7.47 | 298.90 | 8.50 | 339.81 | 2.64 | 105.44 |
| 2 | Bearing steel roof frame | 7.93 | 1704.70 | 9.71 | 2087.10 | 5.09 | 1093.39 |
| 3 | Frame of the window | 8.32 | 3.33 | 10.81 | 4.33 | 8.66 | 3.46 |
| 4 | Frame of the door | 8.45 | 6.76 | 11.19 | 8.96 | 10.26 | 8.21 |
| 5 | Uninsulated steel concrete socle | 13.71 | 589.37 | 17.94 | 771.29 | 9.18 | 394.83 |

## Conclusion

The energy efficiency of buildings is significantly affected by right structure design. A farm building for animal production (piggery) is a heated building with high energy consumption. Modern structures have possibility for well technological solutions and energy performance of a building. Our study confirms that not only modern materials but also well technological solutions of critical structure details are very important because thermal bridges cause high heat losses, a risk of condensing of air humidity and mildew growing. The most problematic are thermal bridges at the uninsulated socle and flooring, the straining band of the wall, the bearing steel roof frame and the window and door frames. The results of this paper confirm these claims.

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## WPŁYW MOSTÓW CIEPLNYCH NA WŁAŚCIWOŚCI TERMICZNE KONSTRUKCJI NOWYCH BUDYNKÓW CHLEWNI

**Streszczenie.** Chów trzody chlewnej związany jest z wysokim poborem energii, dlatego też wydajność energetyczna budynku jest bardzo ważna. Celem niniejszego artykułu jest jakościowa i ilościowa ocena właściwości cieplnych oraz występowania mostków cieplnych w konstrukcji nowo wybudowanej chlewni. Charakterystyczne właściwości termiczne: ściany zewnętrznej (UT = 0,470 $W \cdot m^{-2} \cdot K^{-1}$), podłogi (UT=1,356 $W \cdot m^{-2} \cdot K^{-1}$), sufitu (UT=0,229 $W \cdot m^{-2} \cdot K^{-1}$) oraz okna i drzwi (UT=1,70 $W \cdot m^{-2} \cdot K^{-1}$).Wyniki potwierdzają nieodpowiednie właściwości termiczne większości konstrukcji. Jakościowa ocena wad cieplnych z wykorzystaniem termografii w podczerwieni umożliwia identyfikację najbardziej znaczących mostków cieplnych, występujących przede wszystkim na nieizolowanych cokołach i podłogach. Nasze badania potwierdzają, że nowoczesne konstrukcje umożliwiają wprowadzanie nowych rozwiązań technicznych oraz technologii, które poprawiają charakterystyki energetyczne budynków inwentarskich.

**Słowa kluczowe:** chlewnia, nowa chlewnia, właściwości termiczne, mostki termiczne, wydajność energetyczna, termografia w podczerwieni

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# AUTOMATIC INDEXING OF INFORMATION RESOURCES CONCERNING AGRICULTURE IN POLISH

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ABSTRACT

Contemporary research and production activity require searching and collecting a variety of information, this also applies to issues in the field of agriculture. Today, the vast majority of resources are available in a digital form. FAO on the portal of the Agricultural Information Management Standards presents an AgroTagger, tool for indexing documents in the field of agriculture, which is designed for the English language. Extraction of knowledge is not very convenient in languages such as Polish language with a very extensive inflection. In Polish, the following parts of speech inflect: verbs, nouns, numerals, adjectives, and pronouns. Proper indexing requires an initial reduction of grammatical forms, to which the authors have used the dictionary of the Polish language and have developed a programme of reducing. Moreover the algorithms for determining weights corresponding to the validity of the appointments taking into account the prevalence of terms and their position in the document were developed and implemented.

## Introduction

In the modern world information, knowledge and skill of using available resources of data is significant. Even greater technological possibilities cause that information resources are growing faster and are at the same time more available, on the other hand modern technology enables their searching and analysis. We have more and more such information as research results, description of experiments or sets of statistical data, which are difficult to be analysed without appropriate technological tools. It may be said that IT systems have become indispensable in the processes of searching, storing, processing or making knowledge available; such situation concerns also issues from the field of agriculture. Presently, publications of articles, research results or results of executed projects are prepared in an electronic form and Internet is widely applied for their availability. A paper form still frequently occurs parallel with a digital form, but it may be said that it has become secondary. Simultaneously, a reverse process is going on, paper publications prepared many years ago are digitized in order to facilitate their access. Description and proper classification of resources, without which searching even with the use of modern tools is difficult and time consuming, is indispensable.

Classification of scientific publications is easier, they define key words, they determine in bibliography references to other publications; however, such information is not always sufficient. Classification of internet websites or other resources which are weakly described is slightly more difficult. In such cases, automatic indexation of included information is useful. It also enables determination of relations between documents through automatic generation of semantic relations which is useful also for scientific publications. Automatic indexation is used by popular search engines - robots which are scanning a global network all the time are a foundation of success of Google company. However, classifications used in search engines are based on the number of connections between pages and rather mechanical indexing of words which occur on these pages. It should be noted that there have been attempts of semantic description of resources, in particular for web pages, these issues were presented for example in the paper written by Karwowski (2010). In order to describe resources, a standard of metadata Dublin Core, of however more general nature, was defined. Presently, one of the newest initiative concerning the Internet is a microdata format which is a composing part of HTML5, onthology prepared for this format is available on schema.org portal. Creators of search engines, who support the initiative focused on issues, which are searched for the most often in the Internet: films, concerts etc. This ontology prepared only in English, does not include concepts related to agriculture, the most close to agriculture are culinary recipes, which are often searched for by the Internet users. Concepts which enable placing advertisements prevail; scientific papers and resources necessary in learning are not of the most interest for advertisers.

Indexing documents is not a new issue in informatics; it has been frequently related to the problems of automatic translation of texts. It was dealt with when documents in electronic form constituted only a margin of informative resources. Presently this issue, in the times of the Internet gets again an important meaning, analysis of texts and searching for information is commonly used, for example in the scope of management of knowledge. Investigation of semantic relations between concepts gets more significance, which allows the use of automatic concluding methods. Indexing, a more generally extracting knowledge from documents is difficult in languages which have an extensive inflection. Polish language is one of them. The following parts of speech are inflective: verbs, nouns, numerals, adjectives and pronouns. Moreover, the number of forms is high. Some verbs have even over one hundred inflectional forms (Słownik Języka Polskiego) formed based on an infinitive. Due to extensive inflection, the process of automatic indexing prepared for English used for Polish generates many "artificial" concepts, which in reality are examples of one concept. Many scientific papers in agriculture are written in mother tongues. It mainly results from the fact that papers in this field often refer to many problems specific for each country. Such situation takes place also in Poland.

The initial objective of this paper was to investigate how to use existing tools to index texts related to agriculture in Polish. Then, based on specificity of both language as well as a field, a prototype of author's system for indexing documents, was designed and implemented. The paper presents results of contemporary research and conclusions developed based on the obtained indexing results.

**Tools for indexation of texts**

Issues of information retrieval from text documents, as mentioned above, have been the object of research in the field of processing a natural language and more up-to-date management of knowledge for many years. Information retrieval is related to its representation and manners of storing and access to it. It may be said that the main objective of the system of information retrieval is "finding material (usually documents), which meets our information requirements from among big collections (usually stored in computers)" (Manning et al., 2008). Indexing a text is a part of the process of information retrieval in a given context. The indexation process is generally the first step of this process, thanks to this process the system may select and rank documents according to the users' question. The most important techniques applied at indexing is *part of speech tagging* and recognition of stems occurring in inflection (English *stemming*). Many algorithms of stemming have been developed. The most popular are: algorithm by Lovins (Lovins, 1968), Paice/Husk (Paice and Husk, 1990) and Portera (Porter, 1980);an extensive review of literature may be found in the second chapter (Manning et al., 2008). Majority of methods can be easily used only in English, thus attempts of adjusting these methods to the Eastern Europe languages, have been made (Dolamic and Savoy, 2008). On the other hand, recognition of speech parts is described for example in Manning's paper (2011), on this basis it may be said that presently in English texts, parts of speech tagging is quite precise. Recently many papers devoted to the issue of scientific information retrieval and in particular to indexing scientific works, have been written, they are devoted generally to specific issues (Gupta and Manning, 2011). In order to carry out indexing, the use of existing commercial solutions such as Key Phrase Extractor by Sematext or service by AlchemyAPI, is possible. In academic designs, mainly non-commercial solutions or demonstrative solutions are used, such as Translated Lab Terminology Extraction (http://labs.translated.net/terminology-extraction/) or project TexLexAn (http://texlexan.sourceforge.net/). Similarly to previously mentioned paper, they concern English or specific languages, such as Catalan (http://www.uoc.edu/serveilinguistic /home/index.html). Developing own algorithms specialized for realization of a specific aim is also possible; research in this field were carried out for Polish (Branny, 2005).

This paper tackles the issue of indexing text in publications on agriculture and more generally in life sciences. In this field, AgroTagger, which for key words extraction uses (Thesaurus AGROVOC) as a set of admissible key words, is a very interesting initiative undertaken by FAO

As a part of this initiative, an internet system was developed in Indian Institute of Technology Kanpur (moreover, an analogous system is created in cooperation with MIMOS company; unfortunately both those systems are periodically unavailable). AgroTagger extracts the most important concepts and presents them in RDF format (fig. 1). Unfortunately, AgroTagger analyses concepts from English version of thesaurus AGROVAC (AGROVAC is a multi-language dictionary, includes concepts also in Polish), thus, an abstract of an article written in English and English words placed in the text are decisive. Figure 1 presents the result of indexing the article written by professor Jerzy Weres (2010): „*Informatyczny system pozyskiwania danych o geometrii produktów rolniczych na przykładzie ziarniaka kukurydzy*", according to the above, the result is not useful for a person who seeks

information in Polish. FAO cooperates also with University of North Carolina, which in its tool Hive Indexer enables selection of thesaurus AGROVOC.

```
- <rdf:RDF xmlns:Tagger="http://agropedialabs.iitk.ac.in/Tagger#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
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*Figure 1. Example of concepts extracted from article in Polish*

This last service is based on KEA tool (*keyphrase extraction algorithm*),which is free of charge and allows indexation of resources towards the thesaurus in SKOS format. The result of indexing is presented on the web site (fig.2). As AgroTagger, Hive-Indexer analyses only concepts from English version of thesaurus AGROVOC, so in practice it concerns the abstract of an article written in English (the results presented in figure 2 concerns the same article written by Jerzy Weres), according to the above, the result is not useful for a person who seeks information in Polish.

Authors, with the use of AgroTagger carried out a row of tests and experiments on various documents in Polish, both of scientific articles and internet publications. A conclusion is explicit, although AGROVOC is a multi-language thesaurus, the indexation process is carried out only in English and in the present form it is is of small usefulness for publication in Polish. The condition for obtaining a reasonable result (but necessary to be translated into Polish) is a good abstract and the set of key words in English.

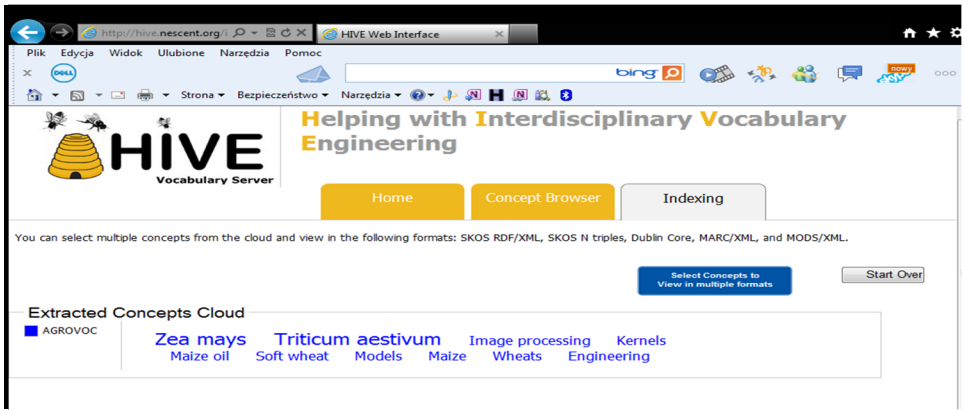


*Figure 2. Result of indexing article in Polish*

**A prototype of the indexing system of articles in Polish**

During the execution of the project on the knowledge management in the Department of Informatics of the Warsaw University of Life Sciences (N N310 038538 „Narzędzia zarządzania wiedzą w produkcji roślinnej" [Tools of knowledge management in plant production]) a need to index resources has occurred. Since, the use of AgroTagger has not given relevant results, it was decided to create the own system. The main requirement was formulated: indexing papers published in Polish and ultimately profiling indexing to the subject related to agriculture based on AGROVOC thesaurus. Investigating semantic relations between publications was an additional requirement. In order to build a base of varieties of words, free Dictionary of Polish Language with open licenses was used, which was important for authors. This dictionary is being extended all the time. Hobbyists carry for development and editing of the dictionary similarly to editing, which take place in case of Wikipedia, but the content is at a relevant high level. Presently it consists of 17,000 definitions and the whole content may be loaded in the text form. A prototype of the indexing system, was created in the architecture client-server, in the present version of the prototype, PHP language and the base my SQL were applied. Data base of Polish words was designed, which includes inflection forms, data from the dictionary were introduced to this base.

In order to store words and their varieties in the local data base a table was created, the records of which include 5 fields: Identyfikator [Id] – is a main key of the table, Forma Słownikowa [Dictionary Form] – is a basic form of a word, Forma Odmienna [Inflected Form] – is one of forms of a word, Część Mowy [Part of Speech] – includes information on the part of speech, Czy Odmienny [Whether Inflected – includes information whether it is an inflected word. It means that the Dictionary Form occurs in many records, whose number depends on the number of different forms. Table constructed in such a way facilitates finding a word stem, in the column Inflected Form, main search is performed, if a word is in the dictionary then the remaining fields are read out. However, recognition of the part of speech was a serious problem. For this purpose, number of varieties was analysed, which is presented in the diagram (fig. 3). The presented diagram helps automatically to recognize the parts of speech for words placed in the data base. The firs maximum (only

one form) includes non-inflected parts of speech, the second maximum (x=6) includes adjectives, the third maximum (x=11) represents nouns, the remaining maxima (x = 23, 38, 57, 77) represent verbs. Unfortunately, these are ambiguous, number of forms of inflection is not sufficient to recognize the part of speech, some adjectives and nouns have the same number of inflections. In order to differentiate adjectives from nouns, the ending of the basic form should be analysed. A similar situation takes place for verbs, but here in practice number of forms of inflections suffices. The following rules help in differentiation of parts of speech. If the basic form ends in "i" or "y" and at the same time number of varieties is bigger than 3 then we deal with an adjective. If the basic form ends in "c" or "ć" and at the same time number of varieties is bigger than 11 then we deal with a verb. If the number of varieties is bigger than 4 and at the same time, the end of the word is different than "i", "y", "c" or "ć" then we deal with a noun.

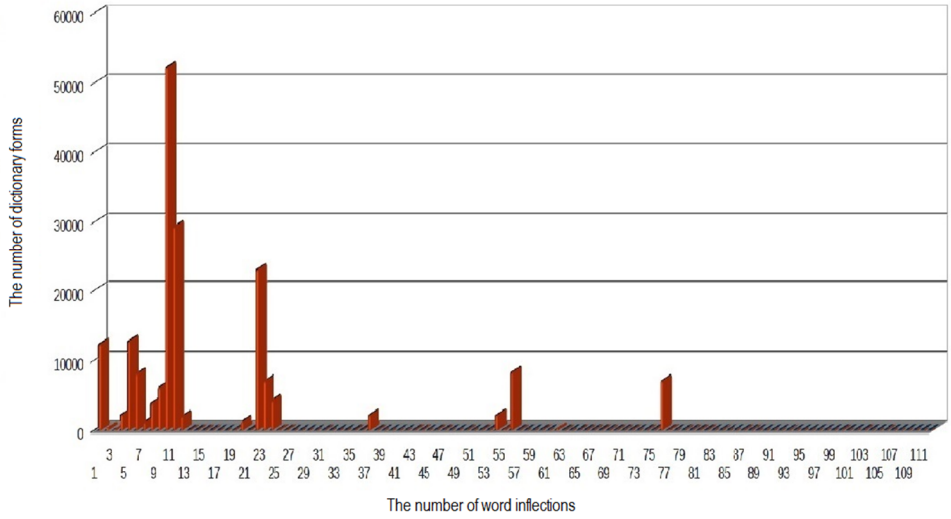


*Figure 3. Relationship between dictionary form and the number of inflected forms*

During indexing of publications on agriculture, new words in the basic form or inflected appeared. In the specialist language, words, which are not present in the dictionary of Polish language, which we use, occur. Many of them origins in Latin e.g. names of viruses or bacteria (many of them is a combination of two or more words). Principles of inflection of words of foreign origin are generally different than Polish words. Due to complicated inflection of Polish, similarity of new words with those in the dictionary is checked. For this purpose, the method based on Hamming distance is used. When a new word occurs the next word is checked, if it is this next word is not present a new definition is created in the dictionary and then we check in the auxiliary dictionary whether the words which compose the new term have already been recorded. If the word is not recorded, it should be checked whether a stem is already present, if yes, then we add a word as a form of inflection, if not,

we add a word to the base as a noun. Indexing in our system consists in determination of the number of times the word appears in the text. In majority of cases, one word corresponds to one concept in the text.

Tests, which have been carried so far, proved that it is possible to divide indexed definitions into two groups: the first group consist in words, which relatively often occur in the text from 5% to approx. 13%, the second group are words which relatively rarely appear in the text. On the investigated group of articles from agrosukces.pl portal, it was determined that papers on the similar subject have the same words which appear in the text the most frequently. The relation between the most popular noun, verb and the second popular noun, which can be used to build a word e.g.: "cow" "have" bacteria" was reported. The gathered data allowed formation of a simple semantic network based on relations between the most frequently occurring words and constittue a basis for additional research trend presented in the paper by Wrzeciono and Karwowski (2013).

## Conclusion

The indexing system has accepted so far publications in the text form obtained by copying as a text from web sites or from available scientific articles in doc, pdf, etc. format. The first tests of a prototype allow conclusion that results are promising; in the Polish texts isolation of basic terms is possible. Since, research concern subjects related to agriculture and life sciences, cooperation with thesaurus AGROVOC is a next planned step. The next step should be preparation of interfaces for reading different formats of publications. Ultimately it is necessary to prepare a body stub of texts designated for systematic testing, which would enable further improvement of the system.

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## AUTOMATYCZNE INDEKSOWANIE ZASOBÓW INFORMACYJNYCH W JĘZYKU POLSKIM DOTYCZĄCYCH ROLNICTWA

**Streszczenie**. Współcześnie działalność badawcza i produkcyjna wymaga wyszukiwania i gromadzenia różnorodnych informacji, dotyczy to także zagadnień z dziedziny rolnictwa. Obecnie większość zasobów dostępna jest w formie cyfrowej. FAO w ramach portalu Agricultural Information Management Standards prezentuje AgroTagger narzędzie do indeksowania dokumentów z dziedziny rolnictwa, które przeznaczone jest dla języka angielskiego. Ekstrakcja wiedzy jest utrudniona w językach takich jak język polski, posiadających bardzo rozbudowaną fleksję. W języku polskim odmienia się rzeczowniki, czasowniki, przymiotniki oraz zaimki osobowe. Właściwa indeksacja wymaga wstępnej redukcji form fleksyjnych, wobec czego wykorzystano słownik odmian języka polskiego i opracowano program redukujący. Ponadto opracowano i zaimplementowano algorytmy wyznaczania wag odpowiadających ważności terminów uwzględniające częstość występowania terminów i ich pozycję w dokumencie.

**Słowa kluczowe**: indeksowanie, integrowanie źródeł informacji, sieć semantyczna, zarządzanie wiedzą

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# IMPACT OF THE MENTAL ACTIVITY TYPE ON THE MENTAL FATIGUE AND DEGREE OF PHYSIOLOGICAL WORKLOAD[1]

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ABSTRACT

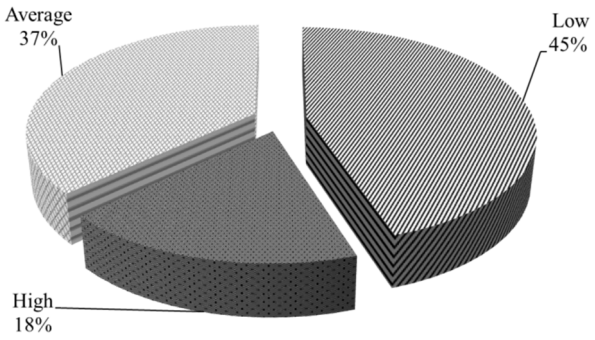
The paper is an attempt to determine mutual relations between the length and type of activity related to intellectual work and the degree of mental fatigue and the heart rate reserve. The tests were carried out on the group of 25 persons, who through realization of particular training stages concerning operation of modern farm tractors through special logical tests and measurement of the heart rate generated information on the mental fatigue and stress during the experiment. It was found out that along with the increase of the duration of intellectual work, the time necessary for accomplishing a logical task and number of mistakes increases. It was also reported that with each test of a similar logical structure, the stress factor decreased and the process of learning took place in case of learning persons. Thus, during the last measurement, the investigated group obtained relatively better results than in the previous test.

## Introduction

Work is a significant factor of human development and an organizing element which consumes approx. 66% of the adult life (Wróblewska, 2004). Traditionally, two types of work are distinguished. The first one is the work of muscles – occupational physiology deals with this issue and the intellectual work – defined by the occupational psychology (Olszewski, 1997). The intellectual work focuses on taking decisions based on external information (exteroceptive) and internal (prioceptive). Thus, in the analysis of the human-work system, the intellectual work focuses on the first two stages of the process: reception of information and its processing and decision taking. Whereas the third stage – performing an activity- is an element of mainly physical work (Olszewski, 1997). The trend in favour of increasing the role of the intellectual load and in consequence the impact on the production process also relates to widely understood agriculture, where the degree of technical and technological complexity forces out automation and robotization of activities and human roles comes down to the operator- programmer role.

[1] The paper was written as a part of the statutory research

Awareness of the effects of undertaking an improper decision intensifies stress increasing the burdening of the nervous system. The degree of the aptitude for learning how to operate technical means by operators with the use of the user's manual becomes very important and influences directly the safety and efficiency of work (Juliszewski et al., 2013). No compatibility of interfaces of machines which carry out the same technological function intensifies the mental fatigue and in consequence possibility of making a mistake. Juliszewski et al. (2010; 2012) tested a number of computer onboard interfaces of machines and farm tractors and procedures of starting the selected functions observing many times the lack of logical relations between them in tractors and machines of other makes. According to Złowodzki et al. (2011) loading with information results not only from its amount but also from the necessity of knowing many sequences and proper information decoding. An algorithm for operating various machines and thus other various signalling devices by relatively short time during a year is a specific feature of work in agriculture (Juliszewski, 2008a). Technical progress caused intensification of agricultural work and increase of the degree of complexity of agricultural machines and devices. The problem of operation and supervision of the units operation appeared, which is related to the necessity of having proper knowledge and qualifications by farmers. Research proved that farmers with a high stress index were more accident-prone by 65% more than farmers, who were more stress-resistant (fig.1). It was also proved, that such stressful events as farm debts, financial problems influence the increase in the accident rate (Cież, 2008).




*source; PIP (2013)*

*Figure 1. The level of stress causing factor of work in agriculture*

Estimations show that every four employee in the European Union experiences intellectual workload and 50-60% of sick absenteeism is related therewith. Stress is at the second position (after muscular and skeleton ailments) among the most often health problems related to professional work (PIP, 2012). As a part of operations included in the programme, a PIP inspector [Polish State Work Inspection Office] evaluated stress causing properties of work in 289 establishments for the total number of 1012 various work stations. It was found out that 40% of stations is burdened with low level of stress causing features of work, also 40% with the average level of stress causing factor and 20% with high (PIP, 2007).

## Objective, scope and methodology of work

The objective of the paper was to determine the impact of the length and type of activity related to intellectual work on the mental tiredness of a man and their relationship with the heart rate reserve. The scope of work included the tests on the mental fatigue with the mathematical tests and physical load method with the use of HRR. The experiment was carried out on the group of 25 people with similar intellectual abilities and the degree of knowledge advancement in the scope of technique and technology applied in agriculture. In order to force out mental fatigue, user's manuals for Fendt factors 930 Vario and John Deere series 8320 were used. They were being read (analysed) by the tested people for 30 minutes and then they answered control questions which verified the degree of knowledge on the operation of the said tractors. This cycle was repeated three times. Initially the questions concerned the basic functions of controlling tractors and then practical identification of sub-assemblies and procedures, with which they were acquainted during the analysis of the user's manual.

Before the experiment the tested persons solved logical tasks with the use of the "tester" program (Juliszewski, 2008b). The test assumes that the number of mistakes and the duration of the test are related to the level of the mental fatigue: the bigger fatigue the higher number of mistakes and the longer time of calculations. The test consists of 50 calculations of differences from randomly generated numbers or figures. The result of operations is also a one-figure value (from 0 to 9), which is introduced to the computer with the use of a numeric keypad. The number of tasks was 50 and the time interval was not limited, at the same time the number of heart contractions of particular persons was measured with the use of the following measuring devices: POLAR S-810$^{TM}$ and Omron M3 manometer. Then, the heart rate reserve index was calculated (Groborz et al., 2005) defining the degree of physiological load with the use of Buchberger scale (1984). The measurement of the above-mentioned value was carried out four times i.e.:

- a standard measurement was carried out before the experiment in order to determine the reference point for relative measurements and to determine variability of experimental population on account of the tested properties,
- the measurement after the first stage of fatigue was carried out after the experimental population had read the selected fragments of the user's manual and answered questions checking their knowledge,
- the measurement after the second stage of fatigue was carried out after practical realization of identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual.
- the measurement after the third stage of fatigue carried out after the problem task on the analysis of the user's manual was accomplished.

## Research results

In case of the first measurement (standard measurement) which constitutes the output data base, which were considered as the standard data, it was found out that the average time necessary to provide an answer (fig.2) was 1.87 seconds and characterized with a high coefficient of variation which was approx. 64%. High variation could have resulted from varied skills of the tested persons in functioning in the stressful situation, but it could not have resulted from a varied level of education.

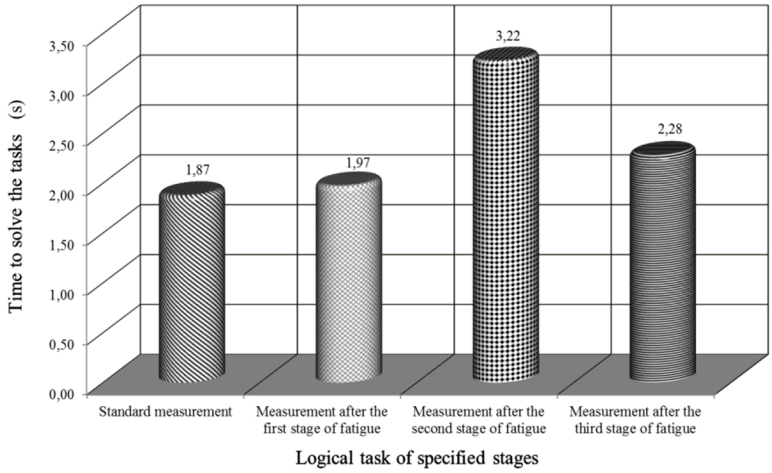



*Figure 2. Time necessary to accomplish a single logical task at particular stages of the experiment*

When analysing the time spent on accomplishing a single logical task after the first stage of the experiment, i.e.: "the experimental population had acquainted with the selected fragments of the user's manual and took the test" it was determined that the time necessary to take the logical test was not extended. Answering a single logical task in case of the measurement carried out after the second stage of fatigue was the longest and it was as much as 3.2 seconds (fig. 2), i.e. "carried out after a practical identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual, assessed with points". It should be emphasised that is was 1.72 times longer than the time necessary to accomplish a single logical task in case of the standard measurement. When analysing the last measurement (attempt after the third stage of fatigue), it was determined that the time necessary to accomplish a single logical task was 0.94 seconds lower in comparison to the time reported after the second stage of fatigue and it was 2.28 seconds. One should pay attention to the high coefficient of variation, which in case of the measurement after the third stage of fatigue was over 67%, which proves a considerable individualization of the level of fatigue within the experimental group. Information stating that despite a long time of mental fatigue, the time necessary to accomplish a logical task was relatively shorter, which seems to be alogical, should not be omitted. However, taking into consideration that ability to accomplish specific type of logical tasks could be learned and accustoming the experimental population to a given procedure, the obtained result may be assumed as correct. Figure 3 presents the scope of variation of the time of answering particular logical questions.

In order to determine statistically significant difference between the length of time for accomplishing a single logical task after listed stages of the experiment the analysis of variance with the test of differences significance was carried out (table 1).

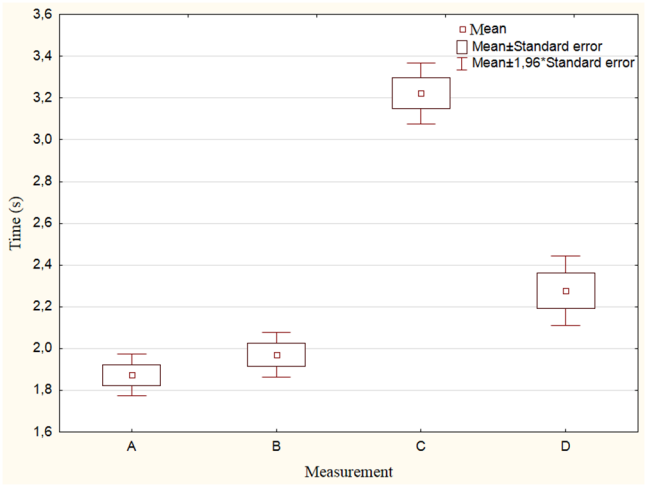



*Figure 3. Diversification of the time required to accomplish a single logical task including a standard mean error*

Table 1
*The results of Tukey's test for testing statistical significance of differences in the time required for accomplishing a single logical task between particular stages of mental fatigue*

| Stages of experiment | A | B | C | D |
|---|---|---|---|---|
| Standard measurement (A) | X | X | X | X |
| Measurement after the first stage of fatigue (B) | ---- | X | X | X |
| Measurement after the second stage of fatigue (C) | * | * | X | X |
| Measurement after the third stage of fatigue (C) | * | * | * | X |

* statistically significant difference
--- - no differences

As much as 5 statistically significant differences in the mean values of the analysed parameter out of six possible were reported. No statistically significant differences were reported (table 1) only between the time needed to give an answer in case of the standard sample "A" and the test carried out after the first stage of fatigue "B". No difference may result from a small initial fatigue.

In case of the standard measurement, which constituted the output data base, it was reported that average frequency of heart contractions during the test was 71.6 ud·min$^{-1}$ at low, because only 11.6% coefficient of variation. The highest value of rate, namely 81.3 ud·min$^{-1}$ was reported after the first stage of fatigue "B" (fig. 4) i.e. after the part checking the group's participants' knowledge on sub-assemblies and procedures included in the analysed user's manuals of tractors. It should be emphasised that the the difference of the reported rate values in comparison to the standard measurement was 9.7 ud·min$^{-1}$.

Increase in the frequency of heart contractions after the first stage of fatigue may be justified with a stress causing factor, namely the test. When analysing the following heart rate measurements, that is after the second and the third stage of fatigue (measurements "C" and

"D") a downward trend of the heart rate during the test (logical one) was reported. It should be mentioned that the next stages of the experiment were more practical in nature and the logical test does not constitute a novelty, which could have resulted in the decrease of the stress causing factor. Thus, a relative normalization of the frequency of heart contractions was reported. Despite this, the heart rate value in the "C" and "D" measurement was at the level which was higher than in case of the standard measurement and after the third stage of fatigue it was 75.4 ud·min$^{-1}$. Figure 5 presents the scope of the variability of heart contractions during the test at particular stages of the experiment.

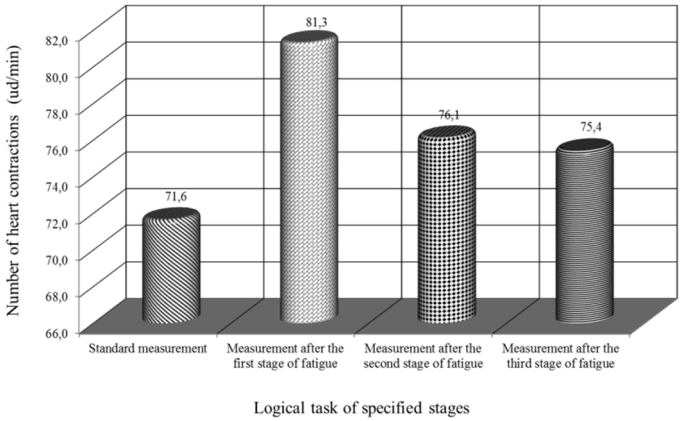



*Figure 4. Number of heart contractions during the test at particular stages of experiment*

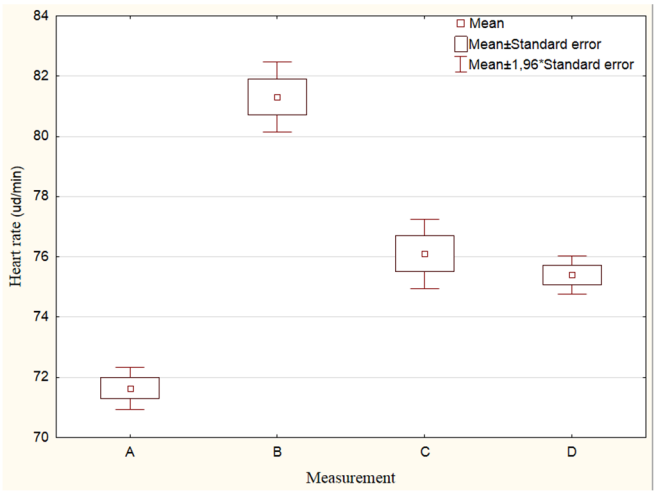



*Figure 5. Diversification of the number of heart contractions during the test including the standard mean error*

As much as 5 statistically significant differences in the mean values of the analysed parameter out of six possible were reported (table 2). No statistically significant differences were reported only between the number of heart rate contractions in case of the test after the second stage of fatigue "C" and the test carried out after the third stage of fatigue "D".

Table 2
*The results of Tukey's test for testing statistical significance of differences of the number of heart contractions between particular stages of mental fatigue*

| Stages of experiment | A | B | C | D |
|---|---|---|---|---|
| Standard measurement (A) | X | X | X | X |
| Measurement after the first stage of fatigue (B) | * | X | X | X |
| Measurement after the second stage of fatigue (C) | * | * | X | X |
| Measurement after the third stage of fatigue (C) | * | * | ----- | X |

* statistically significant difference
--- - no differences

When analysing the number of mistakes made in the logical test, it was reported that in case of the first measurement (standard measurement) a percentage coefficient of the number of mistakes in the logical test (fig.6) was 1.8%.

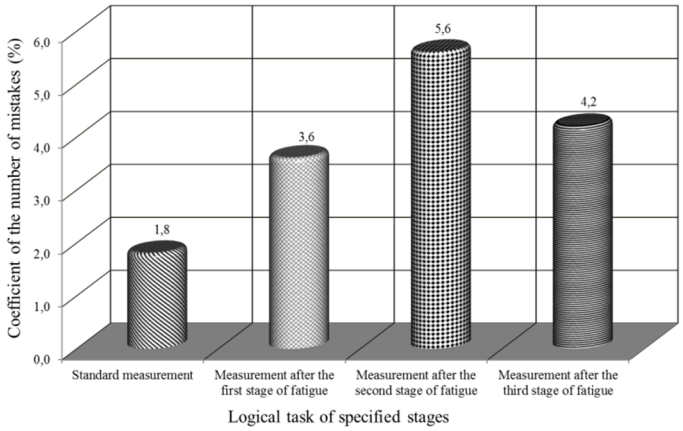



*Figure 6. Percentage coefficient of the number of mistakes made in the logical test at particular stages of the experiment*

The highest number of mistakes, which was 5.6% was registered in case of the measurement after the second stage of fatigue "C" that is after the part concerning the identification of sub-assemblies and procedures acquainted with during the analysis of the user's manual. It was determined that the value reported in the "C" test is over three times higher than the value reported in the standard test. After the analysis of the results of the last test "D" (measurement after the third stage of fatigue) it was determined that the number of mistakes was 4.2% and was by 1.4% lower than the number of mistakes made in the logi-

cal test taken after the second stage of fatigue. When observing the trend of the number of mistakes made in the logical test, one may notice, that their number increased at the stages "A", "B", "C" which is justified with the growing mental fatigue, whereas it decreases at the stage of the "D" measurement. Growing mental load should generate the highets level of mistakes in the test, which was obtained after the third stage of fatigue. However, taking into consideration that ability to accomplish specific type of logical tasks could be learned and accustoming the experimental group with a procedure, the obtained result may be assumed as correct. Figure 7 presents the scope of the variability of the number of mistakes made in the logical test.

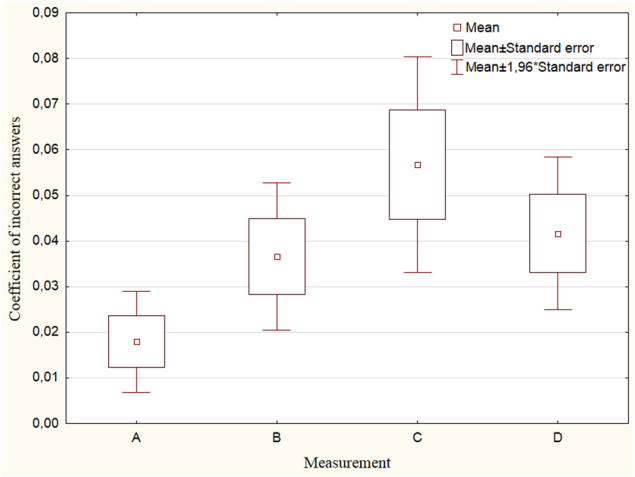



*Figure 7. Variability of the number of mistakes in the logical test including the standard mean error*

Only one statistically significant difference in the mean values of the analysed parameter out of six possible was reported (table 3). This difference appeared between the number of mistakes made in the standard sample "A" and the sample carried out after the second stage of fatigue. In the remaining cases no statistically significant differences were reported.

Table 3
*The results of Tukey's test for testing statistical significance of differences of the mistakes made in the logical test between particular stages of mental fatigue*

| Stages of experiment | A | B | C | D |
|---|---|---|---|---|
| Standard measurement (A) | X | X | X | X |
| Measurement after the first stage of fatigue (B) | ---- | X | X | X |
| Measurement after the second stage of fatigue (C) | * | ---- | X | X |
| Measurement after the third stage of fatigue (C) | ---- | ---- | ---- | X |

* statistically significant difference
--- - no differences

In case of the index of using the heart rate reserve in the first measurement "A", which constitutes the output data base considered as standard, it was reported that the index of using the heart rate reserve (fig. 8) was 11.6% at the coefficient of variation which was 50.8%.

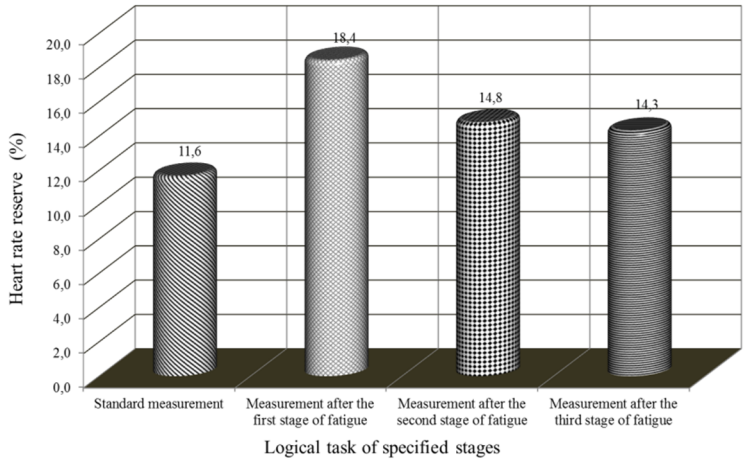



*Figure 8. The index of heart rare reserve at particular stages of the experiment*

The highest because 18.4% index of using the heart rate reserve was reported after the first stage of fatigue "B" i.e. after the part verifying the knowledge of the experimental group on sub-assemblies and procedures included in the tractors user's manual analysed for 30 minutes. It should be emphasised that it was a value 1.59 times higher than the heart rate reserve index which was reported at the standard measurement. Taking into consideration mean values of the heart rate reserve for subsequent stages of the experiment, a classification of the effort can be made. However, the index of using a heart rate reserve in any case does not exceed 25%, thus the level of burdening with work may be classified as very low. Five statistically significant differences in the mean values of the analysed parameter out of six possible were reported (table 4).

Table 4
*The results of Tukey's test for testing statistical significance of differences of the heart rate reserve between particular stages of mental fatigue*

| Stages of experiment | A | B | C | D |
|---|---|---|---|---|
| Standard measurement (A) | X | X | X | X |
| Measurement after the first stage of fatigue (B) | * | X | X | X |
| Measurement after the second stage of fatigue (C) | * | * | X | X |
| Measurement after the third stage of fatigue (C) | * | * | ---- | X |

* statistically significant error
--- - no differences

No statistically significant differences were reported only between the value of the heart rate reserve in case of the test after the second stage of fatigue "C" and the test carried out after the third stage of fatigue "D".

## Conclusion

It was reported that along with the increase of the mental fatigue, time necessary to accomplish a single logical task increases. A possible decrease of the absolute time necessary to accomplish a task may result from the process of learning how to answer specific logical tasks and accustoming the tested persons with the procedures. It was proved that the factor which causes the highest increase in the number of heart contractions is mainly stress caused by a quantity control of the possibility of learning given units in the set time interval. While, the highest number of mistakes was reported after the practical part of the experiment, which proves that real use of knowledge in practice generates the highest mental fatigue of a body.

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## WPŁYW RODZAJU CZYNNOŚCI UMYSŁOWEJ NA ZMĘCZENIE PSYCHICZNE I STOPIEŃ OBCIĄŻENIA FIZJOLOGICZNEGO PRACĄ

**Streszczenie.** W pracy podjęto próbę określenia wzajemnych relacji między długością i rodzajem czynności związanej z pracą umysłową a stopniem znużenia psychicznego i wskaźnikiem rezerwy tętna. Badania przeprowadzono na grupie 25 osób, które realizując poszczególne etapy procesu szkolenia dotyczącego obsługi współczesnych ciągników rolniczych poprzez specjalne testy logiczne i pomiar tętna generowały informację dotycząca zmęczenia psychicznego i występującego w czasie eksperymentu stresu. Stwierdzono ze wraz ze wzrostem długości pracy umysłowej zwiększa się czas potrzebny do wykonania zadania logicznego i liczba popełnianych błędów. Zaobserwowano również, że z każdym następnym testem o podobnej konstrukcji logicznej zmniejszał się czynnik stresu oraz następował proces uczenia się badanych osób, dlatego w czasie ostatniego pomiaru badana grupa uzyskała relatywnie lepsze wyniki niż w teście wykonanym wcześniej.

**Słowa kluczowe**: znużenie psychiczne, ergonomia, tętno, praca umysłowa

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# ERGONOMIC ASSESSMENT OF LOADING THE MUSCULOSKELETAL SYSTEM OF WORKERS IN THE GEOTEXTILE PRODUCTION PROCESS[1]

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ABSTRACT

It is estimated that in the European countries approx. 27% of people works for more than half time of their work in a tiresome position resulting in muscle pains, which may disturb coordination of the posture, which increases the risk and possibility of error during operation of the machine. The tests concerned estimation of the risk of the muscoskeletal system disorders of workers who operate on particular work stations, which constitute a technological line for production of geotextile. Moreover, an attempt to improve organization of work was made in order to minimize the impact of the unfavourable postural system of a man on his/her health. Using the "OWAS" method (*Ovako Working Posture Analysis System*) the size and structure of loading of the workers' musculoskeletal system was determined. It was reported that on all work stations, which constituted the subject of the research, the 1st category of evaluation, where loading with the statical work was average but acceptable, prevailed.

## Introduction

The assessment of the risk related to impairment of the musculoskeletal system, which results from performance of professional activities was the object of the research carried out by a number of authors and concerned in principle each production activity of a human. Roman-Liu (2008) based on the analysis of the exposure to musculoskeletal disorders in the EU countries, stated that occurrence of tiring and painful body positions mainly concerns persons within the age of 40-50 and focuses mainly on three sectors of economy i.e. agriculture and fishery and the construction industry. Other research prove that over 62% of employees is exposed for at least 25% of the working time to performance of repeatable motions of arms and hands (Parent-Thirion et al., 2007). It is relatively easy to estimate loading of the motor system through a visual observation of the body position at work and measurement of the time of the employee's stay in a particular position with the OWAS

[1] The paper was written as a part of the statutory research

method (*Ovako Working Posture Analysis System*). Suitable tables, which classify the body position of a man at work, were developed (Corlet et al., 1979). With the use of the OWAS method (Karhu et al., 1986; Kivi et al., 1991) carried out the quantity analysis of the standard positions, taken during work, with the use of the external forces values. Roman-Liu et al. (2010) carried out the research of the following work stations with the "OWAS" method: a renovator of ventilating trunks and a work station responsible for maintenance of a heating substation , Groborz et al. (2005) used, inter alia, the OWAS method for estimation of loading employees, working at the poultry farm, with work and the obtained results were similar to the results obtained with the HRR ratio method (the heart rate reserve ratio). The same method was used by Kai Way Li et al. (1999) and Tzu-Hsien Lee et al. (2013) for assessment of loading the musculoskeletal system during the construction works. Kiełbasa et al. (2008) determined postural load of milkers working at the mechanical milking of cows. Undoubtedly, geometry of the working station, which many times forces position of a worker during manipulation activities, is significant. Muscular pains may cause that involuntary changes of the body position disturb coordination of a posture, which increases the risk and possibility of error during operation of a machine. It is significant in the process of the quality management (Korenko, 2014). This unsatisfactory state of affairs may be intensified by economic factors, which result in adapting non-production buildings for such purposes. Thus, carrying out the research with this regard and optimization of work stations on account of minimization of threats for the musculoskeletal system of a man seems to be justified.

## Purpose, scope and methodology of research

The objective of the paper was to determine the size and structure of the static load of workers at the particular work stations during realization of the geotextile production process and its impact on the musculoskeletal system of the examined persons.

The object of the research was the system in the form of a man - a work station. In this case five working stations were analysed (operation of a carding machine, a textile machine line, a needling machine, a cutter, a packing machine. The scope of the research covered preparation of the time study of the working time for three workers operating on each of five investigated working stations, which constituted a technological line. Moreover, after a degree of loading the musculoskeletal system of the examined workers was determined, activities, which are particularly dangerous from the point of view of possible lesions, were selected and those, at which an improper postural system follows mainly from the workers' subjective habits, were indicated. A technological characteristic of the said working stations and machines, which comprise a technological line of geotextile production, was presented in the publication on the acoustic environment of the said production process – Kiełbasa et al. (2013). The tests were carried out in PCPW Eko-Karpaty where the time study of a working day of employees on the work stations, which comprise the technological line of geotextile production, were carried out with the film method. A full cycle of work, performed by workers, who operate particular machines of a production line, was registered. Based on the post-frame analysis (each second of the film was analysed) activities were selected including variability of the taken bodily positions, pressed forces and time of their performance. A picture of a work day was carried out with the use of a digital camera Sony

DCR-PC1000E at the speed of 24 expositions per second. With the use of a computer program based on the algorithm of the OWAS method (*Ovako Working Posture Analysis System*) the quantity analysis of the standard positions taken during work, including external forces values, was carried out. The OWAS method enables classification of the body position and the external loading values. Digits, which describe component back, shoulders and legs positions, form the work position code. Based on the position code, a particular work position was qualified to one out of four categories of the assessment. Whereas, after including the accumulative time of maintaining this position during technological activities performed by a worker and frequency of changes, loading of the musculoskeletal system was qualified as: small, average or big (Kiełbasa et al., 2008). Recommendations concerning revision of the actual state resulted from the degree of loading of the musculoskeletal system.

## Analysis of the research results

A prevailing body position, taken by the tested workers, who operated the initial stage of geotextile production (fig. 1) i.e. a work station for operation of a carding machine (Kiełbasa et al., 2013), acc. to the classification of the "OWAS" method, was characterized with the fact that a worker for 75.4% of the shift time had straight back at the relatively low coefficient of variability, which was approx. 5.5%.

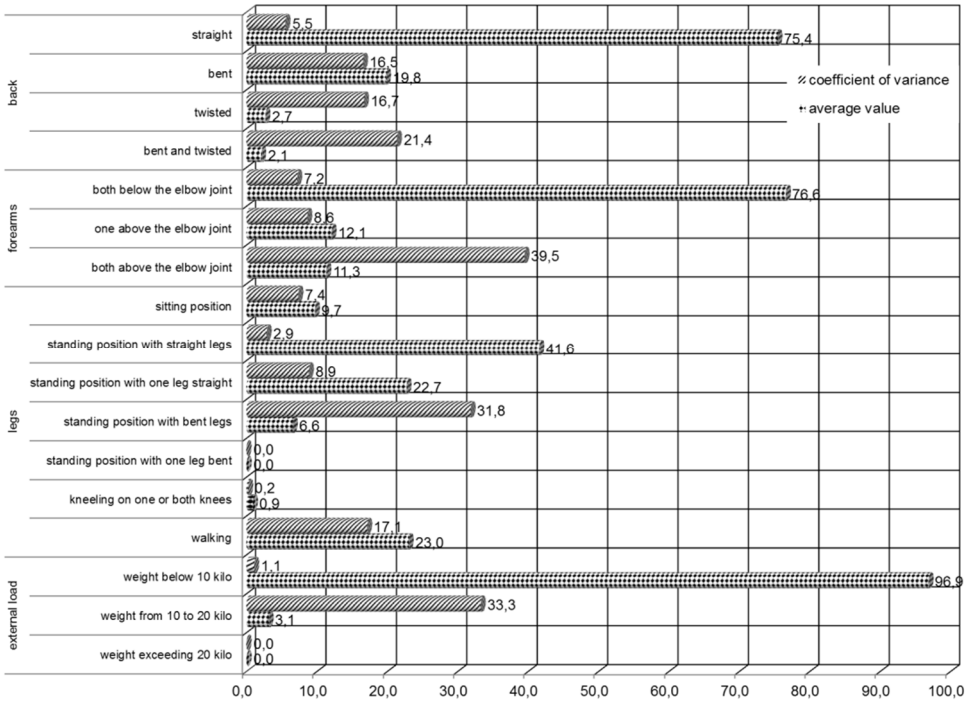

*Figure 1. The time structure of maintaining a particular position during a work shift at the station operating a carding machine*

Taking into consideration the most unfavourable back position for a man from the point of view of possible lesions, that is, a bent and twisted back, at the said work station such position was maintained only for 2.1% of the total working time. Attention should be paid to a high coefficient of variation, which exceeds 21%, which may prove a significant impact of the individual technique of performing activities by the investigated workers on the postural system. Analysing the position of forearms during operation of a carding machine, it was determined that a position, in which both arms are below the elbow joint constituted 76.6% of the total working time and was characterized with a low coefficient of variance, which was only 7%. In case of the position of legs of the investigated workers, a position in which both legs were straight (46.1% of the working time) was prevailing at the coefficient of variance of 2.9%. Weight of the lifted material in 96.6% did not exceed 10 kilo. Taking into consideration combination of the listed human body parts, described in the used method with four digits, it was stated that in the working time structure, an employee took a position described with the code "1121". Whereas, loading of the musculoskeletal system was classified to the 1st category of the assessment. In case of the 2nd category of assessing the load, the worker's position could be described the most frequently with the code "2121" (bent back, both forearms below the elbow joint, working in a standing position with straight legs). Moreover, at the analysed work station, 3 different codes of the body position, comprising the 3rd category of loading with the static work as well as 2 codes of the body positions comprising the 4th category of assessing the load were reported. However, their participation in the employee's working time structure was marginal. In the structure of operation of a carding machine, 7 groups of activities were selected, out of which the control of the machine, which constituted approx. 59% of the working time had the highest participation, including two categories of assessing the load, i.e.: The 1st category and the 2nd category constituting respectively 47.4% and 12.3% of the shift time of the listed categories. Activities related to the process of including a carding machine were the shortest, that is only approx. 3% of the employee's working time.

Generally, as much as 73.8% of the working time at the operation of a carding machine was classified to the 1st category of loading of the musculoskeletal system (fig. 2). In case of the 2nd category, its participation in the working time structure constituted 21.5% and the 3rd category only 4.5%. Whereas, the most unfavourable category, from the point of view of a worker, that is the 4th category constituted only 0.3% in the working time structure.

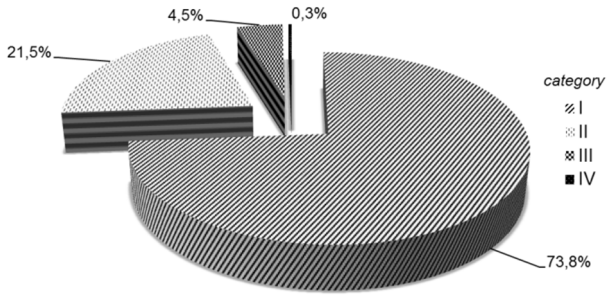


*Figure 2. The structure of the category of loading at the station operating a carding machine*

During the second stage of the technological process of geotextile production (operation of a technological line), a worker maintained a straight position of his back for 78.8% of the working time and the coefficient of variance was 39.9% (fig.3).

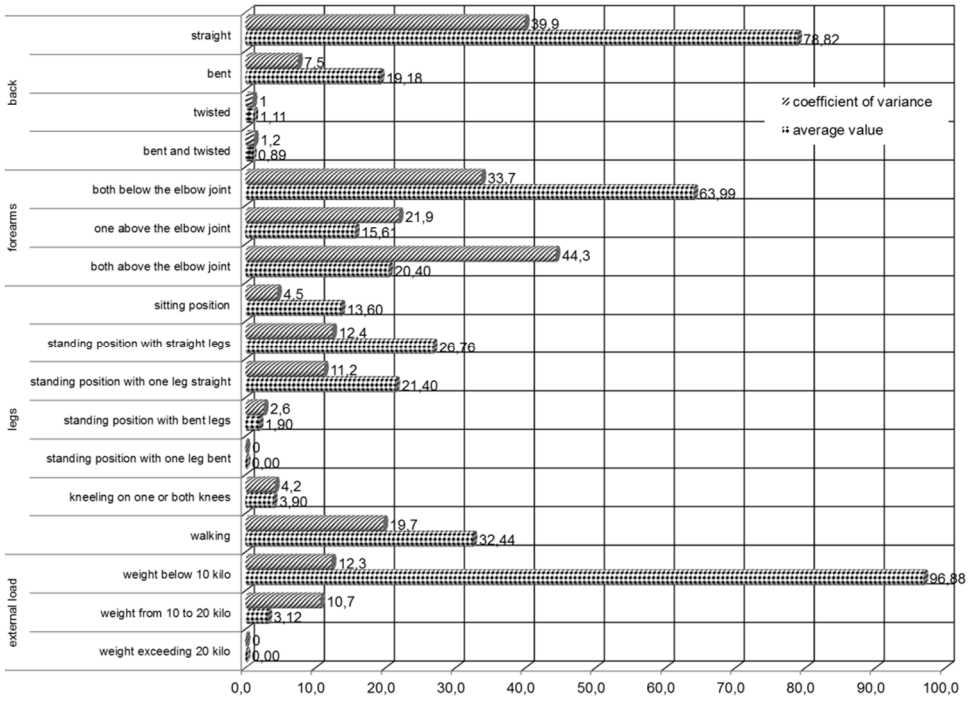


*Figure 3. The time structure of maintaining a given position during a work shift at the station operating a textile machine line*

When analysing the worker's forearms position, it was reported that over 63% of the working time both forearms were below and 20.4% were above the elbow joint. It should be emphasized that there was a considerable variability in the above mentioned value between the tested persons (the coefficient of variability was within 33.7-44.3%) which may prove considerable individualization of the manner of performing the activity.

Work consisting in operation of the technological line required from a worker constant walking for 32.4% of the working time, whereas the sitting position could be maintained only for 13.6% of the shift. A coefficient of variance, which is 19.7% in case of the "walking" activity, should be emphasized. It proves that in case of a relevant arrangement of work, time for this activity could be lowered. This statement does not refer to the kneeling position, which in the working time structure was 3.9% and was characterized with approx. 4% coefficient of variance. It was reported that in case of the 1st category of loading with the static work, the body position described with the code "1171" appeared. This code meant that a worker was walking with his back straight, he kept his forearms below the elbow joint and the weight of the carried material did not exceed 10 kilo. Whereas, among positions belonging to the 2nd category of the static load the position described with the code "2131" prevailed (it constituted 5.8% of the working time), which meant that the employee had his back bent, both forearms were below the elbow joint, he was working in the standing position with one leg straight and the weight of the handled material similarly to the previous case did not exceed 10 kilo. In the 3rd category of loading, the position, which was maintained for the longest time (1.4% during a shift) was defined with the "2141" code, which stands for the bent back, forearms below the elbow joint, a standing position with bent legs.

It was reported that the most time-consuming activities, performed by a worker who operated a textile machine line was control of the machine operation – 35.9% (fig.4) and batching of polyester fibres to the feeder – 28.9% of the working time. Carrying bales with non-woven fabric was the shortest activity – it took 1.8% of the working time.

During each of the performed activities at the analysed station, the 1st category of the static load prevailed – 79.71% of the working time. The activity consisting in cutting out the non-woven fabric samples was an exception, which was almost entirely classified as the 3rd category of assessing loading with the static work. Taking into consideration the time of maintaining one position, the static load was at the average level.

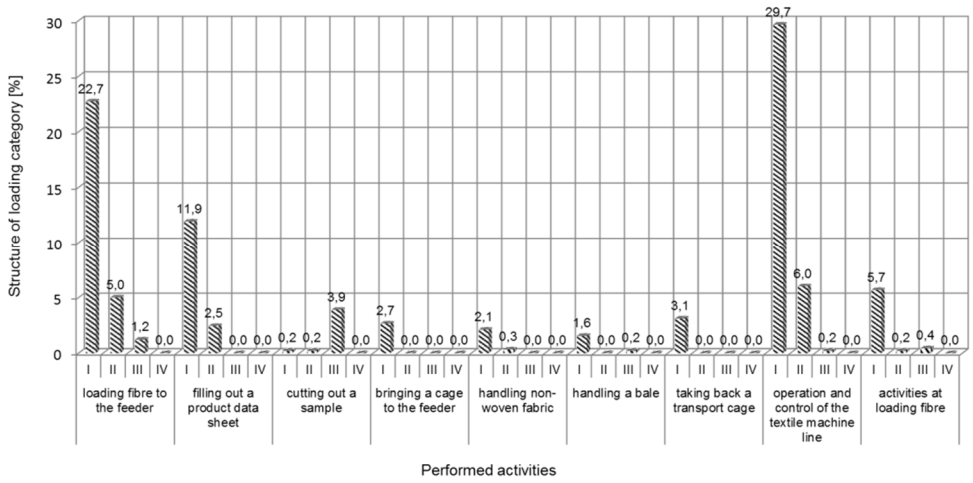


*Figure 4. The structure of the loading categories during performance of activities at the station operating a textile machine line*

During operation of the needling machine, which is the third stage of geotextile production, the most popular back position of workers, who carry out the technological process, is a straight back, which constitutes 66% of the shift (fig. 5).

It was stated that in the working time structure as much as 76.9% both forearms were below the elbow joint. The examined workers carried out their activities mainly (44.8% of the work shift time) in the standing position with straight legs. High variability in case of the back position, which was twisted, should be emphasized. It was 162% expressed with the coefficient of variance.

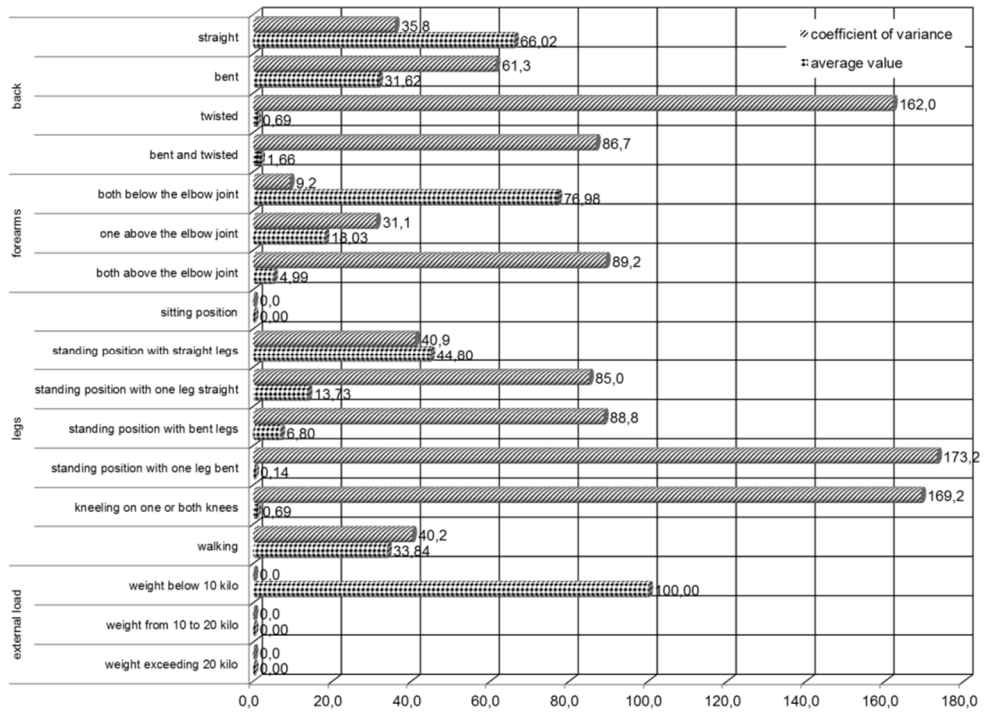


*Figure 5. The time structure of maintaining a particular body position during a working day at the station operating a needling machine*

Also, a high value of the coefficient of variance was reported at the standing position with one leg bent and it was 173% and the kneeling position amounting to 169% (fig.6). Although, the above-mentioned positions generally constitute a low percent in the structure of the shift working time, they constitute a significant threat for the workers' health and to a great extent depend on the subjective work technology and do not result from improper technology. It was reported that 27% of the working time, the workers' body position could be described with the code "1171" which stands for the worker's straight back, both forearms below the elbow joint, w*ork* performed during walking. This position was classified to the 1st category of assessing loading with the static work. It was reported that from among the body positions, described with codes classified to the 2nd category of loading, the most frequently, because as much as 9.7% the position described with the "2121" code, standing for the bent back, both forearms below the elbow joint, a standing position with straight legs, was reported. Whereas, from among the positions, described with the codes belonging to the 3rd category of loading, which constitute 6.1% of the total working time, the code "2141" was reported, which stands for the bent back, both forearms below the elbow joint, the standing position with bent legs. The longest activity, because as much as 83.2% of the time at the operation of the needling machine, consisted in controlling its working parameters (fig.6).

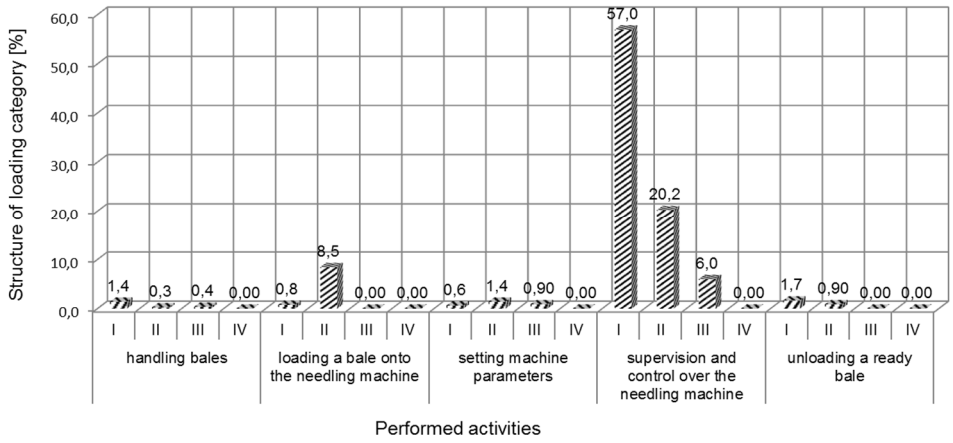


*Figure 6. The structure of the category of loading during the performed activities at the station operating a needling machine*

Whereas, the shortest activity in the structure of the shift time, which constituted only 2%, was carrying bales of non-woven fabric. The 1st category of loading with the static work prevailed at the station operating the needling machine and it was 61.5% of the shift time (fig. 8). It was stated that for over 30% of the working time, they took positions, which could have negatively influenced the musculoskeletal system (the 2nd category). Taking into consideration, the structure of categories of the reported loading, it was determined, that it was at the average level. The last but one stage of geotextile production consisted of activities related to its cutting and packing. It was reported that in case of cutting geotextile, this activity required a worker to keep his/her back straight for approx. 94.9 of the working time (fig.7). Whereas, for 83.7% of the shift time, a worker maintained forearms below the elbow joint and for 80.5%, straight legs and the standing position. \

From among all body positions reported during the research at the said working station, position prevailed (66.7% of the working time), which could be described with the code "1121" which meant that the worker's back were straight, both hands were below the elbow joint, legs were also straight and the weight of the handled material did not exceed 10 kilo. It was stated that approx. 95% of activities related to cutting geotextile performed by workers was placed in the 1st category of loading with the static work. The 2nd category of assessing the load constitutes 4.4% of the time for the performed activities. Whereas, the 3rd and 4th category of loading with the static work were not reported during the analysed working shifts. The final stage of the technology of geotextile production was packing the ready-made product in the plastic sleeve. During this activity (fig.8) the most often workers took a body position, which in case of a back stood for – a straight back (79.1%), in case of legs - the standing position (93.4% of the shift duration). Whereas, the activity, performed by a worker for 51.1% of the working time, required maintaining forearms above the elbow joint.

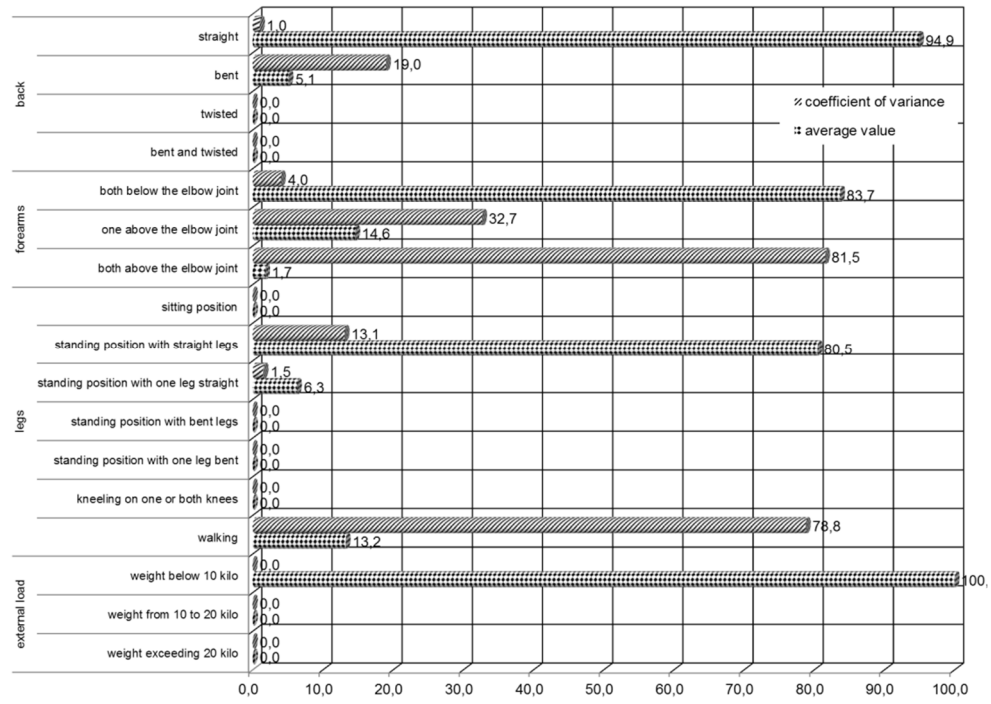


*Figure 7. The time structure of maintaining a particular body position during a working day at the station of cutting geotextile*

The most frequent position at this station may be described with the code "1321" (the worker's back straight, both forearms above the elbow joint, the standing position with straight legs), which generally constituted 54.9% in the structure of the working time classifying it to the 1st category of loading with the static work. In case of the second category of loading a worker with the static work, it was determined, that a position with the bent back and forearms below the elbow joint and straight legs was a prevailing and it was described with the code "2121", which constituted 24.2% of the total working time.

During packing a ready-made product the 1st category of assessing the static load prevailed in 72.5%. 26.37% of the working time belonged to the 2nd category, which forced out positions, which could have had a negative impact on the musculoskeletal system of a man. Taking into consideration the structure of the working time, loading with the static effort at this work station was classified as high.

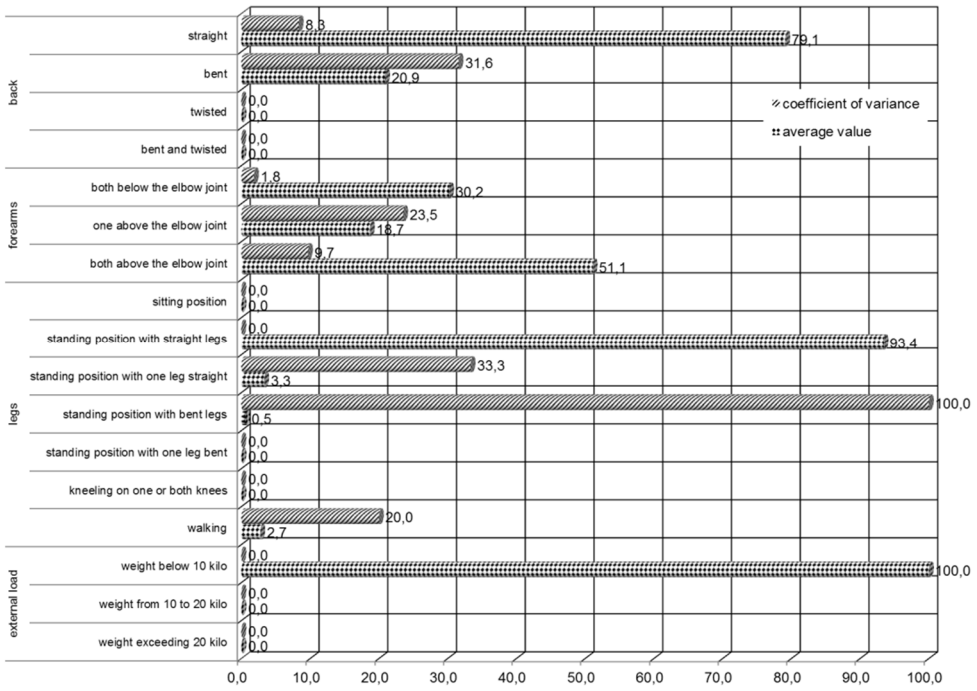


*Figure 8. The time structure of maintaining a particular body position during a working day at the packing work station*

## Conclusion

1. The tests, which were carried out in the production establishment PCPW – Eko Karpaty, allowed determination of the size and structure of the static load of workers during work at the particular work stations. It was reported almost in all cases of stations, that loading with the static work was at the average level.
2. It was stated that at all work stations, which constitute a production line of geotextile, workers in majority, took a natural body position and their loading was at the acceptable level, classified to the 1st category of the static load. Loading employees with work, estimated with the OWAS method, at 4 out of 5 tested work stations, resulting from the category of the body position at work and duration of maintaining one position was classified as average loading and only in one case this loading was identified as high.

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## ERGONOMICZNA OCENA OBCIĄŻENIA UKŁADU MIĘŚNIOWO-SZKIELETOWEGO PRACOWNIKÓW W PROCESIE PRODUKCJI GEOWŁÓKNINY

**Streszczenie.** Szacuje się, że w krajach europejskich ok. 27% osób pracuje przez więcej niż połowę czasu pracy w pozycji, która wywołuje zmęczenie i bóle mięśniowe mogące zakłócać koordynację postawy, co zwiększa ryzyko i możliwość popełnienia błędu przy obsłudze maszyny. Badania dotyczyły oszacowania ryzyka wystąpienia dolegliwości układu mięśniowo-szkieletowego pracowników operujących na poszczególnych stanowiskach roboczych stanowiących ciąg technologiczny do produkcji geowłókniny. Ponadto podjęto próbę korekcji organizacji pracy pozwalającej na minimalizację wpływu niekorzystnego układu posturalnego człowieka na jego zdrowie. Wykorzystując metodę „OWAS" (*Ovako Working Posture Analysis System*) określono wielkość oraz strukturę obciążenia układu mięśniowo szkieletowego pracowników. Odnotowano, że na wszystkich stanowiskach roboczych stanowiących przedmiot badań dominowała I kategoria oceny gdzie obciążenie pracą statyczną było średnie bądź duże, ale akceptowalne.

**Słowa kluczowe:** ergonomia, układ mięśniowo-szkieletowy, stanowisko pracy, metoda OWAS

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# RESPONSE OF THE SELECTED VARIETIES OF COMMON OSIER (*SALIX VIMINALS*) TO ORGANIC AND MINERAL FERTILIZATION IN LIGHT SOIL

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ABSTRACT

Research was carried out on light soil in 2010-2012 on plantations of a willow tree (*Salix viminalis* founded in Spring 2010. The objective of the paper was to assess a response of two cultivars – Sprint and Boks of common osier on organic and mineral fertilization in light soil. The experiment included two varieties - Sprint and Boks and three fertilization combinations: without compost 0, 10 and 20 t·ha$^{-1}$ of dry matter of compost produced from urban greenery waste. In facilities under experiment the following were used every year in the form of mineral fertilizers: 100 kg N, 80 kg $P_2O_5$ and 100 kg·ha$^{-1}$ $K_2O$. Detailed research included: the number of shoots on the plant, thickness of shoots on 10 cm height from the surface of soil and length of shoots and the yield of fresh and dry matter. Boks variety in all fertilization combinations formed less shoots on a plant but with a greater thickness and length in comparison to Sprint variety. Boks variety also characterized with greater production potential, reacted with higher increase of fresh and dry matter yield after the use of compost in 10 and 20 t·ha$^{-1}$ doses compared to mineral fertilization.

## Introduction

Biomass constitutes the source of renewable energy and may play a significant role in the energy balance of our country. Biomass for production of renewable energy may come from purposefully set permanent plantations of the selected species of native grasses, e.g. reed canary-grass, couch grass as well as introduced species e.g. maiden grass, prairie cordgrass and others (Golińska et al., 2012). Many authors (Dubas, 2003; Gradziuk, 2003; Szczukowski et al., 2004a) pay attention to favourable economic and ecological effects obtained at the cultivation of a willow tree for energy purposes. Kozak et al. (2004) think that a common osier may be cultivated in the entire country and factors restricting its cultivation are mainly water and nutrients deficiencies. The positive reaction of a common osier to mineral and organic fertilization, e.g. in the form of sewage sludge is proved by the research carried out by Nowak et al. (2011), Szczukowskiego et al. (2004a), MacPherson (1995), Szwedziak (2006). At the cultivation of a willow tree for enriching soil in nutrients,

by-products or waste, which are formed in various production processes, may be used. Composts produced from waste from greenery treatment and sewage sludge may be used for plant production (Styszko et. al., 2009; 2010; 2012), or waste which come from plant production (Denisiuk, 2006).

## Material and methods

Experiment was set out in the Agricultural Experimental Station in Lipki near Stargard Szczeciński on mineral soil, of good rye complex, IV valuation class. Schematic representation of an experiment, which included two factors – various cloned varieties of a common osier (*Salix viminalis*) (Sprint, Boks) – (factor I) and compost doses – 0, 10 and 20 t·ha$^{-1}$ of dry matter (factor II), was planned in the split-plot system in four repeats. In early spring 2010 after first spring cultivations, organic fertilization in the form of compost, which was mixed with soil in the depth of approx. 15 cm was applied. Compost was composed of: tree leaves, conifer needles, moss and cones. Chemical analysis of compost proved that it characterizes with the following content of macro-elements (g·kg$^{-1}$s·m): N - 9.54, P – 194.8, K – 354.0, Ca – 3497, M*g* – 291.2. pH in KCl was 6.78. Directly before planting of willow stem cuttings, uniform mineral fertilization was used for experimental purposes. Phosphorus dose was 80 kg·ha$^{-1}$ $P_2O_5$ potassium – 120 kg·ha$^{-1}$ $K_2O_5$, and nitrogen – 50 kg·ha$^{-1}$N. Fertilization with nitrogen in the dose of 50 kg·ha$^{-1}$ was repeated when young plants achieved the height of approx. 10 cm after mechanical treatment. Mineral fertilization in provided doses was also used in the following years of research. Stem cuttings with length of approx. 20 cm was planted on 8th April 2010 in the distance between rows 70 cm and in the distance of 35 cm in a row. It was planted to a depth in which 2-3 buds were over the surface of soil. A favourable system of meteorological conditions after planting caused that stem cuttings have taken root in 100%. No diseases or pests were reported and in protection against damages by animals, experiment was fenced with a forest wire. In the year when the experiment was set out, shoots were not mowed after vegetation. Plantation was run in a three-year cycle. In each year after the vegetation was finished, biometric measurements were carried out and they covered: number of stems in a plant, thickness of stems at the height of 10 cm from the soil surface and the length of shoots. Yield of fresh and dry matter and content of dry matter was determined after three years of research. Willow was harvested in March 2013.

The obtained results were subjected to analysis of variance at the level of significance 0.05 and uniform groups were created with the use of Tuckey's test.

## Discussion on results

The research which was carried out proved that plants of a willow tree form a small number of shoots if in the year when the plantation was set, their cutting is performed in order to initiate tillering in the following year. Bury and Czyć (2006) obtained similar results on plantations of a willow set out on organic and mineral soil.

In the first year of research, in relation to the facility, plants formed from 1.8 to 3 shoots. Average value in case of Sprint variety was 2.6 and in case of plants from Boks variety – 2.1 shoots for one rootstock. This difference was statistically significant (table 1).

Small number of shoots on a plant indicated high domination of first shoots, which form on planted stem cuttings. Confirmed values in the first year were not subject to explicit change in the following years. Statistical analysis proved that fertilization with compost had not essential impact on the number of shoots in a plant (table 1). Boks variety, which formed lower number of shoots, distinguished with their bigger thickness (table 2). In the year, when plantation was set, differences between varieties were not big, but they were statistically significant. In the following years differences increased in favour of Bok variety. Significant interaction between varieties and fertilization combinations were reported. In the first year of research on fertilized facilities, additionally treated with compost in doses 10 and 20 t·ha$^{-1}$ the increase of shoots thickness was 42.0% and 65.9% for Sprint variety and 53.8 and 72.1 % for Boks variety. In the second year (2011) increases were respectively: 14.3% and 17.0% – for Sprint variety and for Boks variety only after using 20 t of compost – 8.4%. In the last year of research (2012) in which average thickness of shoots was 26.5 mm (Sprint variety) and 40.4 mm (Boks variety) fertilization favourably influenced the shoots thickness but interaction between doses and fertilization combinations were determined. For Sprint variety in the facility treated with mineral fertilizers, average thickness of shoots was 24.5 mm, whereas for Boks variety – 35.3 mm. In combinations with additional compost in doses 10 and 20 t·ha$^{-1}$, increase of average thickness of a shoot was: 8.5 and 15.3% for Sprint variety and 22.7 and 21.0% – for Boks variety (table 2). Average results from three years of research prove that additional fertilization with compost favourably influenced the shoots thickness and shoots in relative numbers were similar in case of both varieties, although shoots of Boks variety were thicker.

Table 1
*The structure of a number of shoots per plant (pc)*

| Variety | Doses of compost | Years | | | Mean |
|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | |
| | (t·ha$^{-1}$) | | (item) | | |
| Sprint | 0 | 2.0 | 2.6 | 3.0 | 2.5 |
| | 10 | 3.0 | 2.6 | 2.0 | 2.5 |
| | 20 | 2.8 | 1.8 | 2.2 | 2.3 |
| | Mean | 2.6 | 2.3 | 2.4 | 2.4 |
| Boks | 0 | 1.8 | 1.8 | 1.6 | 1.7 |
| | 10 | 2.2 | 2.2 | 1.6 | 2.0 |
| | 20 | 2.2 | 1.8 | 1.4 | 1.8 |
| | Mean | 2.1 | 1.9 | 1.5 | 1.8 |
| Mean for doses of compost | 0 | 1.9 | 2.2 | 2.3 | 2.1 |
| | 10 | 2.6 | 2.4 | 1.8 | 2.3 |
| | 20 | 2.5 | 1.8 | 1.8 | 2.1 |
| $NIR_{0.05}$ – $LSD_{0.05}$ | | | | | |
| Varieties | (I) | 0.3 | 0.4 | 0.5 | 0.2 |
| Doses of compost | (II) | n.i | n.i | n.i | n.i |
| Interaction | IxII | n.i | n.i | n.i | n.i |
| | II x I | n.i | n.i | n.i | n.i |

Table 2
*The structure of shoots thickness (mm)*

| Variety | Doses of compost | Years | | | Mean |
|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | |
| | (t·ha$^{-1}$) | | (mm) | | |
| Sprint | 0 | 13.5 | 22.3 | 24.5 | 20.1 |
| | 10 | 19.2 | 25.5 | 26.6 | 23.7 |
| | 20 | 22.4 | 26.1 | 28.3 | 25.6 |
| | Mean | 18.4 | 24.6 | 26.5 | 23.1 |
| Boks | 0 | 14.0 | 29.7 | 35.3 | 26.3 |
| | 10 | 21.5 | 28.1 | 43.3 | 30.9 |
| | 20 | 24.1 | 32.2 | 42.7 | 33.0 |
| | Mean | 19.9 | 30.0 | 40.4 | 30.1 |
| Mean for doses of compost | 0 | 13.8 | 26.0 | 29.9 | 23.2 |
| | 10 | 20.4 | 26.8 | 35.0 | 27.3 |
| | 20 | 23.3 | 29.2 | 35.0 | 29.3 |
| $NIR_{0.05}$ - $LSD_{0.05}$ | | | | | |
| Varieties | (I) | 1.3 | 0.8 | 1.9 | 1.9 |
| Doses of compost | (II) | n.i | n.i | n.i | n.i |
| Interaction | IxII | 1.8 | 2.7 | 2.9 | 3.9 |
| | IIx I | 2.6 | 6.5 | 5.6 | 5.1 |

The obtained results concerning the length of shoots (table 3), in relation to the research combination indicate that this property, similarly to the shoots thickness depended on the properties of a variety and the applied fertilization. In the year of planting stem cuttings, plants developed shoots with average length of 229.9 cm (Sprint variety) and 242.7 cm (Boks variety). In case of plants of both varieties completing the mineral fertilization with doses 10 and 20 t·ha$^{-1}$ of compost favourably influenced the increase of shoots (table 3). Doubling the length of shoots was reported in the second year of vegetation (2011) since their average length was 472.8 cm in the facility with a maple of Sprint variety and 495.6 cm – in the facility with Boks variety maple. Fertilization with compost, similarly to the previous year (2010) caused obtaining considerably longer shoots. In the facility with a dose 10 t·ha$^{-1}$ of compost shoots were longer by 45.2 cm for Sprint variety and by 48.6 cm for Boks variety. Increasing a dose of compost by further 10 t·ha$^{-1}$ caused obtaining longer shoots by 5 cm and 14 cm (respectively Sprint and Boks variety). In the third year (2012) the increase was lower and the obtained lengths of shoots were at the average – 562.5 cm (Sprint variety and 650.0 cm – (Boks variety). In this year, efficiency of fertilization with compost was considerably lower, but statistically significant. Mean results from three years of research prove that the additionally used fertilization with compost favoured formation of shoots for the investigated varieties, which is confirmed by statistical analysis (table 3). Styszko, Fijałkowska and Sztyma (2009) using in their research 15 t·ha$^{-1}$ of fresh mass of compost and hydrofoska 15 fertilizer which provides 90 kg·ha$^{-1}$ N, 90 kg $K_2O$ and 90 kg·ha$^{-1}$ $P_2O_5$ and double dose, reported a positive reaction of a willow tree, expressed with greater lengths and thickness of shoots, but a significant interaction between varieties and fertilizer combination was reported.

Table 3
*The structure of shoots length (cm)*

| Variety | Doses of compost | Years | | | Mean |
|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | |
| | ($t \cdot ha^{-1}$) | | (cm) | | |
| Sprint | 0 | 228.6 | 441.4 | 542.6 | 404.2 |
| | 10 | 217.2 | 486.2 | 568.6 | 424.0 |
| | 20 | 244.0 | 491.2 | 576.4 | 437.2 |
| | Mean | 229.9 | 472.9 | 562.5 | 421.8 |
| Boks | 0 | 232.2 | 458.4 | 633.8 | 441.5 |
| | 10 | 241.2 | 507.0 | 673.6 | 473.9 |
| | 20 | 254.8 | 521.4 | 642.6 | 472.9 |
| | Mean | 247.2 | 495.6 | 50.0 | 462.8 |
| Mean for doses of compost | 0 | 230.4 | 449.9 | 588.2 | 422.9 |
| | 10 | 229.2 | 496.6 | 621.1 | 449.0 |
| | 20 | 249.4 | 506.3 | 609.5 | 455.1 |
| $NIR_{0.05}$ - $LSD_{0.05}$ | | | | | |
| Varieties | (I) | 18.4 | 14.6 | 11.6 | 9.2 |
| Doses of compost | (II) | n.i | n.i | n.i | n.i |
| Interaction | IxII | 22.7 | 27.8 | 19.3 | 19.5 |
| | IIxI | 24.5 | 30.4 | 21.6 | 22.6 |

Energy willow characterizes with high production potential (Dubas, 2003; Szczukowski et al., 2004b). According to many authors (Szczukowski et al., 2004a; Ignatowicz and Styszko 2012; Styszko et al., 2012) willow shows extensive reaction to habitat conditions, especially to water conditions and fertilization with organic and mineral substances. Ignatowicz and Styszko (2012) confirmed that there is a varied reaction of willow varieties to fertilization, in particular to nitrogen. Based on the obtained results they selected a group of varieties which has the highest yield in case of a dose of 180 $kg \cdot ha^{-1}$ of nitrogen and a group of varieties which has the highest yield in case of 55 $kg \cdot ha^{-1}$. In the authors' own research the obtained yield was – 118.0 $t \cdot ha^{-1}$ of fresh matter and 70.7 $t \cdot ha^{-1}$ – of dry matter for Sprint variety and respectively – 156.5 and 97.5 $t \cdot ha^{-1}$ – for Boks variety (tab. 4). This set proves that Boks variety in comparison to of Sprint variety, forming less shoots on a plant, but thicker and longer, it characterized with higher production potential. Plants of a willow tree showed a positive reaction to fertilization with compost used in the experiment. Using 10 tonnes of dry matter of compost per 1 ha, mean increase of fresh matter yield by 31.1% and dry matter by 26.7% was obtained in comparison to the facility with only mineral fertilization. In facilities treated with a dose of compost of 20 $t \cdot ha^{-1}$ the increase of the yield was respectively – 39.1% and 33.5%. Statistical analyses which were carried out confirmed significance of interaction between varieties and the applied fertilization combinations. In the facility with only mineral fertilization (100 kg N, 80 kg $P_2O_5$ and 120 $kg \cdot ha^{-1}$ $K_2O$) cloned plants of Sprint variety had yield at the level of 102.6 $t \cdot ha^{-1}$ of fresh matter and 65.0 $t \cdot ha^{-1}$ – of dry matter, and Boks variety – 156.5 $t \cdot ha^{-1}$ and 75.2 $t \cdot ha^{-1}$. Using additionally 10 $t \cdot ha^{-1}$ of the compost the increase of fresh matter yield by 17.2% and dry matter by 6.5% – (Sprint variety) and respectively – 43.1% and 44.0% – (Boks variety). For facilities, where 20 $t \cdot ha^{-1}$ of compost was applied, the increase was: for Sprint variety – 27.9% and 20.0%, and for Boks variety – 48.8% and 45.1%. The content of dry matter was within

57.5-63.2%. Fertilization with compost influenced insignificant decrease of its content of dry matter (table 4).

Table 4
*The yields of raw and dry matter (t·ha$^{-1}$) and the content of dry matter (%)*

| Variety | Doses of compost | Fresh matter | Dry matter | Content of dry matter |
|---|---|---|---|---|
| | | (t·ha$^{-1}$) | | (%) |
| Sprint | 0 | 102.6 | 65.0 | 63.0 |
| | 10 | 120.2 | 69.2 | 57.5 |
| | 20 | 131.2 | 78.0 | 59.4 |
| | X | 118.0 | 70.7 | 60.1 |
| Boks | 0 | 119.8 | 75.2 | 62.8 |
| | 10 | 171.4 | 108.3 | 63.2 |
| | 20 | 178.3 | 109.1 | 61.2 |
| | X | 156.5 | 97.5 | 62.4 |
| Mean for doses of compost | 0 | 111.2 | 70.1 | 63.1 |
| | 10 | 145.8 | 88.8 | 60.4 |
| | 20 | 154.6 | 93.6 | 60.3 |
| $NIR_{0,05}$ - $LSD_{0,05}$ | | | | |
| Varieties | (I) | 3.0 | 1.4 | |
| Doses of compost | (II) | 4.7 | 2.9 | |
| Interaction | IxII | 4.8 | 3.0 | |
| | IIxI | 6.7 | 4.2 | |

In the research, which was carried out, Styszko et al. (2009, 2010) confirmed a positive effect of the compost itself and compost used in combination with mineral fertilizers on the obtained yields of willow biomass. According to Gostomczyk (2014) organic products may constitute alternative for artificial fertilizers in the energy willow cultivation. Philip (1997) says that a willow tree of *Salix viminalis* type characterizes with strong increase of biomass. According to this author, biomass of one hectare of two-year willow collects 350 kg of nitrogen and 80 kg of phosphorus each year.

## Conclusions

1. Boks willow variety compared to Sprint variety forms less shoots but with greater thickness and length.
2. Fertilization with compost of 10 and 20 t·ha$^{-1}$ doses of dry matter will favourable influence the thickness and length of shoots and the obtained increases are not significantly equal in case of investigated varieties.
3. Boks variety compared to Sprint variety characterizes with higher production potential and shows more extensive reaction to additional fertilization with compost from urban greenery waste, used on the background of mineral fertilization (100 kg N, 80 kg $P_2O_5$ and 120 kg $K_2O$ per 1 ha).

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# REAKCJA WYBRANYCH ODMIAN WIERZBY KRZEWIASEJ (*SALIX VIMINALIS*) NA NAWOŻENIE ORGANICZNO-MINERALNE W WARUNKACH GLEBY LEKKIEJ

**Streszczenie.** Badania przeprowadzono na glebie lekkiej w latach 2010-2012 na plantacji wierzby (*Salix viminalis*) założonej wiosną 2010 roku. Celem badań była ocena reakcji dwóch odmian – Sprint i Boks wierzby krzewiastej na nawożenie organiczno-mineralne w warunkach gleby lekkiej. W doświadczeniu uwzględniono dwie odmiany – Sprint i Boks oraz trzy kombinacje nawozowe: bez kompostu 0, 10 i 20 t·ha$^{-1}$ suchej masy kompostu wyprodukowanego z odpadów zieleni miejskiej. Na obiektach doświadczenia corocznie stosowano w formie nawozów mineralnych: 100 kg N, 80 kg $P_2O_5$ i 100 kg·ha$^{-1}$ $K_2O$. Badania szczegółowe obejmowały: ilość pędów na roślinie, grubość pędów na wysokości 10 cm od powierzchni gleby i długości pędów oraz plonu świeżej i suchej masy. Odmiana Boks na wszystkich kombinacjach nawozowych wykształciła mniej pędów na roślinie, ale o większej grubości i długości w porównaniu do odmiany Sprint. Odmiana Boks, także charakteryzowała się większym potencjałem produkcyjnym, reagowała większym przyrostem plonu świeżej i suchej masy, po zastosowaniu kompostu w dawkach 10 i 20 t·ha$^{-1}$, na tle nawożenia mineralnego.

**Słowa kluczowe**: wierzba, odmiany, nawożenie mineralne, kompost, plony, pomiary biometryczne

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# INTENSITY OF PRODUCTION ORGANIZATION COMPARED TO THE WORK FACTOR IN FAMILY FARMS

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ABSTRACT

The paper presents the level of incurred labour inputs and the equipment in the form of production means in 46 family farms listed according to the intensity of production organization. The obtained results were presented with a table and description method. The analysis which was carried out proved that along with the intensity of production organization the number of physical workers increases in farms with simultaneous decrease of AL area. The investigated farms featured quite variable size of participation of capital calculated into the replacement value of mechanization means per a hectare of agricultural land. A positive average correlation between intensity of production organization and objectified work inputs and a weak correlation between intensity of production organization and human work inputs were determined.

## Introduction

Intensity of agricultural production may be determined with various indexes which explain structural and organizational conditions, environmental and agri-technical as well as economic and organizational ones. Intensity of agricultural production is determined based on two concepts, that is, intensity of organization and intensity of production. Determination of the level of intensity of production organization in farms is related to quality evaluations composed of both organizational departments of production in a farm as well as participation of production means (Kopeć, 1987).

Intensity of production is a quantity phenomenon, measured with the value of production inputs, the size of live labour inputs and objectified labour inputs per a unit of area (Manteuffel, 1979).

Labour as one of three factors of production is an essential element which influences effectiveness and competitiveness of agricultural farms (Pepliński, 1999). It is determined as a human effort put in production of a given good or service, in other words, as an organizer and creator of the production process. Number of full-time employees is a measure unit. Whereas, labour inputs are expressed in man-hour or man-day.

## The objective and the scope of research

The objective of the paper is analysis of human labour inputs and objectified labour inputs which occurs in 46 family farms set acc. to intensity of production organization.

Farms, which participated in the research project (carried out by the Institute of Technology and Natural Sciences Branch in Warsaw as a part of the program by the National Centre for Research and Development No. 1204306/2009 "Technological and ecological modernization of the selected family farms" managed by professor Wójcicki (2009), constituted material for research.

Farms were divided into four groups based on the category acc. to points of intensity of production organization presented by Kopeć. The level of human labour inputs in man-hour·ha$^{-1}$ AL and the level of the objectified labour inputs level in kWh·ha$^{-1}$ AL.

Intensity of production organization (Kopeć, 1987) was calculated acc. to the formula:

$$I_{op} = I_r + I_z = \Sigma p \cdot s + \Sigma q \cdot t \quad (1)$$

where:

$I_{op}$ – total intensity of production organization (points),
$I_r$ – intensity of plant production organization (points),
$p$ – participation of sowing area of a plant in agricultural land (%),
$s$ – coefficient of crop intensity for particular plants (points·%$^{-1}$),
$I_z$ – intensity of animal production organization (points),
$q$ – number of LSU of particular animal species per 100 ha AL,
$t$ – index of intensity for particular animal species per 1 LSU·100 ha$^{-1}$ AL.

Moreover, a calculated technical index of work infrastructure which images "infrastructure" of live labour with objectified labour. It enables assessment of the level of enterprises saturation with fixed assets (Wędzik, 2006).

$$Tup = MT \cdot L^{-1} \quad (2)$$

where:

$MT$ – average value of fixed assets (thousand PLN·farm$^{-1}$),
$L$ – employment level (persons).

Stocking density was calculated based on the calculation coefficients of animal items into livestock units (LSU) (Journal of Laws 2010 no.213, item 1397). Table and description methods and basic statistical methods were used in the paper. Statistical analysis was based on the linear correlation coefficient assuming a scale acc. to Stanisz (1998):

$r_{xy} = 0$ – variables are not correlated,
$0 < r_{xy} < 0.1$ – dim correlation,
$0.1 \leq r_{xy} < 0.3$ – weak correlation,
$0.3 \leq r_{xy} < 0.5$ – average correlation,
$0.5 \leq r_{xy} < 0.7$ – high correlation,
$0.7 \leq r_{xy} < 0.9$ – very high correlation,
$0.9 \leq r_{xy} < 1$ – almost certain correlation,
$r_{xy} = 1$ – certain correlation.

## Research results

The analysed group of 46 farms characterized with high range of agricultural land areas (table 1), which was 141.42 ha and standard deviation of 29.84 ha. Average area of agricultural land is 33.68 ha when standard deviation was 30.85 ha. All farms had meadows and pastures and the biggest area of permanent grasslands in a farm was 47.55 ha. Not in all analysed farms, animal production was carried out.

Average stocking density was 80.26 LSU·ha$^{-1}$ AL. The replacement value of mechanization means characterized with high range which was 1686.70 thousand PLN·farm$^{-1}$ at the standard deviation equal to 427.02 thousand PLN·farm$^{-1}$.Whereas, average replacement value of mechanization means expressed in thousand PLN·ha$^{-1}$ AL was 10.97.

Table 1
*Description of the researched farms*

| Specification | Minimal value | Maximum value | Average | Standard deviation |
|---|---|---|---|---|
| Area of agricultural land (ha·farm$^{-1}$) | 8.58 | 150 | 42.74 | 29.84 |
| Arable land (ha·farm$^{-1}$) | 5.00 | 150 | 33.68 | 30.85 |
| Permanent grasslands (ha·farm$^{-1}$) | - | 47.55 | 9.05 | 10.00 |
| Animal livestock (LSU·ha$^{-1}$ AL) | - | 295.91 | 80.26 | 67.30 |
| Replacement value of mechanization means (PLN ·ha$^{-1}$ AL ) | 2.90 | 58.06 | 27.03 | 10.97 |
| Replacement value of mechanization means (thousand PLN·farm$^{-1}$) | 231.60 | 1918.30 | 975.26 | 427.02 |

In the crop structure (fig. 1) grains along with maize for grain constituted 56% of the area of all crops. Oil plants had 4%, root 5% and papilionaceous plants 2% participation in agricultural lands. Meadows and pastures had in total 21% of participation in the crops structure.

Farms were divided into four groups acc. to the level of intensity of production organization (table 2) where average area of farms was 42.74 ha AL (8.58-150 ha AL). Farms in these groups proved decrease of intensity of production organization with the increase of the farm area respectively from 771.23 points to 236.56. Acc. to the assumed criteria the most numerous group of 17 farms constituted farms, where intensity of production organization was within 400-550 points. Whereas, the biggest farms (95.83 ha AL) were in the first group of production organization (to 300 points).

Farms with the highest production organization, where index was over 771.23 points, farmed on the area of 33.54 ha AL that is almost on three times smaller than farm with the lowest organization of agricultural production, for comparison – average for the investigated group was 42.74 ha AL. The fact, that farms with intensity above 550 points obtained high index of livestock which was over 117.64 LSU·100 ha$^{-1}$ AL is significant. Assessment of work inputs proved relations between the level of employment and the increase of intensity of production organization.

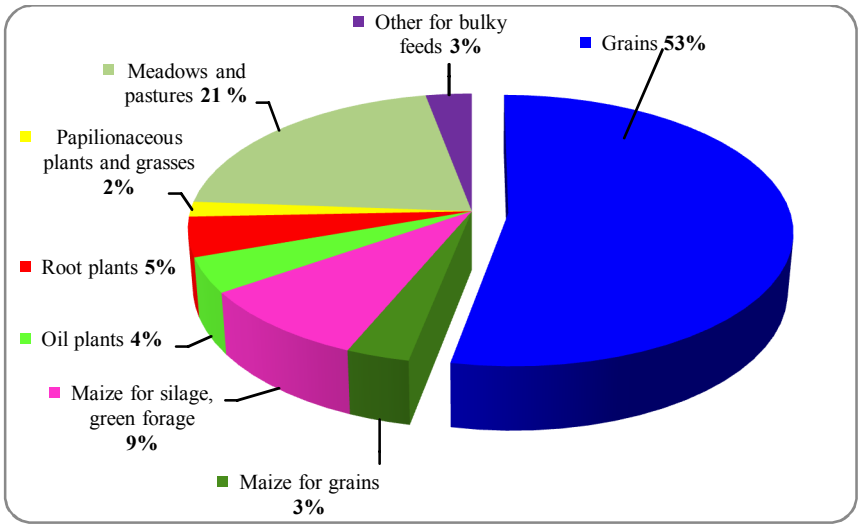


*Figure 1. Structures of crops in the investigated farms*

Table 2
*Labour resources in the researched farms*

| Specification | Unit | Categories of farms acc. to points of intensity of production acc. to Kopeć | | | | At the average for 46 farms |
|---|---|---|---|---|---|---|
| | | >300 | 300≤400 | 400≤550 | ≥550 | |
| Number of farms | – | 6 | 7 | 17 | 16 | - |
| Area of farms | (ha AL) | 95.83 | 42.56 | 38.88 | 33.54 | 42.74 |
| Stocking density | LSU·100 ha$^{-1}$UR | 27.18 | 46.83 | 76.97 | 117.64 | 80.26 |
| Intensity of production organization | (points, including in: | 236.56 | 320.74 | 449.96 | 771.23 | 517.75 |
| | plant production | 137.49 | 162.83 | 137.09 | 172.98 | 156.27 |
| | animal production) | 99.06 | 157.91 | 312.87 | 598.25 | 361.47 |
| Employment in a farm | people·farm$^{-1}$ | 2.15 | 2.60 | 2.81 | 3.50 | 2.93 |
| - conversion employees | employee·100 ha$^{-1}$ UR | 2.25 | 6.11 | 7.22 | 10.42 | 9.41 |
| - foreign employees | | 0.20 | 0.60 | 0.97 | 0.81 | 0.76 |

Farms with intensity to 300 points employed 2.25 employees per 100 ha AL, where in farms with intensity above 550 points this number was 10.42. The highest number of foreign employees were employed by farms with intensity from 400 to 550 points (0.97 conversion employees per 100 ha AL). That is almost five times higher than farms with intensity to 300 points and over 1.5 times higher than farms with intensity from 300 - 400 points. Whereas, in comparison to the fourth group of intensity over 550 points, these farms employed the number of conversion employees per 100 ha of AL almost at the same level (0.81).

Taking into consideration the structure of labour inputs, manner of organization of agricultural production and degree of participation of technical means, the nature of the production system in a farm may be determined, e.g. capital intensive, labour-intensive (Michałek and Kowalski, 1993; Wójcicki, 2001). The investigated farms characterized with quite variable size of capital participation calculated into replacement value of mechanization means per a hectare of agricultural land. Along with the increase of production organization intensity, the index of value of all possessed groups of machines expressed in thousand PLN·ha$^{-1}$ AL (tab. 3) increased.

Taking into account the replacement value, it may be stated that farms with intensity to 300 points farming on big areas show almost 1.5 times higher participation of capital in technical mechanization means.

Particular groups of farms, when executing the production process, except for capital participation in mechanization means showed also variable human labour inputs. Employment of physical workers in the investigated systems was also variable and increased along with production intensity from 2.15 employees in farms with intensity to 300 points to 3.50 persons in farms with intensity above 550 points. Whereas, these indexes referred to the number of people employed per 100 ha AL allowed stating that farms with intensity to 300 points employ 2.25, from 300 to 400 points – 6.11 while from 400 to 550 points – 7.22 and above 550 points – 10.42 employees per 100 ha AL. It may be stated that farms with intensity above 550 points in comparison to farms with intensity to 300 points use the area of AL almost three times smaller.

The increasing intensity in production is related to higher loading with work of employees. In the system with intensity above 550 points this loading is lower by 1208.51 man-hour in comparison to employee in farms with intensity to 330 points. Farms with intensity over 550 points incur the highest inputs per 1 ha of AL in comparison to three remaining groups of intensity. One may state that farm with intensity to 300 points with low level of employment of conversion employees incur almost five times lower inputs of live work per 1 ha of AL compared to farms with intensity above 550 points of production organization.

When analysing descriptions of relations between human labour and objectified labour a technical infrastructure index was assumed expressed in PLN·man-hour$^{-1}$ and PLN per an employee (Zaremba, 1977). Farms with intensity to 300 points but with bigger area at comparable employment of natural persons proved the highest index of technical infrastructure, referred to three remaining, which was 1173.69 PLN·man-hour$^{-1}$ and 2354.83 thousand PLN per an employee but the highest level of work load (1930.61 man-hour per a farm per a year). The mentioned indexes express only possibilities of participation of technical means in the labour process (it is practically the replacement value of mechanization means per an employee or an hour of his work).

Table 3
*Level of technical infrastructure of the work process in the investigated farms*

| Specification | Unit | Categories of farms acc. to points of intensity of production acc. to Kopeć | | | | At the average for 46 farms |
|---|---|---|---|---|---|---|
| | | >300 | 300≤400 | 400≤550 | ≥550 | |
| Number of farms | – | 6 | 7 | 17 | 16 | |
| Area of farms | (ha AL) | 95.83 | 42.56 | 38.88 | 33.54 | 42.74 |
| Intensity of production organization | (points, including in: plant production animal production) | 236.56<br>137.49<br>99.06 | 320.74<br>162.83<br>157.91 | 449.96<br>137.09<br>312.87 | 771.23<br>172.98<br>598.25 | 517.75<br>156.27<br>361.47 |
| Number of employees in a farm | (Persons) | 2.15 | 2.60 | 2.81 | 3.50 | 2.93 |
| Number of conversion employees | employee·100ha$^{-1}$ AL | 2.25 | 6.11 | 7.22 | 10.42 | 9.41 |
| Loading employees with work | man-hour·year$^{-1}$ | 1930.61 | 904.00 | 818.78 | 722.10 | 1093.87 |
| Inputs of human work | man-hour·ha$^{-1}$ AL | 45.27 | 129.82 | 151.97 | 224.29 | 209.67 |
| Inputs of objectified work | kWh·ha$^{-1}$ AL | 877.98 | 1334.88 | 1501.65 | 1842.34 | 1538.88 |
| Replacement value of mechanization means | thousand PLN·farm$^{-1}$ | 1238.70 | 862.94 | 965.43 | 991.95 | 975.26 |
| Replacement value of mechanization means | thousand PLN·ha$^{-1}$ AL | 12.93 | 20.28 | 24.83 | 29.57 | 27.03 |
| Technical infrastructure index of the work station | PLN·man-hour$^{-1}$ | 1173.69 | 467.12 | 456.36 | 440.56 | 537.49 |
| Technical infrastructure index of the work station | thousand PLN·employee$^{-1}$ | 2354.83 | 472.80 | 443.00 | 441.10 | 1115.98 |

Statistical analysis of farms proved a positive average correlation between intensity of production organization and objectified labour inputs (fig. 2). Coefficient of correlation r = 0.52 shows, acc. to the scale by Stanisz (1998), average relation between these variables. The calculated coefficient of determination $R^2$ informs on explaining by the variable intensity of production organization 26.71% of the objectified labour inputs.

The statistical analysis, which was carried out proved a positive weak correlation between the intensity of production organization and human labour inputs expressed in man-hour·ha$^{-1}$ AL. Coefficient of correlation was r = 0.33.

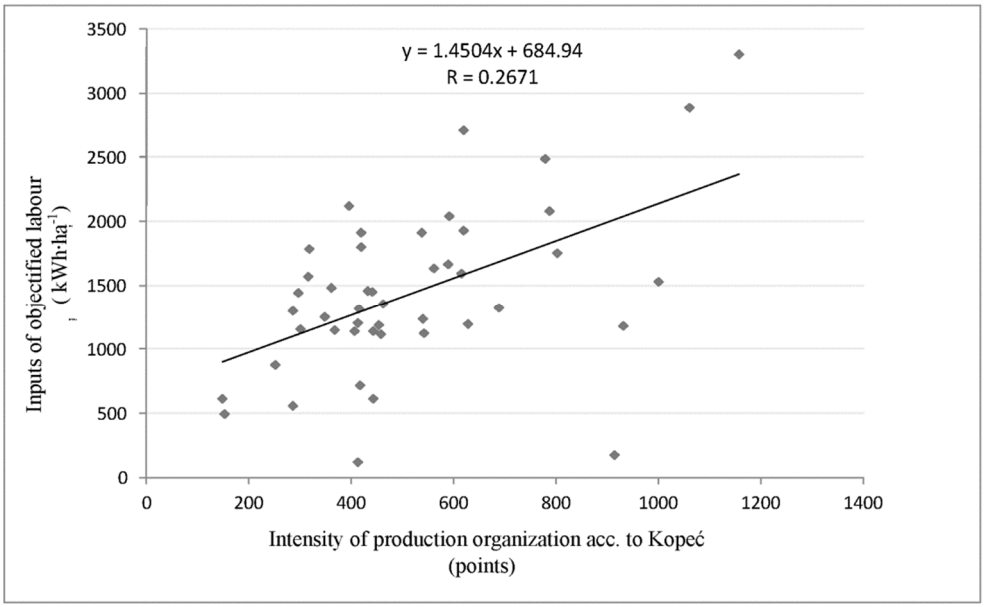


*Figure 2. Impact of changes of intensity of production organization on the objectified labour inputs*

## Conclusion

The analysis which was carried out proved that along with the increase of the intensity of production organization the number of physical workers increases in farms with simultaneous decrease of AL area.

The investigated farms featured quite variable size of participation of capital calculated into the replacement value of mechanization means per a hectare of agricultural land. Taking into account the replacement value, it may be stated that farms with intensity to 300 points farming on big areas show almost 1.5 times higher participation of capital in technical mechanization means.

Farms with intensity to 300 points but with bigger area at comparable employment of natural persons proved the highest index of technical infrastructure, referred to three

remaining, which was 1173.69 PLN·man-hour$^{-1}$ and 2354.83 thousand PLN per an employee but the highest level of work load (1930.61 man-hour per a farm per a year).

A positive average correlation between intensity of organization intensity and objectified work inputs and a weak correlation between intensity of production organization and human work inputs were determined.

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## INTENSYWNOŚĆ ORGANIZACJI PRODUKCJI A CZYNNIK PRACY W GOSPODARSTWACH RODZINNYCH

**Streszczenie.** W pracy przedstawiono poziom ponoszonych nakładów pracy i wyposażenia w środki produkcji występujące w 46 gospodarstwach rodzinnych zestawionych wg intensywności organizacji produkcji. Uzyskane wyniki przedstawiono metodą tabelaryczno-opisową. Przeprowadzona analiza wykazała, że wraz ze wzrostem intensywności organizacji produkcji wzrasta liczba pracowników fizycznych w gospodarstwach z jednoczesnym spadkiem powierzchni UR. Badane gospodarstwa charakteryzowała się dość zmienną wielkością zaangażowania kapitału w przeliczeniu na wartość odtworzeniową środków mechanizacji, przypadającą na hektar użytków rolnych. Stwierdzono dodatnią przeciętną korelację między intensywnością organizacji produkcji a nakładami pracy uprzedmiotowionej oraz słabą korelację między intensywnością organizacji produkcji a nakładami pracy ludzkiej.

**Słowa kluczowe:** intensywność organizacji produkcji, czynnik pracy, praca uprzedmiotowiona, gospodarstwa rodzinne

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# CHARACTERISTIC AND EFFICIENCY OF OPERATION OF THE UNIT FOR NON-PLOUGH SOIL CULTIVATION AND THE CULTIVATION AND SOWING UNIT IN CONDITIONS OF THE EASTERN EUROPEAN PART OF RUSSIA

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ABSTRACT

The article contains technical description of the tool and the unit used for basic and pre-sowing soil cultivation and sowing: a combined unit for basic non-plough soil cultivation and the cultivation and sowing unit. Results of the research on the efficiency of their use in the soil and climatic conditions of the north and eastern European part of Russia were presented. The analysis of the agrophysical properties of soil showed that the relative moisture of soil in the 0-10 cm layer did not depend on the manner of the basic and pre-sowing cultivation, but in the 0-20 cm layer the decrease of the soil moisture by 0.9-1.4% was reported after the use of KBM -4,2 cultivator and after cultivation with with APPN-2,1 (LSD05=0.63) unit. All the tested units ensured optimal density of the cultivated layer of the sod podzol soil within 1.1-1.3 g·cm$^{-3}$. The water content of soil in the cultivation of winter rye in the non-plough cultivation with KPA-2,2 unit was higher by 1.5 mm in comparison to cultivation after ploughing (LSD05=0.51). No differences were reported in cultivation of vetch with oats. A non-plough cultivation of soil was also characterized with better values of indexes of the grain size distribution in comparison to the plough. The use of the cultivation and sowing unit APPN-2.1allowed decrease of energy inputs by 366 MJ·ha$^{-1}$ (45.7%) compared to the total inputs on cultivation with KPS-4,0, fertilization and sowing. Sowing with the unit APPN-2.1 influenced the increase of the winter rye yield by 0.88 t·ha$^{-1}$ compared to cultivation with KPS-4,0 and plough (LSD05AB=0.8). In the conditions with the use of APPN-2,1 the yield of dry mass of vetch and oats was higher by 0.75 t·ha$^{-1}$ compared to the variants with KBM-4,2 (LSD05B=0.39).

## Введение

Современное земледелие, основанное на традиционных технологиях возделывания, в последнее время, испытывает ряд негативных последствий интенсификации. При этом особую остроту приобретают проблемы переуплотнения почвы ходовыми системами машин и тракторов (Алетдинова и Бахарев, 2001; Алешкин и др., 2009; Buliński, 2006). Отмечено, что при проведении полного комплекса полевых работ при возделывании сельскохозяйственных культур различные машины проходят по полю от 5 до 15 раз, что отрицательно влияет на водно-воздушный режим почвы, приводит к увеличению энергозатрат на её обработку и к снижению урожайности (Chaudhuri, 2001; Dawidowski, 2008; Kamiński, 2011a; 2011b; Орда и др., 2008). Такое положение дел, сложившееся в сельскохозяйственном производстве заставило пересмотреть систему обработки почвы и посева в направлении сохранения и повышения почвенного плодородия и снижения себестоимости производства продукции сельского хозяйства (Viselga и Kamiński, 2006; Zotarelli и др., 2007). Это привело к необходимости создания почвозащитных энергоресурсосберегающих технологий, предусматривавших выполнение ряда ранее самостоятельно выполняемых агротехнических операций за один технологический проход агрегата (Писарев, 2004; Horn и Fleige, 2009; Rathke и др., 2007; Riley, 2009; Saffih-Hdadi и др., 2009).

Среди комплексных агротехнических мероприятий, направленных на получение устойчивых урожаев сельскохозяйственных культур, качественная основная и предпосевная обработка почвы и посев играют первостепенную роль. Одно из перспективных направлений модернизации сельскохозяйственной техники для растениеводства - разработка комбинированных агрегатов, которые за один технологический проход выполняют комплекс агротехнических операций. Наиболее рационально использование комбинированных агрегатов при совмещении предпосевной обработки почвы и посева, а также при дополнении основной безотвальной обработки почвы операциями по созданию мульчирующего поверхностного слоя (Sławiński, 2008; Talarczyk и Zbytek 2005; 2012; Szeptycki, 2006).

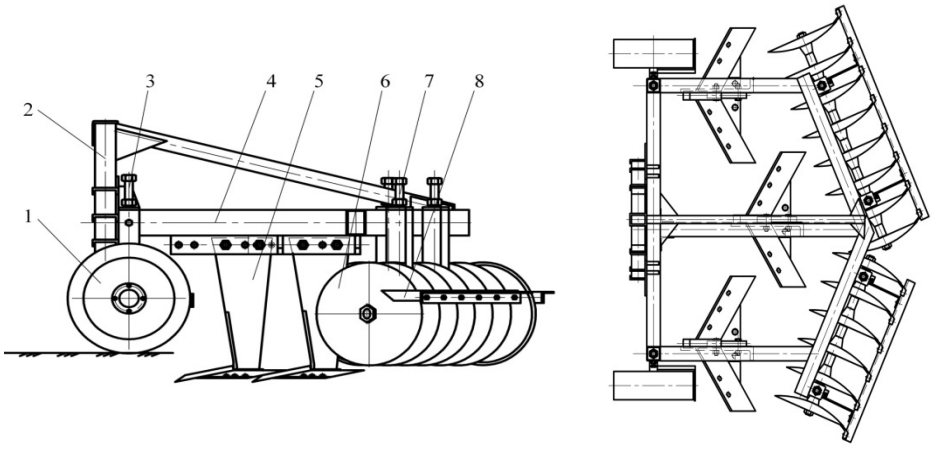
Применение комбинированных агрегатов для основной безотвальной обработки почвы и почвообрабатывающе-посевных агрегатов создает благоприятные условия для вегетации растений за счёт лучшего качества обработки почвы, сохранения почвенной влаги, а также сокращает длительность производственного цикла, уменьшает вредное воздействие ходовых систем машин на структуру почвы.

## Цель исследований

Целью исследования являлось определение эффективности применения комбинированных орудий и агрегатов для основной и предпосевной обработки почвы, адаптированных к почвенно-климатическим условиям Северо-Восточного региона европейской части РФ.

## Техника для обработки почвы и посева

Для проведения основной безотвальной обработки почвы с одновременным лущением поверхностного слоя в НИИСХ Северо-Востока разработан комбинированный почвообрабатывающий агрегат КПА-2,2 для тракторов тягового класса 1,4 и 2,0 (рис. 1, табл. 1). Он состоит из рамы с опорными колесами, на которой последовательно установлены три плоскорезные лапы, две дисковые секции и сменный рабочий орган для дополнительной обработки почвы - прутковый каток или гребнеобразующие корпуса. Плоскорезные лапы расположены на раме агрегата по схеме обратного клина для снижения тягового сопротивления и лучшей заглубляемости. Плоскорезные лапы унифицированы с рабочими органами плуга-плоскореза ППН-3-35/2-70, дисковая борона – с дисковыми секциями лущильника ЛДГ-5.




1 – опорное колесо; 2 – автосцепка; 3 – механизм регулировки глубины обработки; 4 – рама; 5 – лапы плоскорезные; 6 – дисковые секции; 7 – механизм регулировки глубины обработки дисковой секции; 8 – чистик

*Рисунок 1. Комбинированный почвообрабатывающий агрегат КПА-2,2 для безотвальной обработки почвы: а) вид сбоку; б) вид сверху*

Данный агрегат предназначен для основной безотвальной обработки почвы на глубину 16-20 см с одновременным лущением поверхностного слоя. При плоскорезной обработке почвы на глубину 8-16 см с одновременным лущением поверхностного слоя агрегат может быть оснащён прутковым катком для последующего выравнивания и прикатывания почвы (рис. 2а). При обработке почвы под посадку картофеля предусмотрено оснащение почвообрабатывающего агрегата гребнеобразующими корпусами (рис. 2б).

Таблица 1
*Техническая характеристика почвообрабатывающего агрегата КПА-2,2*

| Показатель | Выполняемая операция: | | |
|---|---|---|---|
| | основная безотвальная обработка | обработка почвы с прикатыванием | обработка почвы с нарезанием гребней |
| Производительность за час основного времени, (га·ч$^{-1}$) | до 1,6 | до 2,0 | до 2,0 |
| Глубина обработки, (см) | 16-20 | 8-16 | 10-16 |
| Рабочая скорость, (км·ч$^{-1}$) | | 5-9 | |
| Ширина захвата, (м) | | 2,2 | |
| Ширина захвата плоскорезной лапы, (м) | | 0,76 | |
| Габаритные размеры, (мм): - длина | 1970 | 2450 | 2500 |
| - ширина | 2200 | 2400 | 2400 |
| - высота | 1300 | 1300 | 1300 |
| Масса, (кг) | 475 | 590 | 575 |
| Средняя трудоемкость переоборудования орудия, (чел.-ч.) | не более 2,5 | | |

Полевые испытания показали, что агрегат устойчиво выполняет безотвальную обработку почвы согласно агротехнических требований, выдерживает рабочую ширину захвата и установочную глубину обработки. В ходе производственного использования в 2007-2013 гг. проводилась обработка чистых паров под посев озимой ржи, зяблевая обработка и обработка почвы перед посадкой картофеля на площади 150 га. Отказов по итогам испытаний не выявлено (кроме замены изношенных лемехов).

а б

*Рис. 2. Комбинированный почвообрабатывающий агрегат КПА-2,2 в комплектации с прикатывающим катком (а) и с гребнеобразующими корпусами (б)*

Для осуществления, предложенного в НИИСХ Северо-Востока, ресурсосберегающего способа предпосевной обработки почвы и посева (Жук и Ревякин, 2007), который включает выполнение за один проход предпосевной обработки почвы (в т.ч. полосное рыхление, культивацию, фрезерование и выравнивание), внесения стартовой дозы минеральных удобрений, посева и послепосевного прикатывания,

разработан почвообрабатывающе-посевной агрегат АППН–2,1 (рис. 3, табл. 2). В качестве основы его почвообрабатывающей части принят бесприводной ротационный рыхлитель, а посевной части – зернотуковая сеялка рядового посева с сошниковой группой из килевидных сошников, расположенных на поводках в виде прицепов пружин кручения.

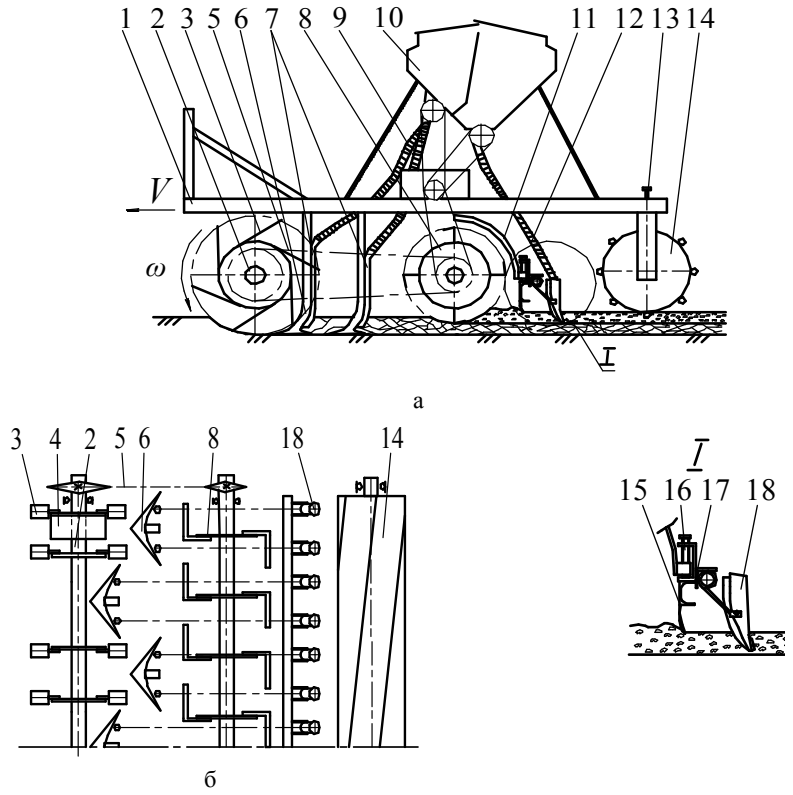



*Рисунок 3. Почвообрабатывающе-посевной агрегат:а – вид сбоку; б – схема размещения рабочих органов: 1 – рама; 2 – ротор приводной; 3 – почвозацепы; 4 – опорные реборды; 5 – цепная передача; 6 – культиваторные лапы; 7 – тукопроводы; 8 – измельча–ющий ротор; 9 – коробка перемены передач; 10 – зернотуковый ящик; 11 – защитный кожух; 12 – семяпроводы; 13 – механизм регулировки глубины обработки; 14 – каток; 15 – выравниватель; 16 – механизм регулировки глубины посева; 17 – брус сошников; 18 – сошники*

Агрегат состоит из рамы, на которой расположены приводной ротор с почвозацепами и опорными ребордами, два ряда культиваторных лап, измельчающий ротор с Г-образными ножами, закрытый кожухом, выравниватель, бункер для семян и удобрений, ряд килевидных сошников и каток.

При поступательном движении почвозацепы приводного ротора, принудительно перекатываясь под действием тяговой силы трактора, производят рыхление почвы полосами и одновременно через ускоряющую передачу приводят во вращение измельчающий ротор. Стрельчатые культиваторные лапы подрезают и рыхлят пласт почвы в необработанных междурядьях. Одновременно с этим через туконаправители культиваторных лап в почву подаются минеральные удобрения. Далее Г-образные ножи измельчающего ротора обрабатывают верхний слой почвы на глубину, превышающую на 20-40 мм глубину посева семян. Неровности микрорельефа сглаживаются выравнивателем. Килевидные сошники формируют в зонах локального внесения туков бороздки с уплотнённым посевным ложе, в которые высеваются семена. Каток производит послепосевное прикатывание для обеспечения лучшего контакта высеянных семян с почвой.

Таблица 2
*Техническая характеристика агрегата АППН-2,1*

| Показатель | | Значение |
|---|---|---|
| Производительность за час основного времени, (га·ч$^{-1}$) | | 1,4-2,0 |
| Рабочая скорость, (км·ч$^{-1}$) | | 6-10 |
| Рабочая ширина захвата,(м) | | 2,1 |
| Глубина обработки почвы, (см): приводным ротором | | 12-15 |
| стрельчатыми лапами | | 6-12 |
| измельчающим ротором | | 4-8 |
| Объём бункера для туков, (дм$^3$) | | 120 |
| Объём бункера для семян, (дм$^3$) | | 250 |
| Габаритные размеры орудия, (мм): | длина | 2450 |
| | ширина | 2600 |
| | высота | 1850 |
| Масса агрегата, (кг) | | 1020 |
| Агрегатируется с тракторами тягового класса | | 1,4 и 2,0 |

Благодаря установке опорных реборд на приводном роторе обеспечена постоянная глубина его погружения в почву, что стабилизирует частоту вращения высевающих аппаратов, а также снижает нежелательное варьирование скольжения ротора при изменении физических свойств почвы или скорости движения агрегата.

Выравнивание почвы обеспечивает ровную поверхность поля. В этом случае для копирования рельефа достаточно небольшой амплитуды хода механизма подвеса сошников, что позволило использовать в качестве их поводков прицепы пружин кручения. Объединение функций крепления, защиты от повреждения при наезде на препятствие и копирования поверхности в одном конструктивном элементе - пружине кручения с прицепами в виде поводков, значительно снизило металлоёмкость сошниковой группы. Использование килевидных сошников при установке их в один ряд с междурядьем 0,15 м позволило сделать сошниковую группу максимально компактной.

Для оценки агротехнических показателей работы опытного образца агрегата (рис. 4) изучено влияние скорости движения на качество обработки почвы и заделки

семян. Исследования проводились на супесчаной и среднесуглинистой дерново–подзолистой почве. Предшественник - чистый пар. На супесчаной почве влажность составляла 13,5%, твердость – 1,75 МПа, плотность в слое 0-0,1 м – 1,38 г·см$^{-3}$, гребнистость – 28 мм; на суглинке – влажность – 15%, твердость – 0,9 МПа, плотность – 0,95 г·см$^{-3}$ и гребнистость – 56 мм.

Агротехническая оценка показала, что агрегат устойчиво выполняет технологический процесс предпосевной обработки почвы и посева, обеспечивая требуемую глубину обработки почвы и заделки семян. При этом на супеси содержание фракции почвы до 25 мм равно 97%, на суглинке – 92%. Гребнистость поверхности поля на супесчаной почве составила 12 мм, на суглинистой – 18 мм, плотность в слое 0-0,1 м соответственно - 1,28 г·см$^{-3}$ и 1,22 г·см$^{-3}$.

*Рисунок 4. Опытный образец почвообрабатывающе-посевного агрегата АППН-2,1*

Вне зависимости от типа почвы с ростом скорости средняя глубина заделки семян уменьшается на 5-7 мм, при этом её среднее квадратическое отклонение на среднесуглинистой почве находится в пределах 4 мм, коэффициент вариации $v$ – 8-10%; на супесчаной почве $\sigma$ возрастает с 2 до 4 мм, а $v$ – с 5 до 13%. Семян на поверхности почвы не наблюдалось.

## Методика исследовании

Для сравнения эффективности различных способов основной и предпосевной обработки почвы на агрофизические показатели почвенного плодородия и урожайность возделываемых культур был заложен полевой опыт. В ходе опыта использование почвообрабатывающего агрегата КПА-2,2 сравнивалось со вспашкой

на 18-20 см плугом ПЛН-3-35 при следующих операциях предпосевной обработки почвы и посева: весеннее боронование зяби – бороны БЗСС-1,0; культивация – культиваторы КПС-4 и КБМ-4,2, посев – сеялка СЗ-3,6. В качестве одного из вариантов использован почвообрабатывающе-посевной агрегат АППН-2,1.

Осенью 2011 г. в первой закладке высеяна озимая рожь, весной 2012 г. во второй закладке – викоовсяная смесь на зеленый корм. Для посева использовали районированные сорта: озимая рожь Вятка 2, овес Сельма, вика Льговская-28. Повторность опыта четырехкратная, размещение вариантов рендомизированное. Площадь делянок 4·8=32м$^2$, учетная площадь 17,6 м$^2$. Общее число делянок – 72. Почва опытного участка – дерново-подзолистая среднесуглинистая. Агрохимические показатели почвы: pH (солевое) – 5,0; гидролитическая кислотность – 3,6; содержание $P_20_5$ – 140-180 мг и $K_20$ – 150-200 мг на 1 кг почвы, гумуса – 1,7%. Удобрения вносили под культуры севооборота в дозе $N_{45}P_{45}K_{45}$.

## Результаты исследований

Анализ влажности почвы показал, что как основные, так и предпосевные обработки почвы не оказали существенного влияния на этот показатель в фазу кущения озимой ржи. Влажность в слое 0-10 см была в пределах 15,22-17,23%, в слое 10-20 см – 17,10-18,41%. Отмечалось лучшее сохранение влаги весной в вариантах с плоскорезной обработкой (табл. 3).

Таблица 3
*Влажность почвы по слоям, (%)*

| Основная обработка | Предпосевная обработка | Влажность почвы | | | |
|---|---|---|---|---|---|
| | | Озимая рожь (фаза кущения) | | Викоовсяная смесь (фаза всходов) | |
| | | 0-10 см | 10-20 см | 0-10 см | 10-20 см |
| ПЛН-3-35 | КПС-4,0 | 15,60 | 18,03 | 15,88 | 17,58 |
| | КБМ-4,2 | 15,03 | 17,07 | 16,14 | 17,29 |
| | АППН-2,1 | 15,22 | 17,06 | 15,22 | 17,10 |
| КПА-2,2 | КПС-4,0 | 14,87 | 16,39 | 17,23 | 18,35 |
| | КБМ-4,2 | 14,42 | 14,98 | 16,19 | 17,73 |
| | АППН-2,1 | 14,66 | 16,15 | 17,08 | 18,41 |

В посевах викоовсяного пара влажность почвы в фазу всходов в слое 0-10 см не имела достоверных различий, в слое 10-20 см достоверно снижалась на 0,96 и 0,97% при культивации КБМ-4,2 и обработке АППН-2,1 по фону вспашки, по фону плоскорезной обработки – на 1,41% при культивации КБМ-4,2 по сравнению с культивацией КПС-4 ($НСР_{05}B$ = 0,63).

Плотность почвы после ранневесеннего боронования озимой ржи различий по вариантам обработки не имела и была в слое 0-10 см в пределах 1,17-1,25 г·см$^{-3}$, в слое 10-20 см – 1,21-1,32 г·см$^{-3}$ (табл. 4).

Плотность почвы после посева викоовсяной смеси различий по вариантам обработки также не имела. Все агрегаты создавали в слое 0-10 см рыхлое состояние

1,10-1,20 г·см$^{-3}$ с наименьшей плотностью в контроле КПС-4,0 по фону вспашки. В нижнем слое 10-20 см различий также не было, но все предпосевные обработки способствовали уплотнению этого слоя почвы до 1,25-1,32 г·см$^{-3}$.

Таблица 4
*Плотность почвы по слоям, г·см$^{-3}$*

| Основная обработка | Предпосевная обработка | Плотность почвы, (г·см$^{-3}$) | | | |
|---|---|---|---|---|---|
| | | Озимая рожь (фаза кущения) | | Викоовсяная смесь (фаза всходов) | |
| | | 0-10 см | 10-20 см | 0-10 см | 10-20 см |
| ПЛН-3-35 | КПС-4,0 | 1,17 | 1,21 | 1,10 | 1,28 |
| | КБМ-4,2 | 1,19 | 1,22 | 1,15 | 1,25 |
| | АППН-2,1 | 1,20 | 1,26 | 1,14 | 1,28 |
| КПА-2,2 | КПС-4,0 | 1,17 | 1,26 | 1,17 | 1,28 |
| | КБМ-4,2 | 1,19 | 1,25 | 1,20 | 1,32 |
| | АППН-2,1 | 1,25 | 1,32 | 1,19 | 1,30 |

Запасы продуктивной влаги (табл. 5) в посевах ржи в слое почвы 0-10 см были выше на 1,5 мм по плоскорезной обработке, чем по вспашке ($НСР_{05}$А=0,51).

Таблица 5
*Запасы продуктивной влаги в почве (фаза кущения),(мм)*

| Основная обработка (А) | Предпосевная обработка (В) | Озимая рожь (фаза кущения) | | Викоовсяная смесь (фаза всходов) | |
|---|---|---|---|---|---|
| | | 0-10 см | 10-20 см | 0-10 см | 10-20 см |
| ПЛН-3-35 | КПС-4,0 | 12,13 | 13,78 | 11,04 | 14,75 |
| | КБМ-4,2 | 12,74 | 14,26 | 10,94 | 14,50 |
| | АППН-2,1 | 11,66 | 13,49 | 11,11 | 14,92 |
| КПА-2,2 | КПС-4,0 | 13,74 | 16,15 | 10,91 | 13,88 |
| | КБМ-4,2 | 12,78 | 15,27 | 11,66 | 12,98 |
| | АППН-2,1 | 14,52 | 17,08 | 10,91 | 14,40 |

В слое 10-20 см запасы влаги также увеличивались по плоскорезной обработке на 2,3 мм, но существенной разности не обнаружено.

Запасы продуктивной влаги в начале вегетации викоовсяного пара не зависели от способов основной и предпосевной обработки почвы.

Агрономически ценной структурой почвы считается комковато-зернистая структура с размером агрегатов от 0,25 до10 мм, обладающая пористостью, механической прочностью и водопрочностью. Сочетание вспашки с агрегатом АППН-2,1 способствовало созданию лучшей почвенной структуры (табл. 6) по содержанию агрономически ценных агрегатов (76,6%) и коэффициенту структурности (3,3). В среднем же основные показатели структурного состояния почвы лучше по предпосевным обработкам, идущим по основной плоскорезной обработке.

Таблица 6
*Структурное состояние почвы 0-10 см (викоовсяная смесь)*

| Основная обработка | Предпосевная обработка | Содержание агрегатов 0,25-10 мм, (%) | Водопрочность структуры, (%) | Коэффициент структурности |
|---|---|---|---|---|
| ПЛН-3-35 | КПС-4,0 | 62,0 | 63,0 | 1,6 |
| | КБМ-4,2 | 65,2 | 59,4 | 1,9 |
| | АППН-2,1 | 76,6 | 55,6 | 3,3 |
| КПА-2,2 | КПС-4,0 | 70,0 | 63,8 | 2,3 |
| | КБМ-4,2 | 69,8 | 63,5 | 2,3 |
| | АППН-2,1 | 71,0 | 59,6 | 2,4 |

Анализ энергетической эффективности показал, что замена вспашки на 20-22 см (1023 МДж·га$^{-1}$) плоскорезной обработкой агрегатом КПА-2,2 на 14-16 см (689 МДж·га$^{-1}$) позволяет экономить до 334 МДж·га$^{-1}$ или до 32,6% энергетических затрат на основную обработку почвы. На культивацию культиватором КБМ-4,2 тратится на 5,5% меньше энергии, чем на контроле – культивации КПС-4. При этом в вариантах с культивацией КПС-4 и КБМ-4,2 на внесение минеральных удобрений затраты энергии составляют 227 МДж·га$^{-1}$, на посев сельскохозяйственных культур – 294 МДж·га$^{-1}$. Суммарные затраты на внесение удобрений, культивацию и посев по варианту с культиватором КПС-4 составят 800 МДж·га$^{-1}$, по варианту с культиватором КБМ-4,2 – 785 МДж·га$^{-1}$. По варианту с комбинированным агрегатом АППН-2,1, который одновременно выполняет операции по обработке почвы, внесению удобрений, посеву и послепосевному прикатыванию затраты энергии равны 434 МДж·га$^{-1}$ (на 45,7% меньше контроля). Приведенные значения остаются постоянными, меняется только коэффициент энергетической эффективности, который напрямую зависит от полученного урожая.

Урожайность озимой ржи в среднем по вспашке составила 2,34 т·га$^{-1}$, по плоскорезной обработке – 2,52 т·га$^{-1}$ (табл. 7).

Посев почвообрабатывающее-посевным агрегатом дает прибавку урожая 0,88 т·га$^{-1}$ по сравнению с культивацией КПС-4,0 по фону вспашки ($НСР_{05}$АВ=0,8). При плоскорезной обработке прибавка урожая 0,82 т·га$^{-1}$ получена по культивации КПС-4 по сравнению с КБМ-4,2. Средняя урожайность викоовсяной смеси составила по вспашке 4,77 т·га$^{-1}$ сухого вещества (СВ), по плоскорезной обработке – 5,03 т·га$^{-1}$ СВ. На вариантах с применением АППН-2,1 урожайность сухого вещества на 0,75 т·га$^{-1}$ выше, чем на вариантах с КБМ-4,2 ($НСР_{05}$В= 0,39).

Коэффициент энергетической эффективности по технологии возделывания озимой ржи с плоскорезной обработкой в среднем составил 2,14, что на 12,6% выше, чем по вспашке (1,87). При возделывании викоовсяной смеси этот показатель был примерно на одном уровне.

Наибольший коэффициент энергетической эффективности получен для озимой ржи по варианту плоскорезная обработка + культивация КБМ-4,2 – 2,21; для викоовсяной смеси – вспашка + АППН-2,1 – 2,85.

Таблица 7
*Энергетическая эффективность возделывания культур*

| Основная обработка | Предпосевная обработка | Урожайность, (т·га$^{-1}$) | | Получено энергии, (МДж·га$^{-1}$) | | Полные затраты, (МДж·га$^{-1}$) | | К.Э.Э. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Озимая рожь | Вико-овсяная смесь | Озимая рожь | Вико-овсяная смесь | Озимая рожь | Вико-овсяная смесь | Озимая рожь | Вико-овсяная смесь |
| ПЛН-3-35 | КПС-4,0 | 2,01 | 4,52 | 33,7 | 45,6 | 19,2 | 19,4 | 1,76 | 2,35 |
| | КБМ-4,2 | 2,09 | 4,86 | 35,0 | 49,1 | 19,2 | 19,5 | 1,83 | 2,52 |
| | АППН-2,1 | 2,30 | 5,27 | 38,5 | 53,2 | 19,0 | 18,7 | 2,02 | 2,85 |
| КПА-2,2 | КПС-4,0 | 2,32 | 4,78 | 38,9 | 48,3 | 18,8 | 19,1 | 2,07 | 2,53 |
| | КБМ-4,2 | 2,50 | 4,32 | 41,9 | 43,6 | 18,9 | 19,0 | 2,21 | 2,30 |
| | АППН-2,1 | 2,39 | 4,87 | 40,0 | 49,2 | 18,7 | 18,3 | 2,14 | 2,69 |

## Выводы

1. Разработанные комбинированные агрегаты позволяют проводить основную и предпосевную обработку почвы и посев согласно агротехнических требований.
2. Применение комбинированных агрегатов КПА-2,2 и АППН-2,1 позволяет поддерживать оптимальные агрофизические свойства почвы. Использование для посева агрегата АППН-2,1 повышает урожайность озимой ржи и смеси вика +овёс на 0,8 и 0,39 т·га$^{-1}$ в сравнении с общепринятой обработкой почвы и посева. Экономия энергозатрат при применении агрегата для основной обработки почвы составляет 32,6%, при использовании почвообрабатывающе-посевного агрегата – 45,7%.

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# CHARAKTERYSTYKA I EFEKTYWNOŚĆ PRACY AGREGATU DO BEZORKOWEJ UPRAWY GLEBY I AGREGATU UPRAWOWO-SIEWNEGO W WARUNKACH WSCHODNIEJ EUROPEJSKIEJ CZĘŚCI ROSJI

**Streszczenie.** W artykule zamieszczono charakterystyki techniczne narzędzia do podstawowej i agregatu do przedsiewnej uprawy gleby i siewu: kombinowanego agregatu do podstawowej bezorkowej uprawy gleby, agregatu uprawowo-siewnego. Zamieszczono wyniki badań nad efektywnością ich zastosowania w warunkach glebowo-klimatycznych północnego wschodu europejskiej części Rosji. Analiza właściwości agrofizycznych gleby wykazała, że wilgotność bezwzględna gleby w warstwie 0-10 cm nie zależała od sposobu uprawy podstawowej i przedsiewnej, natomiast w warstwie 10-20 cm stwierdzono obniżenie wilgotności gleby o 0,9-1,4% po kultywatorze KBM-4,2 i uprawie agregatem APPN-2,1 ($LSD_{05}$=0,63). Wszystkie badane agregaty zapewniały optymalną gęstość warstwy uprawnej gleby darniowo-bielicowej w zakresie 1,1-1,3 g·cm$^{-3}$. Zasobność wodna gleby w uprawie żyta ozimego w uprawie bezorkowej agregatem KPA-2,2 była wyższa o 1,5 mm w porównaniu z uprawą po orce ($LSD_{05}$=0,51). W uprawie mieszanki wyki z owsem różnic nie stwierdzono. Bezorkową uprawę gleby charakteryzowały również lepsze wartości wskaźników składu granulometrycznego w porównaniu z polem po orce. Energochłonność uprawy bezorkowej była o 334 MJ·ha$^{-1}$ (32,6%) mniejsza w porównaniu z orką. Zastosowanie agregatu uprawowo-siewnego APPN-2,1 pozwoliło obniżyć nakłady energetyczne o 366 MJ·ha$^{-1}$ (45,7%) w porównaniu z sumarycznymi nakładami na kultywację KPS-4,0, nawożenie i siew. Siew agregatem APPN-2,1 wpłynął na zwiększenie plonu żyta ozimego o 0,88 t·ha$^{-1}$ w porównaniu z kultywacją KPS-4,0 i orką ($LSD_{05}$AB=0,8). W warunkach z zastosowaniem APPN-2,1 plon suchej masy wyki i owsa był wyższy o 0,75 t·ha$^{-1}$ w porównaniu z wariantami z KBM-4,2 ($LSD_{05}$B=0,39).

**Słowa kluczowe**: maszyna rolnicza, narzędzie uprawowe, kultywator, głębosz, siewnik

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# PROSPECTS OF SOLAR ENERGY USE IN UKRAINE

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ABSTRACT

The object of the research is to analyze the politics and economics of the solar energy sources in Ukraine. Application of alternative energy sources in Ukraine, especially solar energy, is extremely promising. The adopted strategy of power by 2020 assumes that Ukraine should play an important role. The methods of analysis, comparison and synthesis were used to assess the level of theoretical studies. The analysis of solar energy enabled to get the result of historical research and forecasting functional areas for possible development paths. The advantages and disadvantages of solar energy were posted. Fundamental directions and applied research in Ukraine related to the development of solar energy. The dynamics of the solar industry in Ukraine was posted. Practically in almost all regions of Ukraine, the investment projects aimed at creating plants that run on solar energy are implemented actively. At various stages of implementation in Ukraine there are more than 100 solar power projects with the total capacity of over 1380 MW in all regions of the country.

## Introduction

The main driving mechanism of mankind's scientific and technological progress is energy. At present we get 90% of the energy through the consumption of fossil fuels (oil, coal, gas), the world's reserves of which deplete in this century. It should be noted that the current traditional sources of fuel are actually irreplaceable and extraction and processing of raw materials includes human pressure on the environment. Therefore, the world began to increasingly give preference to renewable energy, especially solar energy. Industry which associated with the use of solar radiation began to develop in the late 20th century and in 2012 the world energy market produced this type of energy industry accounted for almost 2% (fig. 1).

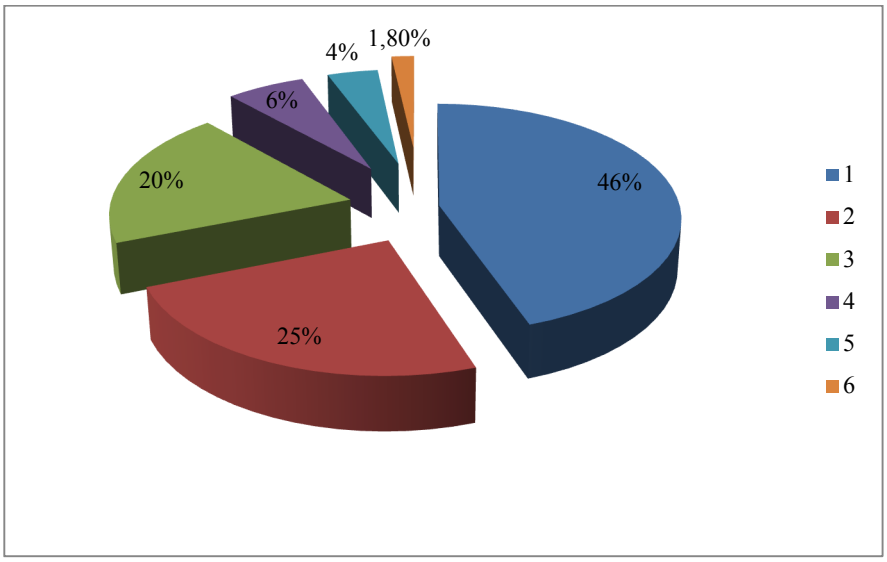



*Figure 1. Distribution of solar energy among traditional sources of energy: 1 – oil; 2 – coal; 3 – natural gas; 4 – nuclear energy; 5 – hydropower; 6 – solar energy (by IEA – World Energy Outlook, 2014)*

By different estimates the processing of solar energy in the world is growing rapidly. For comparison, the growth rate of solar cells' production annually accounted for more than 30% in the period of 1994-2005. Since the 2000s the average annual dynamics of growth was 37%. In 2006-2009, the figure rose more than threefold.

**The object and subject of the research.** The article considers the prospects of the development of solar energy sources in Ukraine.

**The research methods** are analyzing the development of solar energy, including potential sources of solar energy and synthesis of the results of studies in historical and functional areas.

**The objective consists in** the evaluation of the advantages and disadvantages of solar energy and the prospects for its use in Ukraine.

**The main part**

The largest percentage of the world market of solar energy falls on the European market. According to the European photovoltaic industry association, now in Europe more than 3 million buildings are provided with electricity entirely or partially by solar modules (Hybylysko, 2010). In 2010, the total installed solar capacity in Europe grew to 16 GW, but only in the world – nearly 40 GW (fig. 2). Is expected that in 2020 it will reach 430 GW.

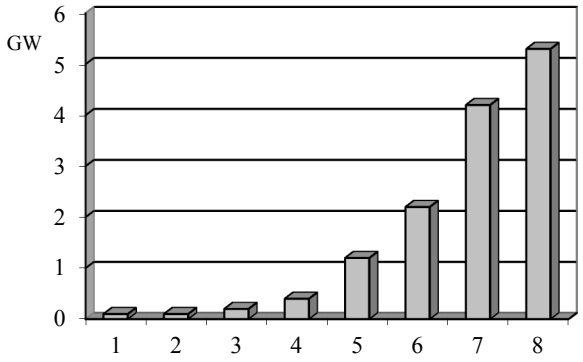
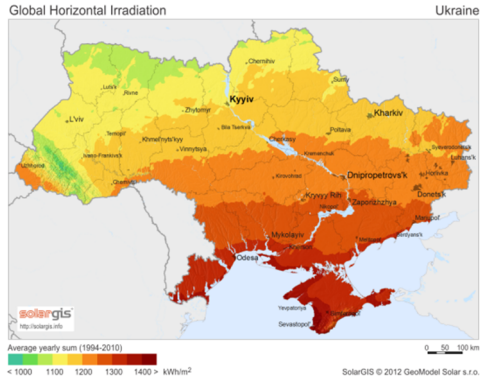



*Figure 2. Distribution of the total capacity of solar power in the world: 1 – France; 2 – India; 3 – China 4 – Korea; 5 – USA; 6 – Japan; 7 – Spain; 8 – Germany (by Hybylysko)*

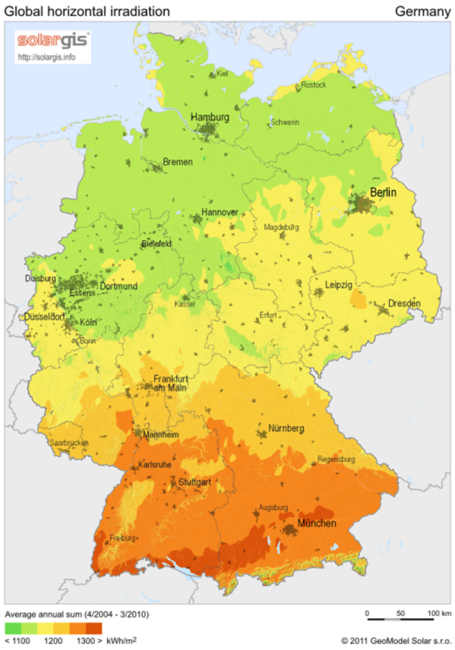
Germany (8,000 MW) and Italy (1500 MW) are the leaders in the consumption of solar energy among the European countries (Scheer, 2002). Leaders in the manufacture of solar modules are Chinese and Taiwanese manufacturers.

The most promising regions of the country for the development of solar energy is the Crimean peninsula and Steppe Ukraine. Today in Ukraine the largest helioelectrostation is in Ohotnikov (Saki District ARC). In the end of 2012 its capacity has reached 80 MW. Dimensions of the helioelectrostation are equivalent to 207 football fields. After the completion the facility is equipped with 360 thousand terrestrial modules. Solar park in Ohotnikov district is the fourth power of PV-installation in the world and third in Europe. Much research is devoted to effectiveness and efficiency of solar energy in Ukraine (Wozniak, 2010; Lyashkov, 2004). Significant results were obtained at the Institute of Semiconductor Physics and Institute of Electrodynamics of NAS of Ukraine, Shevchenko Kyiv National University, Yuriy Fedkovych Chernivtsi National University, National Technical University "KPI", Lviv Polytechnic National University, some industrial enterprises ("Pillar", "Quasar") and other Ukrainian laboratories. The scientific research showed that the cost of solar cells has decreased to 0.5-1.1 euro per watt of power. Thus over the past quarter century it decreased 20 times (as compared to the first sample of 1950-1000!) In principle, it is not so far from the characteristics of the gas and gasoline engines: 0.1-0.15 euros per watt.

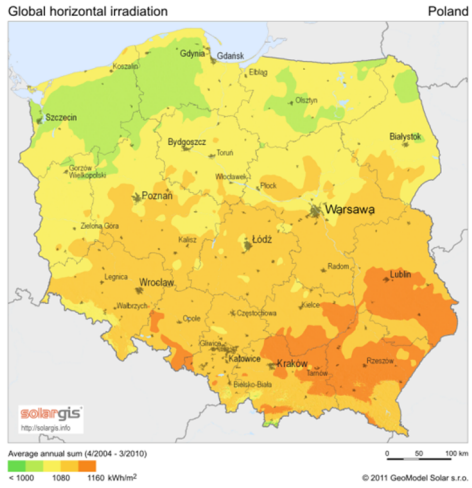
The using in Ukraine of alternative energy sources, primarily solar energy is very promising. The average potential of solar energy in Ukraine (1235 $kWh \cdot m^{-2}$) (fig. 3a) is quite high and much higher than in Germany for example W – 1000 $kWh \cdot m^{-2}$ (fig. 3b) or even in Poland – 1080 $kWh \cdot m^{-2}$ (fig. 3c).




a)




b)




c)

*Figure 3. Annual average potential of solar energy in Ukraine (a) Germany – (b), in Poland (c) (by Stryczewska)*

Therefore, we have good opportunities for effective use of thermal power equipment in Ukraine. The term "effective using" means that a helioplant can work with efficiency of 50% or more, which is 9 months in the southern regions of Ukraine (from March to November), and 7 months – in the northern region (from April to October). Winter performance decreases, but does not disappear.

Consequently in our climate conditions the solar systems work all year round only with variable efficiency. Therefore it is necessary to consider the total annual potential of solar energy in Ukraine.

Regarding the use of solar radiation to produce energy, it is technically permissible potential of solar energy roof housing Ukraine today is 26-37 TWh·year$^{-1}$, which is in cash (at the present value of 1 kWh = 0.05 euros): 1.3-1.8 billion per year. The using and development of alternative energy sources leads to a unique new technology. An example is the use of solar energy in the domestic aviation. Ukraine has its own aircraft engineering industry (State Aircraft Manufacturing Concern "Antonov" and State Concern "Aviation of Ukraine") and inherited third space potential of the former USSR ("National Space Agency of Ukraine"), which in turn is the basis to enter into the life of the pilot project (Pohrebennyk, 2013).

*Advantages of Solar Energy*: Solar energy is inexhaustible and accessible; it is safe for the environment.

*Disadvantages*: Depending on the weather conditions; depending on the day and night; it should be able to accumulate energy; quite expensive is the construction of power plants of this type; it should periodically clean the surface of cells from dirt and dust; atmosphere over power pretty hot.

In the developed countries the strong investments are made in new research and development, the main purpose of these are to reduce the cost of solar energy and new consumption markets is going to form. It suffices to recall the program "Million Solar Roofs" in the United States, "100,000 solar roofs" in Germany and Italy, and others. The governments of the USA, Japan and Western Europe encourage the consumption of solar energy of the population, primarily because this energy is environmentally friendly and saves limited resources of fossil fuels. To do so interest-free long-term loans allot to people for the purchase of solar panels, free servicing carried these (Oksanich, 2010; Oszczak, 2012).

## The areas of the research in Ukraine

### Fundamental research

Through theoretical limitations in converting into useful energy range (about 30%) very large plots of land must take for solar power plants based on solar cells first and second generations. Thus, for plant of capacity 1 GW the plot area of several dozen square kilometers may need (while in the hydropower, at these same facilities, it is necessary to withdraw the use of even much larger land). Construction of the helioelectrostations the same capacity can cause climate change around the station. Thus, usually the solar power built by capacity of 1-2 MW, which is located not too far from direct consumers. Also the individual or mobile installations are constructed. Panels on the large power plants are installed at a height of 1.8-2.5 meters above the ground, so you can use the land under the power plant for agriculture production for example, for grazing. This problem is solved if applicable Balloon solar station. They can be located both on land and at sea and in the air.

The flow of solar energy that falls on the set at the optimum angle photocell depends on the latitude, season and climate and can vary twofold in the populated parts of the land. An atmospheric phenomenon (clouds, mist, dust, etc.) not only change the range and intensity

of incident solar radiation the Earth's surface but also changes the ratio between direct and diffuse radiation, which greatly affects to the certain types of solar power plants, such as hubs or on elements of a wide range of conversion.

**Applied research**

Photoelectrical cells work during day and with low returns in the morning and evening hours. In this case, the peak electricity consumption is in the evening. In addition, the electricity that they produce can vary dramatically and unpredictably change according to the weather. To reduce this dependence the rechargeable batteries (but in this case they are quite expensive) are used on helioelectrostations. It is possible to convert energy into another form, for example, sometimes pumped storage station was build, which can take up quite a large area and it is possible to implement the projects which are based on the concept of hydrogen energy or now it is currently still not cost effective. The problem is resolved by creation of uniform grids that redistribute generated and power consumption. The problem of the specific power solar power dependence on time of a day and the weather conditions is also solved by means of balloon solar plants.

After 30 years the use performance elements gradually decreases. Sometimes the solar cells contain Cadmium. The problem of their disposal appears.

June 3, 2011 the American magazine "Research and development" has published an annual list of the winners of the prestigious competition "100 R & D world," including the development of the Taiwan Textile Research Institute (TTDI) "Fully flexible fabric supercapacitor" in the "Electrical Appliances". This super-capacitor was invented and designed by TTDI team of scientists from the National University "Lviv Polytechnic" (Il'chuk, 2011). The newspaper "Chicago Tribune» (The Chicago Tribune) calls this the "Oscar among inventions."

**Environmental problems**

The level of polution in the solar cells manufacture does not exceed the permitted level for companies' microelectronic industry. PV cells are 30-50 years old. The use of cadmium compounds in the manufacture of certain types of solar cells raises the question of their disposal. Although these items are not very common, in addition to compounds of cadmium on modern production of solar panels they have already found a replacement. Now more and more common thin-film solar cells are containing only about 1% of the total weight of silicon. Due to the low cost of materials, thin-film silicon solar cells are much cheaper, but they are less effective, and most lose their properties. Now more and more active production is developing in other semiconductor materials, particularly in the CIS and CIGS. They can be serious competitors to silicon. So in 2005 the company «Shell» decided to concentrate on producing only the thin film elements and get rid of its business of producing monocrystalline silicon photovoltaic cells.

**Prospects for solar energy**

According to the estimates of the International Energy Agency (IEA) energy which will be produced by solar energy by 2050 could provide 20-25% of the energy demand of man-

kind that is after 40 years solar energy can produce about 9 000 terawatt hours. This will reduce carbon dioxide emissions by 6 billion tons annually.

In 2001 the price of energy, which is obtained by means of solar collectors was $ 0.09 - $ 0.12 per kW·hour$^{-1}$. The USA Department of Energy predicts that to 2015-2020 years the price of energy generated by solar concentrators will drop to $ 0.04-0.05. In Ukraine the "green" tariff for electricity which was generated by private households is relatively high. The households that install installation prior to 1 January 2015 will be eligible to sell electricity at a price of 4.67 €·kWh$^{-1}$ VAT) or about 36.2 cents·kWh$^{-1}$. This compared with Germany, where the "green" tariff is 19.5 cents·kWh$^{-1}$, looks very attractive. In early 2010, the total global capacity of solar thermal energy (solar concentrator plants) reached one gigawatts.

Production facilities only such giants microelectronics, industrial associations as "Quasar", "IRVA" (Kyiv), "graviton" (Chernivtsi), "Hartron" (Kharkiv), "Gamma" and "Elektroavtomatika" (Zaporozhye), "Dnepr" (Kherson), "Positron" (Ivano-Frankivsk) allow full technological cycle of solar cells. Ukraine has highly qualified scientific potential in this area.

More than 100 solar power projects are in all regions of Ukraine which have the total capacity of over 1380 MW at various stages of implementation. In Ukraine the solar stations are also building in addition to local companies the enterprises from Portugal, Germany, France, Austria, Czech Republic and Israel.

Other applications of solar energy are: telecommunications systems and services (repeaters, telemetry); providing power for navigation lights, buoys, traffic signs, road lighting at night; corrosion protection of metal structures and pipelines; remote and not electrified dwellings to power household appliances; in burglar alarm systems; agriculture and arid areas for mining and water supply; creating a network of automatic stations equipped with various sensors for environmental monitoring and so on. Finally, the solar cells play a crucial role in the spacecraft and artificial satellites as power systems on-board equipment (Afonin et al., 2014).

Thus, the use of the alternative energy sources in Ukraine primarily solar energy will benefit undoubtedly. On the other hand, the economy of Ukraine has sufficient capacity for the production of the necessary components and creation of infrastructure of such power. According to the Ministry of Energy and Coal Industry of Ukraine 2013 the alternative energy produced 1,247 billion kilowatt-hours of electricity which is doubled (or over 608,4 million kWh) more than in 2012. In this case the total share of electricity production from RES (renewable energy sources) also doubled – up to 0.64% – down from 0.32% in 2012. In 2013 it was put into operation 539 MW of new capacity of RES. Showed the largest increase of wind and solar energy, as well as the installation of biomass processing.

According to the Energy Strategy of Ukraine to 2020 the share of renewable energy should be 11% of the total energy produced by Ukraine. This corresponds to the commitment of Ukraine to the European Energy Community, of which Ukraine is a party. 11% – is 12 000 MW, of which 6,800 MW would account for a large share of hydro power plants (HPP and PSP) and 5200 MW – the share of small hydropower, wind power, solar power and biomass and biogas. According to the annual commissioning for 500-700 MW of new renewable energy capacity by 2020 Ukraine will meet its obligations.

## Conclusions

Solar power is a cheap, independent source of inexhaustible energy that has great prospects in all areas of industry in Ukraine and the home. The reasons for these are:

– in Ukraine the average potential of solar energy is much higher than in Germany and Poland;
– Ukraine has concentrated 10 percent of the global production of silicon; it can place the country at the leading place in the world with regard to production of silicon solar cells and electronics;
– the Ukrainian manufacturing capabilities allow enterprises to conduct the full technological cycle of solar cells. Ukraine has highly qualified scientific potential in this area;
– creating positive dynamics of solar power capacity – 8.1 MW in 2010 and 746.9 MW in 2013 – said that Ukraine can provide until 2020 up to 11% of electricity from renewable energy sources;
– relatively high "green" electricity tariff favors the investments in Ukraine.

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## PERSPEKTYWY ENERGETYKI SŁONECZNEJ NA UKRAINIE

**Streszczenie.** Celem badań była analiza polityki i gospodarki źródłami energii słonecznej na Ukrainie. Zastosowanie na Ukrainie alternatywnych źródeł energii, w szczególności energii słonecznej, jest bardzo obiecujące. Przyjęta strategia do 2020 roku przewiduje, że Ukraina powinna odgrywać istotną rolę na tym polu. Aby ocenić poziom studiów teoretycznych zastosowano metody analizy, porównania i syntezy. Analiza energii słonecznej pozwoliła uzyskać wynik badań historycznych oraz prognozowanie obszarów funkcjonalnych dla możliwych ścieżek rozwoju. Przedstawiono zalety i wady energii słonecznej oraz kierunki badań podstawowych i stosowanych na Ukrainie związanych z rozwojem energii słonecznej. Praktycznie prawie wszystkie regiony Ukrainy aktywnie realizowały projekty inwestycyjne mające na celu stworzenie elektrowni, które działają w oparciu o energię słoneczną. Na Ukrainie działa ponad 100 projektów energii słonecznej o łącznej mocy mocy ponad 1380 MW we wszystkich regionach kraju.

**Słowa kluczowe**: energia słoneczna, bezpieczeństwo energetyczne

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# THE ACQUISITION AND PROCESSING DATABASE SYSTEM "ANIMAL HOUSING TECHNOLOGIES"

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ABSTRACT

Many initiatives have been taken to reduce the environmental impact of the livestock production for many years. Development and evaluation of innovative animal production technologies require detailed research based on the collected data. The database systems are used for this purpose. The aim of the study was to design and create the acquisition and processing database system "Animal Housing Technologies". The system allows collection, processing, reporting and analysing the data on the livestock production technologies. It is a useful tool for comprehensive evaluation of the technical and technological solutions in the animal production including the animal welfare, environmental protection and energy consumption criteria. It can be helpful in developing modern, innovative technologies of the animal housing, with the principles of sustainable development.

## Introduction

In the recent decades development of livestock production is related to its progressing intensification and specialization. High concentration of production and a high degree of mechanization and automation of the production processes follows from intensification. It is related to housing of farm animals only in the livestock buildings and to a drop in the human labour demand. A specialization means production of one animal species on the industrial scale (Hartung, 2013). On one hand, intensification and concentration of the production ensures profitability but on the other hand it is related to a negative impact on the environment (Szymańska, 2006; Mroczek and Kostecka, 2008). Various types of initiatives, which aim at limiting the environmental threats related to the animal production, have been taken for a long time. The Common Agricultural Policy (CAP) is one of them. As a part of it, minimal requirements of cross-compliance for farms have been developed. Adjusting Polish commodity and agricultural farms to the requirements of cross-compliance is related mainly to balancing of the production and improvement of techniques and technologies of animal housing, which results in the improvement of the production efficiency ensuring at the same time the animal welfare and the work ergonomics. It also allows limitation of the unfavourable impact on the environment (Wójcicki, 2007; Romaniuk et al., 2009). Development and assessment of innovative solutions for livestock produc-

tion technologies, which meet the principles of the cross-compliance, require detailed research based on the collected data (Strzałkowski, 1999; Šařec et al., 2007). For this purpose, the distributed and one-stand IT systems are created. Their task is to collect, process and visualize data (Mueller et al., 2008; Mielcarek, 2013).

The objective of the paper was to design and develop the database acquisition and processing system "Animal Housing Technologies" which enables assessment of technologies taking into consideration the economic and environmental production aspect and the animal welfare.

## The database system

The database system of data acquisition and processing "Animal Housing Technologies" was designed and developed in the Institute of Technology of Life Sciences in Poznan with cooperation of the ZETO company in Katowice [Electronic Calculation Technique Company] as a part of the Multi-annual Programme for 2011-2015 "Standardization and monitoring of the environmental projects, agricultural technique and infra-structural solutions for safety and the sustainable development of agriculture and the rural areas", Measure 4.2. "Standardization of livestock production mechanization, including the environmental protection and animal welfare". The developed system enables collection, processing, reporting and analysis of the data on the livestock production technologies.

## The system characteristics

The data acquisition and processing system "Animal Housing Technologies" is a relational database developed in the server with the data management system SQL. The developed software is a closed application, which uses the internal data record format. It allows stable system operation and limitation of the external unwanted access in the database. When designing a database application, a special attention was paid to the system simplicity and transparency while preserving functionality.

A logical and physical structure may be separated from the system organization. The logical structure is related to the application functioning. The following modules comprise this area:

- the data collection module (entering and saving the inventory and measurement data),
- the data processing module (presenting the collected data and their record in the processed form),
- the data presentation (presenting the recorded and processed data in the form of previously defined lists and reports).

The physical structure is related to the system access. Connecting with the application takes place through the internet browser. All users have an easy access to the system at the same time from any location, maintaining at the same time the integrity and data safety. Due to the secret nature of some information, using the system is possible after previous certification and obtaining access to the private network, where the server is placed with the installed internet website of the application (fig. 1). The users were divided into groups with various entitlements. Each of them has its own login and a password.

Four independent users' groups can be distinguished.

Administrators are the first group of users. They may manage the system and parametrize and configure the basic parameters of the program e.g.: vocabulary lists and individual data sets. The other group comprise employees, which have a possibility to introduce, up-date and preview of the data in the system. The third group consists of the agricultural producers who have access to the data on their business activity. The last group includes e.g. the selected employees of the administration and governmental institutions as well as the scientific institutions. The entitlements of this group allow them only to preview the reports generated in the system (Dokumentacja techniczna, 2013; Dokumentacja użytkownika, 2013).

## The properties of the system

The developed database system has features which ensure its functionality, simplicity of use and correct operation. The management system used for the operation of the data base ensures optimal efficiency. Even, simultaneous use by many users does not result in significant slowing down and the decrease of efficiency and reliability of use. The system enables cooperation with the peripheral devices and other programmes, such as: Microsoft Excel (within transferring and presentation of reports), Adobe Acrobat (within data export).

The following, can be listed among the operated formats:

XML, TXT (a text file including data in the alphanumeric form), CSV (a text file, where values are separated with a comma) and DBF (a database file).

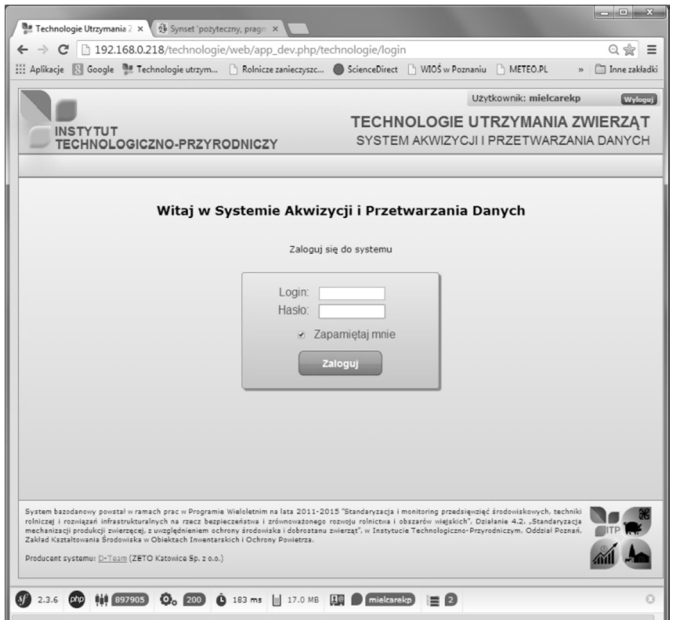


*Figure 1. The login screen to the system*

According to the assumptions, all reports generated in the system are displayed on the screen and printed at request. The system enables control of the data integrity. However, there is a possibility of saving incomplete data and their completion in later time. They are automatically verified on account of essential facts and completeness. The program alarms possible errors in the entered data and their incompleteness (Dokumentacja techniczna, 2013; Dokumentacja użytkownika, 2013).

## The structure of data collection, processing and presentation

In the database system, six basic modules with the following functions have been developed:

1. Users – adding new users and their objects and automatic generation of the users' list and the possibility of their edition.
2. Objects – automatic generation of the list of objects and the possibility of their edition.
3. Questionnaires – the list of questionnaires with the possibility of edition and generation of new questionnaires, adding and edition of questions.
4. Reports – generation of defined reports.
5. Advanced – data export to files.
6. Assistance – instruction of the program operation.

First three modules are used for entering and edition of data in the database system, mainly by users of the *Employee* type. Information, which constitutes the appropriate database, is assigned to the users of the *Producer* type. For each of them, the basic contact data are entered and the possessed O*bjects*, the list of which is in the module *Objects*, are assigned to them. *Object* is meant by a single livestock building, where the animal production is carried out. The building type and the kind of production (the so-called production technology) is selected as a part of the *Object*. 5 types of buildings and 7 production technologies for 3 farm animal species were distinguished (fig. 2). Additionally, data on the buildings location and construction are entered.

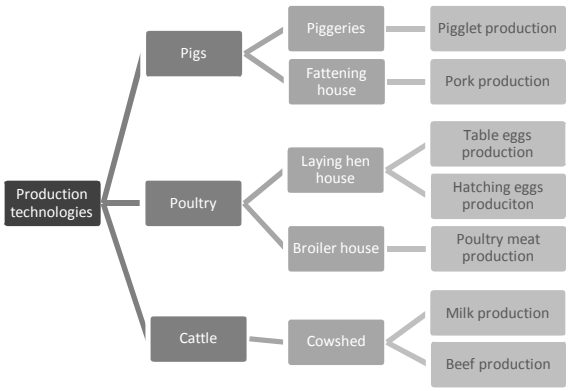


*Figure 2. Production technologies*

For each *Objec*t the *Systems* of: animal housing, ventilation, cooling, lighting, watering, feeding, manure removing, egg collection and milking, related to the production are selected (fig. 3).

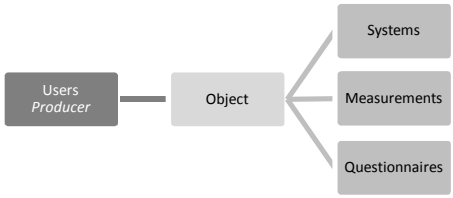


*Figure 3. Data collection modules*

In relation to the S*ystems* selected for the specific *Object* values to the particular properties (represented by attributes) are assigned to them: work time, power and the calorific value. Energy consumption is calculated on this basis (fig.4).


*Figure 4. Table of Systems values*

The Objects also have properties, values of which result from the *Measurements* which were carried out in the buildings. The *Measurements* are marked with a specific moment of time and concern the livestock number, environment and animal welfare. As a part of the research such values as the following are measured: gas pollution concentration, dust pollution concentration and odours concentration as well as air exchange and velocity of air

movement, temperature and relative humidity of air and lighting intensity and the level of noise (fig. 5). Based on the collected measurement data and available methodologies, values of the total gas and dust pollution emission and the momentary odours emission are calculated. In order to compare the objects within the impact on the environment, the emission factors of these pollutions expressed per 1 animal and 1 kilo of animal body mass are determined (PN-EN 13725:2007; PN-EN 12599:2013-04E; Karłowski et al., 2008; Jugowar and Piotrkowski, 2012).


*Figure 5. Form for measurement results*

The animal welfare is assessed based on the questionnaire developed individually for each of the distinguished production technologies. For each *Object* any number of questionnaires may be generated. Questionnaires similarly to the *Measurements* are atrributed to given date. Four categories of questions: animals housing, building equipment and technological systems, micro-climate and animal health safety and hygiene, can be distinguished. Edition of the questionnaires which have been entered to the system in the module *Questionnaires*, as well as from the module level *Objects* is possible. Additionally, the module *Questionnaires* gives an opportunity to correct particular questions and to add new questions within the above-mentioned four categories. The system informs the user on the incomplete questionnaire and does not include it in the generated reports.

The processed data are presented in the module Reports, where the synthetic and detailed result reports are generated. 8 reports were defined in the system:

1. Welfare – histogram - a group list of results of the welfare assessment questionnaires within the selected production technology, divided into four categories of the questionnaire questions; graphical presentation of the distribution of the questionnaire results in the form of a histogram.

2. Energy consumption – histogram – a group list of energy consumption in the selected production technology; a graphical presentation in the form of a histogram.
3. Annual emissions – the list of the annual gas, dust pollution emission and a momentary odour emission for particular *Objects*.
4. Emission factors (animal) – the list of mean values of emission factors per 1 animal for the particular *Objects*.
5. Emission factors (kilo) – the list of mean values of emission factors per 1 kilo of animal body mass for the particular *Objects*.
6. Welfare – the list of results of the questionnaires expressed with percentages for the particular *Objects*.
7. Energy consumption the list of the data on energy consumption of production divided into the Systems for the particular *Objects*.
8. A general report – a synthetic list of the energy consumption results, animal welfare assessment and average emission factors for the particular *Objects*.

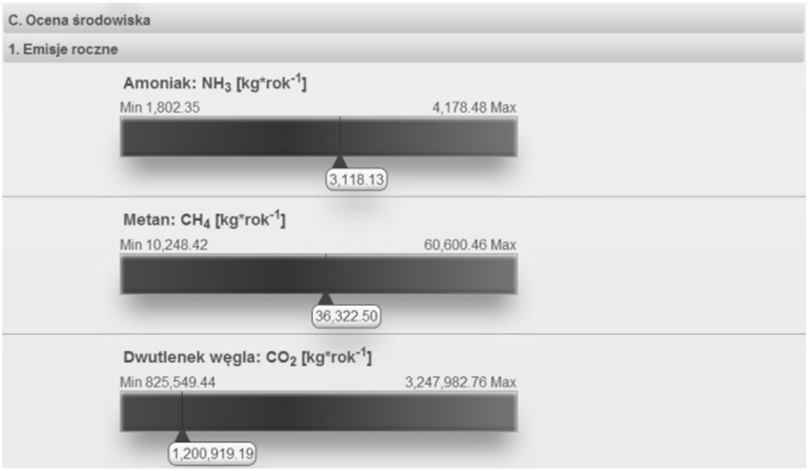


*Figure 6. Fragment of an individual report*

Reports may be filtrated with regard to the production technology, voivodeship and province. Whereas the data included therein may be sorted with regard to the selected parameter. Moreover, the module includes individual reports. They include results of the animal welfare assessment, energy consumption and environmental assessment of the *Object* compared to others within a specific production technology (fig.6). Information on the agricultural producers and the *Objects*, which they possess, are presented in the so-called producer report. It contains the synthetic data and is generated in the module *Users* (fig.7).

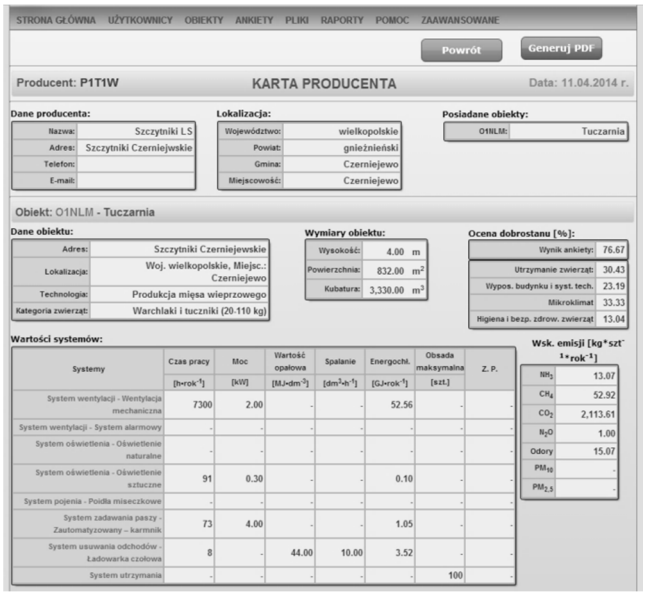


*Figure 7. Producer Report*

The module *Advanced* enables data export to the files, which contain information on the *Systems, Measurements* and *Questionnaires*. The measurement and questionnaires results may be filtrated by entering the searched phrase in the field above the column or by clicking its name. Under the lists there is information on the number of all found positions shown on the website and the number of all websites. The exported files may serve for a starting point for further analysis in the external tools. The module *Assistance* includes the User's Manual of the program and the detailed information on the system function, available for a particular user (Dokumentacja techniczna, 2013; Dokumentacja użytkownika, 2013).

## Conclusion

The knowledge obtained from collection and data analysis by a system may be helpful at developing new, innovative animal housing technologies maintaining the sustainable development principles. In the future it is planned to complement the system with additional modules, which allow a complete assessment of the livestock production impact on the environment, taking into consideration transport, production of feed components and management of natural fertilizers. Development of a methodology, which would allow a total assessment of the animal housing technology is also assumed. It would include three fractional assessments in the following areas: animal welfare, environment and energy consumption.

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# BAZODANOWY SYSTEM AKWIZYCJI I PRZETWARZANIA DANYCH „TECHNOLOGIE UTRZYMANIA ZWIERZĄT”

**Streszczenie.** Od lat podejmowane są inicjatywy mające na celu ograniczanie zagrożeń środowiskowych związanych z produkcją zwierzęcą. Opracowanie i ocena innowacyjnych rozwiązań w zakresie technologii w produkcji zwierzęcej wymaga szczegółowych badań w oparciu o gromadzone dane. Stosowane są do tego dedykowane systemy informatyczne. Celem pracy było zaprojektowanie i wykonanie bazodanowego systemu akwizycji i przetwarzania danych „Technologie Utrzymania Zwierząt” umożliwiającego ocenę technologii biorąc pod uwagę ekonomiczny i środowiskowy aspekt produkcji oraz dobrostan zwierząt. System umożliwia gromadzenie, przetwarzanie, raportowanie i analizę danych, dotyczących technologii produkcji zwierzęcej. Jest on praktycznym narzędziem do oceny rozwiązań technicznych i technologicznych produkcji zwierzęcej, uwzględniającej dobrostan zwierząt, ochronę środowiska oraz energochłonność produkcji. Wiedza ta może być pomocna przy opracowywaniu nowych, innowacyjnych technologii utrzymania zwierząt gospodarskich, z zachowaniem zasad zrównoważonego rozwoju.

**Słowa kluczowe:** system bazodanowy, technologia utrzymania zwierząt, dobrostan, rolnictwo zrównoważone

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# EXPERT SYSTEMS AS A TOOL FOR DECISION SUPPORT IN INTEGRATED PEST MANAGEMENT

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ABSTRACT

An offer of the existing expert systems (ES) for crop production in our country is presented. It was established that the recommendation decision support systems in plant protection are ES-like, since they comprise components typical of ES. The DSS formulate recommendations solving problems concerning justification of protective treatments. Thus such DSS behave similarly to the ES. The availability of the information from the ES in plant protection is still scant in our country. It is necessary to develop new ES for the most important crops. Interpretation of the EU provisions allowed stating the need of presenting the integrated pest management issues in a wider scope of the integrated crop production. The multifaceted scope of these issues calls for a multidisciplinary handling of the ES development: cooperation of agronomists, phytopathologists, plant-protection specialists, meteorologists, economists, agricultural advisers, farmers as well as specialists in databases, software engineering, artificial intelligence, etc.

## Introduction

The Common Agricultural Policy (CAP) of the European Union has been executed in Poland since 2004. The main priority of the CAP is providing the EU citizens with food safety and attaining sustainable development of agriculture with particular attention to the environment. In recent years a lot of attention has been paid to limit excessive use of pesticides in agriculture (Duer et al., 2004).

Pursuant to applicable law, crop protection products must be used according to the integrated pest management principles (Wolny, 2012), which requires specialist knowledge on the biology of pests and the host, environment, crop protection products properties, etc. Using all available pest management methods, especially non-chemical ones, is one of the main principles of the integrated pest management (IPM). The non-chemical methods do not completely eliminate the population of pests, but they limit their development and favourably influence the biological balance, which favours natural mechanisms of protection against pests (Wolny, 2012; Zaliwski, 2013a). Another important principle is a rational

selection of the crop protection product preceded by a detailed analysis of the crop condition. The analysis should include the variety susceptibility, growth stage of plant and pest, the size of the infection source, atmospheric conditions, properties of the protection product, rotation of products with various action mechanisms, and occurrence of pest forms resistant to particular crop protection products (Nieróbca et al., 2010; Zaliwski 2013a). The need to include so many factors makes the integrated pest management difficult to be used by specialists, especially if several diseases infest the crop simultaneously (Urnańska et al., 2010; Zaliwski, 2013a). In many European countries, including Poland, IT tools are more and more often used for decision support in crop protection (Lipa, 1999; Hosstgaart and Wolny, 2002; Mahamana et al., 2003; Thomson and Willoughby, 2004, Kozlowski et al., 2011). Complex systems in the form of interactive computer programs, which use databases and algorithms, are created. Also, systems for many users which transfer information on the need to perform a treatment directly to a farmer via the Internet and SMS are very popular (Hosstgaart and Wolny, 2002; Nierobca, 2009). Nowadays, dynamically developing neural processing techniques create new analytical opportunities. Artificial neural networks can analyse not only the numerical data collections which come e.g. from experimental research, but also fuzzy sets, which is characteristic of a human brain. The research carried out on the use of neural techniques in agricultural practice shows great possibilities for their use in the integrated pest management (Boniecki, 2007).

The objective of the paper is to describe the offers of expert systems for decision support in integrated pest management and to indicate possible trends of their development.

**Legal basis for integrated pest management**

Issues concerning the pest management were regulated in detail by Directive 2009/128/EC of the European Parliament and of the Council of 21st October 2009, which sets forth the frames for the community operation for the sustainable use of pesticides, and the Regulation of the European Parliament and of the Council (EC) no. 1107/2009 of 21st October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 779/117/EEC and 91/414/EEC. The Member States of the European Union are obliged to introduce the integrated pest management not later than on the 1st January 2014 (Wolny, 2012). Regulation 1107/2009 EC (art. 1 and 55 and enclosure III) determine general guidelines for using crop protection products, according to the integrated pest management principles.

According to the EU documentation, general principles of IPM are as follows:

1. Non-chemical methods are favoured over chemical methods if they ensure a sufficient protection against pests.
2. The non-chemical methods except for biological, physical and mechanical protection treatments include:
   a) the use of crop rotation,
   b) the use of relevant agrotechnology,
   c) the use of resistant or tolerant varieties as well as qualified seeds and planting stock pursuant to the provisions on seed production,
   d) the use of the sustainable fertilization, liming, irrigation and melioration,
   e) the use of substances which prevent introduction of harmful organisms,
   f) creation of conditions which favour beneficial organisms and their protection,

g) preventing the spread of harmful organisms through the use of phytosanitary means, such as regular cleaning of cultivation machines and tools,
h) the use of crop protection products in a way which limits the risk of harmful organisms' resistance.

The above principles show that full implementation of the IPM is not possible without placing it in the context of the integrated crop production management.

**The expert system in plant protection**

The expert system (ES) is generally a computer information system which uses the expert knowledge for solving complex problems within a narrow field with a result not worse than one reached by a human expert (Mulawka, 1996; Turban et al., 2010). Basic elements of the expert system are as follows (Boniecki, 2007):

1. Knowledge base, which includes knowledge necessary to solve problems.
2. An inference engine (inference means determination of new facts from the knowledge base and the set of initial facts, declared by the expert system user).

Except for those two basic elements in the ES there are auxiliary elements:

1. Permanent and variable database.
2. The system which explains the strategy of the inference leading to a solution.
3. The knowledge base editor.
4. The user interface.

In the early expert systems "if-then" rules were used for storing knowledge. Second generation ESs combine various methods of knowledge representation and inference, e.g. "if-then" rules with fuzzy logic, neural networks or genetic algorithms (Turban et al., 2010).

If the solutions provided by the ES are designed for decision support, then it becomes a decision support system. And reversely, a DSS may integrate the results obtained from many ESs or include only some components of the ES in its architecture. The use of ESs for decision support is limited to specific problems and is preconditioned by the following assumptions (Kisielnicki and Sroka, 2005):

– decision must depend on the well defined set of variables,
– values assumed by these variables must be known,
– the impact of particular variables on the decision must be known,
– the problem must have solutions, which may be defined at the beginning,
– the inference logic is determined in advance,
– the expert is able to articulate the manner of solving the problem.

In the ES for the integrated pest management, the knowledge base includes practical knowledge acquired as a result of long-term experience and the results of the most recent research. It should also include the applicable law. Construction of such a system requires the cooperation of integrated protection experts and of modelling and IT specialists. In the integrated pest management, the ES in a "pruned" form may be used for decision support, where, through the interface, the user usually has an access only to the solutions of the problem provided in the form of recommendations. The system which explains the inference strategy is omitted and only administrators use the knowledge base. The ESs operating

in the integrated pest management may be defined as open expert systems: they are supplied with the current weather data processed by the advanced mathematical models and rules, which constitute their knowledge base. In plant protection, mathematical models constitute a very valuable tool for determination of recommendations, since, due to the mathematical description of decision options and their results, the selection of the optimal option is possible from among a great number of choices. That usually exceeds the skills of an expert on account of the time limit. These systems, however, require thorough hand-on experience to get acquainted with the principles of their operation. Therefore, simplicity – easy operation and interpretation of results – is the main principle in designing agricultural ES. The implementation and maintenance of the system and its further development require constant inflow of current data, improvement and development of new models, modernization of software, etc. Success in making the system popular depends on the relevant advertising and training (Skwarcz, 2009; Zaliwski, 2013b).

**Deployment of expert systems in practice**

The rules of integrated pest management are successfully implemented in horticultural crops and orchards, particularly those under cover. In the nineties, which was the initial period of IPM implementation, human expert knowledge was mainly used. At present, more and more often meteorological DSSs equipped with components typical of expert systems, as well as actual ESs, are used. The system of early signalling in the protection of apple orchards against apple tree scab *Venturia inaequalis* is an example of a meteorological DSS intended for on-farm operation (Doruchowski, 2005). An algorithm which determines the probability of infection and the date of a preventive anti-fungi treatment is based on the criteria of the modified Mill's table. It includes air temperature and humidity, precipitation, and the time of leaf moistening. Another system "SadEkspert" includes almost all fruit tree varieties and enables recognition of approx. 120 of the most important pests. They are presented in the form of pictures, and the database of the program contains over 70 products against pests and diseases (Boniecki, 2007).

For crops under cover, where environment may be controlled much better, special guidelines for the integrated pest management were developed. They allow efficient reduction of pests with simultaneous sustainable use of pesticides. The guidelines may be easily implemented due to such expert systems as ES "Integrated cultivation of tomato under cover", which was developed at the Institute of Horticulture (Adamicki et al., 2013). This system, among few others in Poland, was made available on the Internet for free-of-charge use. It enables the determination of the causes of the observed disorders with regard to the growth and development of the tomato plant caused by non-infectious agents, as well as the causes of damages to plants by fungi, bacteria, virus diseases and pests. The user session starts with a selection of the key, which enables determination of the above-mentioned agents. Using the key comes down to answering either "Yes" or "No". After the agent has been recognized, the user can read a description and look at the pictures of particular disorders or damages in order to confirm the diagnosis and recommendations for prevention and control of the observed irregularities.

Another ES is designed for recognizing beetroot pests in the vegetation period and enables the user to determine a suitable method of their control. Decision assumptions were developed here in the form of rules and facts and a photographic knowledge was made

available in the multimedia form: pictures, sounds and film sequences. The user carries out a dialogue with the system. The system may connect with external modules to extend its repertoire of the presented information. For groups specializing in vegetable growing, the Internet is an important source of obtaining and transferring agricultural information (Cupiał, 2010).

For large area crops an advisory system "Rzepinfo" was developed. It enables complex protection of the winter rapeseed plantation (Kozłowski and Weres, 2007). Rzepinfo may provide information on the varieties of winter rapeseed, seed dressing, pests and diseases, which cause the greatest damage, crop protection products, etc. It supports identification of pests based on their morphological structure and diseases based on characteristic damages to plants, enables selection of varieties, crop protection products and supports planning of protection treatments. For Rzepinfo system, fast identification methods with regard to pest and diseases of winter rapeseed were developed, using decision trees. They do not require specialist knowledge.

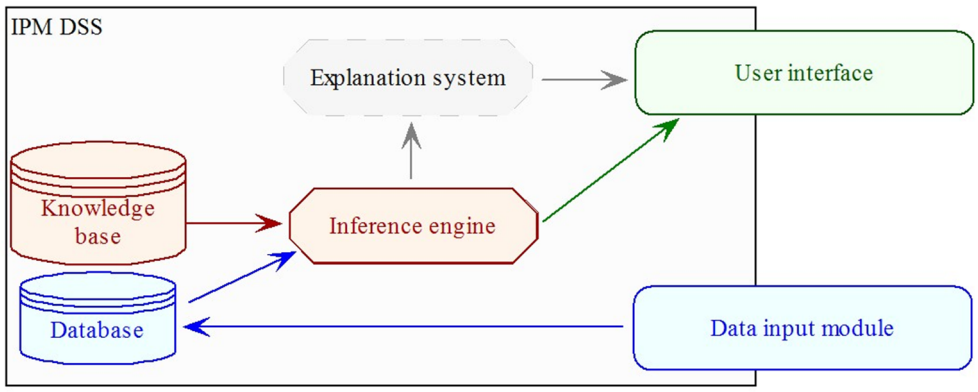



*Figure 1. Architecture of the Internet integrated pest management decision support system (IPM DSS)*

"The Internet integrated pest management decision support system" (IPM DSS) is an example of the DSS which uses almost all components of the expert system except for the explanation system (fig. 1). Work on the system development has been initialized at IUNG in Puławy in 2001 in cooperation with the Danish Institute of Agricultural Sciences, which provided prototypes of disease models (Hosstgaart and Wolny, 2002). Moreover, the following institutes participated in the project: IOR [Institute of Plant Protection] in Poznań as well as IHAR [Plant Breeding and Acclimatization Institute] in Radzików and Bonin, and it was supported by PIORiN [State Inspection of Plant Protection and Seed Science] in Warsaw, LODR [Lublin Agricultural Advisory Centre] in Końskowola and IMGW [Institute of Meteorology and Water Management] in Poznań. The cooperation resulted in the development of the Polish version of the system (components concerning cereals and potato protection) and its verification in Polish conditions (Wolny et al., 2003; Horoszkiewicz-Janka et al., 2005). The main assumption of the IPM DSS (2013) is a precise use of economic thresholds in the models of diseases in order to generate recommendations concerning the

need to carry out a treatment. Economic thresholds were verified in field experiments in various environmental conditions for various diseases (Horoszkiewicz-Janka et al., 2005; Wolny et al., 2005). Moreover, the system enables an interactive access to information on varieties and crop protection products, included in the databases. Figure 2 presents the sequence of analyses in the system.

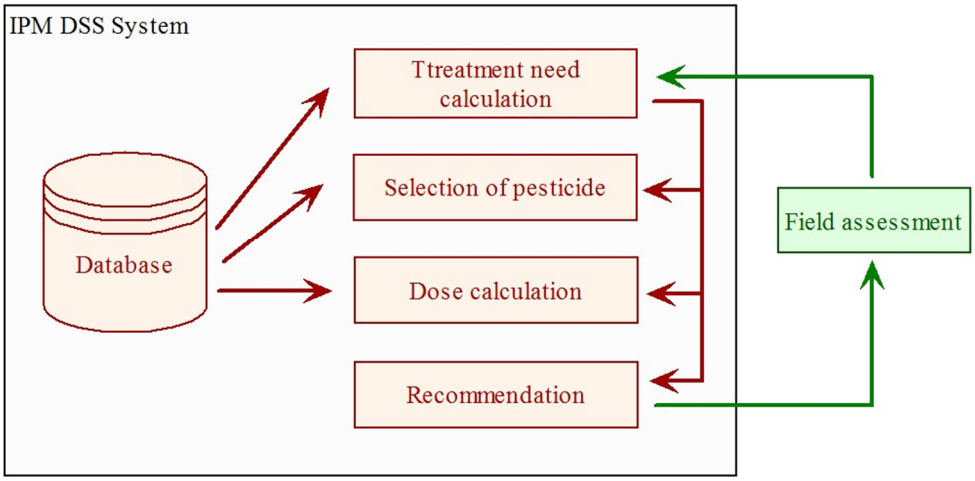
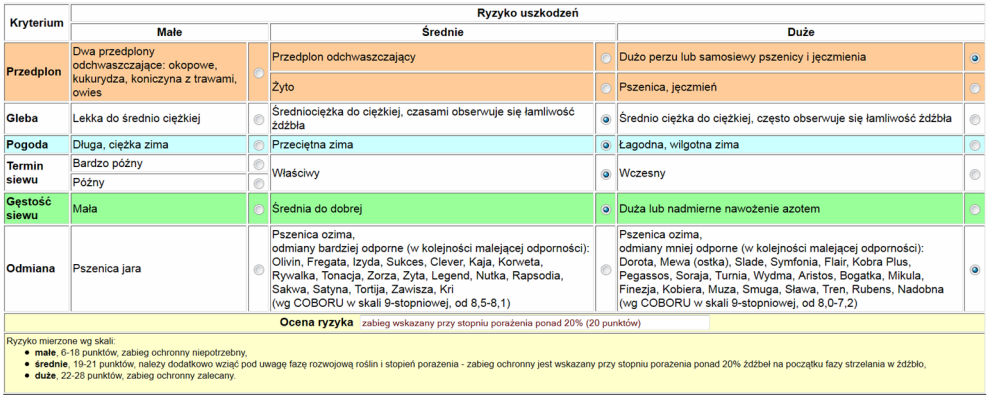



*Figure 2. The sequence of operations performed in the Internet Pest Management Decision Support System*

The most important elements included in the IPM DSS are:
- growth stage of cereals (acc. to Zadok),
- infection degree (number of plants with symptoms of infection expressed in %),
- variety resistance to disease,
- weather conditions,
- effectiveness of pesticides.

For determination of the date of performing the first treatment against potato late blight, the IPM DSS includes the internet application which implements the "Negative prognosis" model. The system generates daily and accumulated risk values, compiled in a table from the day of potato emergence to the day of simulation. Operation of the application consists in the selection of two parameters: the date of potato emergence and the locality of the meteorological station closest to the potato field.

The webpages of the IUNG-PIB [Institute of Soil Science and Plant Cultivation – State Research Institute] include also models for determination of the need to carry out a protective treatment against eyespot and septoria of winter wheat (Zaliwski and Nieróbca, 2007; Zaliwski and Nieróbca, 2010). Recommendations concerning the protection treatment depend on the calculated risk of crop damage, representing a resultant impact of various factors (fig. 3). The risk of damage is measured against the scale of three values: small, average and high. In these models and in all models of the IPM DSS, representation of knowledge with the use of rules "if-then" was used.



| Kryterium | Ryzyko uszkodzeń | | |
|---|---|---|---|
| | Małe | Średnie | Duże |
| Przedplon | Dwa przedplony odchwaszczające: okopowe, kukurydza, koniczyna z trawami, owies | Przedplon odchwaszczający | Dużo perzu lub samosiewy pszenicy i jęczmienia |
| | | Żyto | Pszenica, jęczmień |
| Gleba | Lekka do średnio ciężkiej | Średniociężka do ciężkiej, czasami obserwuje się łamliwość źdźbła | Średnio ciężka do ciężkiej, często obserwuje się łamliwość źdźbła |
| Pogoda | Długa, ciężka zima | Przeciętna zima | Łagodna, wilgotna zima |
| Termin siewu | Bardzo późny | Właściwy | Wczesny |
| | Późny | | |
| Gęstość siewu | Mała | Średnia do dobrej | Duża lub nadmierne nawożenie azotem |
| Odmiana | Pszenica jara | Pszenica ozima, odmiany bardziej odporne (w kolejności malejącej odporności): Olivin, Fregata, Izyda, Sukces, Clever, Kaja, Korweta, Rywalka, Tonacja, Zorza, Zyta, Legend, Nutka, Rapsodia, Sakwa, Satyna, Tortija, Zawisza, Kri (wg COBORU w skali 9-stopniowej, od 8,5-8,1) | Pszenica ozima, odmiany mniej odporne (w kolejności malejącej odporności): Dorota, Mewa (ostka), Slade, Symfonia, Flair, Kobra Plus, Pegassos, Soraja, Turnia, Wydma, Aristos, Bogatka, Mikula, Finezja, Kobiera, Muza, Smuga, Sława, Tren, Rubens, Nadobna (wg COBORU w skali 9-stopniowej, od 8,0-7,2) |
| Ocena ryzyka | zabieg wskazany przy stopniu porażenia ponad 20% (20 punktów) | | |

Ryzyko mierzone wg skali:
- **małe**, 6-18 punktów, zabieg ochronny niepotrzebny,
- **średnie**, 19-21 punktów, należy dodatkowo wziąć pod uwagę fazę rozwojową roślin i stopień porażenia - zabieg ochronny jest wskazany przy stopniu porażenia ponad 20% źdźbeł na początku fazy strzelania w źdźbło,
- **duże**, 22-28 punktów, zabieg ochronny zalecany.

*Figure 3. Interactive application to assess the risk of Pseudocercosporella herpotrichoides infection (www.dss.iung.pulawy.pl/Documents/ior/pseudocercosporella.html)*

## Conclusion

The Polish agriculture is presently at the stage of implementation of the integrated pest management principles. The use of the IPM cannot be effective without the use of innovative solutions, such as expert systems, which allow exhaustive analysis of a decision situation based on the local data. Currently, the offer of expert systems with regard to the integrated pest management is still quite poor in our country. Of the few ESs offered most are available as one-user systems, but there are also ESs for many users available on-line. The existing DSSs in the integrated pest management use components of expert systems. It results from the fact that obtaining information for formulating a recommendation requires solving a problem on the treatment justification. Solving such problems lies within the field of expert systems application.

In order to meet the requirements of the EU, there is a great need to carry out work on the expert systems in the integrated pest management for the most important crops in the country. They must take into account the context wider than the plant protection, including issues of the integrated crop production. Multi-faceted nature of these issues requires a multi-disciplinary approach at the development of knowledge bases – cooperation of agronomists, phytopathologists, plant protection specialists, meteorologists, economists, etc. as well as practicioners: agricultural advisers and agricultural producers. Ensuring high technological standard in this field requires the cooperation of computer specialists: database developers, software engineers, specialists in artificial intelligence, etc.

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## SYSTEMY EKSPERTOWE JAKO NARZĘDZIA WSPIERAJĄCE DECYZJE W INTEGROWANEJ OCHRONIE ROŚLIN

**Streszczenie.** Przedstawiono istniejącą w kraju ofertę systemów ekspertowych (SE) dla produkcji roślinnej. Stwierdzono, że rekomendacyjne systemy wspomagania decyzji (SWD) w ochronie roślin są SE-podobne, ponieważ wykorzystują komponenty właściwe systemom ekspertowym. SWD formułują zalecenia rozwiązując problemy dotyczące zasadności wykonania zabiegu ochronnego, zachowują się więc podobnie jak SE. Dostępność informacji pochodzącej z SE w zakresie integrowanej ochrony roślin jest jeszcze w naszym kraju niewielka. Konieczne jest opracowanie nowych SE dla najważniejszych upraw. Interpretacja przepisów UE pozwoliła stwierdzić potrzebę ujęcia zagadnień integrowanej ochrony roślin w szerszym kontekście integrowanej produkcji roślinnej. Wieloaspektowość zagadnień integrowanej produkcji roślinnej wymagać będzie multidyscyplinarnego podejścia do budowy SE: współpracy agronomów, fitopatologów, specjalistów od ochrony roślin, meteorologów, ekonomistów, doradców rolniczych, producentów rolnych, a także specjalistów od baz danych, inżynierii oprogramowania, sztucznej inteligencji, itd.

**Słowa kluczowe**: system ekspertowy, system wspomagania decyzji, integrowana ochrona roślin, integrowana produkcja roślinna

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# THE INFLUENCE OF TECHNOLOGICAL FACTORS ON GROWTH, DEVELOPMENT AND YIELD OF COMMON BEAN VARIETIES

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ABSTRACT

The article shows the results of research on high-yielding varieties of common bean (*Phaseolus vulgaris L.*), growth and development of plants under the conditions of western forest-steppe. Moreover, it establishes the duration of the vegetation period, formation of elements of bean plant productivity that provides the appropriate level of seed yield, which depends on the cultivar and sowing methods. Sowing in the usual way with wide row spacing of 15 cm provided the highest yield of Mavka variety on the level of 1.78 t·ha$^{-1}$. As a result of sowing in the usual way with wide row spacing of 30 cm Bukovynka variety had the highest yield – 1.72 t·ha$^{-1}$, and as a result of the wide-row planting method with wide row spacing of 45 cm it was – 1.76 t·ha$^{-1}$.

## Introduction

The main objective of agriculture in Ukraine at the present stage is to obtain production with limited expenditure of human energy and to protect the environment against degradation and pollution. One solution is to introduce new varieties, agricultural lands, which due to a considerable adaptive capacity provide a high level of implementation performance with minimal energy costs and provide a positive biogeocenotic impact on the elements of soil fertility.

The cultivation and consumption of beans in Ukraine have become popular. Low production of high-protein foods of animal origin, their high cost, gives impetus to increase the area under leguminous crops (Polyanskaja, 1991; Ovcharuk, 2013). For effective use of the biological potential of the varieties of beans and soil-climatic conditions of forest-steppe, it is important to develop and introduce into production a new adaptive varietal growing technology. Therefore, only a comprehensive study of agro-biological characteristics and technologies of cultivation of beans, establishment of conditions for obtaining high productivity, increases the seed production.

The growth and development of plants and the formation of their productivity are important indicators that characterize the production process of agricultural crops, in particular common beans (Kaminski, 2006; Petrechenko, 2003; Ovcharuk, 2013). The intensity of the growth processes is directly proportional to increases of the productivity of legumes

(Petrechenko, 2003). In turn, the intensification of the processes of growth and development is caused by the influence of environmental and biotic factors (Avadenyi, 2013; Ovcharuk, 2013; Petrechenko, 2003). However, the dominant role belongs to the varieties and growing techniques (Avadenyi, 2013; Golohorinska, 2005; Stakanov, 1986). Technological measures, which play an important role in shaping the productivity of legumes under favorable interaction unregulated factors, can reach 85% or more (Kaminski, 2006). Unlike technological activities, the role of the varieties as one of the most accessible and effective means of production is constantly growing and its contribution, according to the latest years, to the yield increase is estimated at 30-50% (Avadenyi, 2013; Golohorinska, 2005).

**The objective of the research**

The objective of the research was to set the duration of the phenological growth stages and development of bean and harvest patterns, depending on the variety in the western forest-steppe.

**Methodology and source material research**

Experimental studies were conducted within 2009-2013 on the experimental field of Podilsky State Agrarian Technical University.

The soil was deep black soil humus. The humus content (by Turin) in the topsoil was 3.4-3.8%, easily hydrolyzed nitrogen (by Kornfild) amounted to – 10.5-12.2 mg 100 $g^{-1}$ of soil, mobile phosphorus (by Chirikov) – 16.5 mg 100 $g^{-1}$ of soil, potassium (by Chirikov) – 21.0 mg 100 $g^{-1}$ soil, pH (salt) – 7.3.

The climatic conditions in the western forest-steppe are characterized by a sufficient amount of heat, but unstable moistening. A significant temperature increase is observed during March-April and April-May. Summer is characterized by high and stable temperature. In July it is 20ºC, in August 22-23ºC. The warm period ranges from 230 to 265 days, and the period of active vegetation (temperature above 10ºC) ranges from 155 to 170 days. The sum of active temperatures is 2300-2750ºC, SCC reaches 1.3-2.0, annual rainfall varies from 498 to 675 mm in the West to 790 mm, the average air temperature of 7.8ºC.

Sowing of common beans is held in the first decade of May. The total area of the plot was 45.0 $m^2$.

**A brief description of the investigated varieties**

*Kharkivska shtambova*. It is cultivated in Kharkiv Institute of Mechanization and Electrification of Agriculture by weight selection of early non- selective forms of 80-189. Its kind is ellipticus, albus. Plants are clustered, compact shaped, with a height of 40-60 cm. The flower is white. The height of attachment of the lower bean is 12-20 cm. Beans are resistant to cracking. The seeds are white, elliptical, smooth, shiny with hem in white. The weight of 1000 seeds is 245, the protein content in the seed is up to 23.6%. It boils well and has high gustatory properties. It is cold-resistant and suitable for mechanized harvesting. The duration of the vegetation period is 79-90 days. Seeds yield is 16-20 q·$ha^{-1}$ (Polyanskaja, 1991).

*Mavka*. Bred in the Institute of Agriculture of NAAS. Plant height is 50-60 cm. The height of attachment of the lower bean is 12-14 cm. It has many leaves. Plants are an indeterminate growth type, with a curling top and a straight form of a bush. Botanical variety is

*var. ellipticus, albus*. The under-cotyledon knee is light green, flowers are white, beans are yellow, with a pointed tip, the shape of the seed – oval-elliptic, the color of the seed coat is white, with a faint marble pattern. Weight of 1000 seeds is 280 g. Duration of the vegetation period is 105 days. The seeds contain 23% of protein.

This variety is of seed direction usage, it is resistant to lodging. Seeds are very tasty, resistant to shattering and suitable for mechanical harvesting. Seeds yield is 26 to 28 $q \cdot ha^{-1}$. It is recommended for cultivation in the Steppe and in Polissya of Ukraine (Ovcharuk, 2013).

*Nadiya*. It is bred in Bukovina Institute of agro-UAAS. It was created by individual selection from a hybrid combination of Belcka 16×Pervomaiska. Kind-ellipticus, albus. The form of the stem – sectional. Plant height is 45-50 cm. Flowers are white. The height of attachment of the lower bean is 15-18 cm. Beans are resistant to cracking. The seeds are white, elliptical, smooth, shiny with white hem. The weight of 1000 seeds – 226-234 g, the protein content in the seeds is up to 26%. It boils well and has a high gustatory properties. The variety is of seed direction usage, cold-resistant and suitable for mechanized harvesting. The duration of the vegetation period 80-85 days. Seeds yield is 23-27 $q \cdot ha^{-1}$ (Golohorinska, 2005; Ovcharuk, 2013).

*Bukovynka*. Bred in Bukovina Institute of agro-UAAS. Created by individual selection from a hybrid combination of Aluna×Alpha.Variety – ellipticus, albus. The form of the stem – sectional, secondary branching. Plant height is 50-55 cm. Flower is white, 2-6 in the brush. The height of attachment of the lower bean is 15-17 cm. Beans are resistant to cracking. The seeds are white, elliptical, smooth, shiny with white hem and the weight of 1000 seeds amount to 233-246 g. The content of protein in seeds – 26%. It boils well. The variety is of seed direction usage. The duration of the vegetation period is 80-85 days. The expected yield of seeds is 26.3-26.7 $q \cdot ha^{-1}$ (Ovcharuk, 2013).

*Podolyanochka*. It is bred in Podilsky State Agrarian Technical University. It was created by individual selection from the local population. Variety - ellipticus, albus. The form of the stem - sectional. Plant height is 55-58 cm. Flower is white, 2-6 in the brush. The height of attachment of the lower bean is 12-15 cm. Beans are resistant to cracking. The seeds are white, elliptical, smooth, shiny with white hem. The weight of 1000 seeds is 230-245 g. The protein content in the seeds is 25-26%. It boils well. It has the grade of the seed direction; it is cold-resistant, suitable for mechanized harvesting. The duration of the vegetation period is 80-85 days. The expected yield of seeds is 26.5-27.0 $q \cdot ha^{-1}$ (Ovcharuk, 2013).

**The results of the research**

The length of the growing period of crops is a genetically determined trait. An important feature of annual crops is a response to the changing environmental factors. It may be varied with regard to the variety, which is associated with such factors as: the group maturity, type of growth and others. Growing of common beans in a specific soil-climatic zone is important in the duration of the growing period (Golohorinska, 2005; Kaminski, 2006).

A variety and the sowing methods determine the duration of interphase periods in the ontogeny of plants and vegetation period in general. But, it is clear that even varieties of the same group of ripeness have different vegetation periods, due to the genetic characteristics of the variety (hybrid).

The research established that the growth and development of plants of different varieties during the growing period were held simultaneously. There are some differences in the

passage of the interphase periods. The study of interphase periods of development showed that the growing conditions affect the rate of passage stages of plant development of common beans. On average during the years of the research period, sowing-germination lasts for 10-12 days. Period of budding-flowering accounted for 10-13 days, flowering-ripening of beans – 21-23 days.

Therefore, we have analyzed the dynamics of the formation of the vegetation periods for each variety, and with regard to the sowing methods. In particular, the variety of Kharkivska shtambova growing period varied depending on the sowing methods from 75 to 81 days. (table 1).

Table 1
*Effect of sowing methods on the duration of interphase periods in varieties of beans (average over 2009-2013)*

| Varieties | Interphase period (days) | | | | | Duration of vegetation period, days |
|---|---|---|---|---|---|---|
| | Shrouts to first trigeminal | First leaf trigeminal leaf-budding | Budding -flowering | Flowering-ripening beans | Pouring beans-technical ripeness | |
| Ordinary method of sowing (inter-row spacing of 15 cm) | | | | | | |
| Kharkivska shtambova | 10 | 16 | 10 | 21 | 18 | 75 |
| Nadiya | 11 | 18 | 11 | 21 | 20 | 81 |
| Bukovinka | 10 | 17 | 10 | 21 | 19 | 77 |
| Mavka | 11 | 19 | 12 | 23 | 20 | 85 |
| Podolyanochka | 10 | 18 | 11 | 21 | 20 | 81 |
| Ordinary method of sowing (inter-row spacing of 30 cm) | | | | | | |
| Kharkivska shtambova | 10 | 16 | 11 | 22 | 19 | 78 |
| Nadiya | 11 | 18 | 10 | 22 | 21 | 82 |
| Bukovinka | 11 | 19 | 11 | 22 | 20 | 83 |
| Mavka | 11 | 20 | 12 | 23 | 21 | 87 |
| Podolyanochka | 10 | 20 | 12 | 22 | 20 | 84 |
| Wide-row method of sowing (inter-row spacing of 45 cm) | | | | | | |
| Kharkivska shtambova | 10 | 18 | 12 | 21 | 20 | 81 |
| Nadiya | 12 | 19 | 11 | 22 | 21 | 85 |
| Bukovinka | 11 | 19 | 12 | 23 | 22 | 87 |
| Mavka | 12 | 20 | 13 | 24 | 22 | 91 |
| Podolyanochka | 11 | 20 | 12 | 23 | 21 | 87 |

The longest period of vegetation was obtained by sowing with a wide-row method, and the shortest growing period by sowing with the usual string method with wide row spacing of 15 cm.

The indicators characterizing the structural elements of plants, namely, plant height and attachment of the lower bean, the number of internodes and branches depend not only on the varietal, but also on sowing methods for different widths of rows (table 2).

Table 2

*Characteristic of plants of beans depending on the varieties and sowing methods (average over 2009-2013)*

| Variety | Height (cm) | | | Number | |
|---|---|---|---|---|---|
| | Plants | Attachment of the lower bean | From the soil surface to the tip of the lower bean | Internodes | The branches |
| Ordinary method of sowing (inter-row spacing of 15 cm) | | | | | |
| Kharkivska shtambova | 68.3 | 12.4 | 4.3 | 10.1 | 1.5 |
| Nadiya | 55.4 | 15.8 | 7.2 | 10.3 | 1.7 |
| Bukovinka | 57.6 | 15.3 | 6.6 | 11.7 | 1.4 |
| Mavka | 58.1 | 11.2 | 4.1 | 11.4 | 1.8 |
| Podolyanochka | 56.5 | 15.1 | 6.3 | 13.8 | 1.6 |
| Ordinary method of sowing (inter-row spacing of 30 cm) | | | | | |
| Kharkivska shtambova | 75.3 | 10.4 | 1.9 | 14.1 | 2.7 |
| Nadiya | 58.6 | 15.1 | 6.4 | 13.2 | 3.1 |
| Bukovinka | 64.1 | 14.2 | 4.7 | 16.4 | 2.4 |
| Mavka | 66.7 | 9.5 | 1.1 | 15.3 | 2.9 |
| Podolyanochka | 63.4 | 12.7 | 4.2 | 16.3 | 2.7 |
| Wide-row method of sowing (inter-row spacing of 45 cm) | | | | | |
| Kharkivska shtambova | 91.6 | 9.1 | 0.3 | 13.4 | 3.1 |
| Nadiya | 50.2 | 14.9 | 5.4 | 12.7 | 3.8 |
| Bukovinka | 53.8 | 15.6 | 6.7 | 11.3 | 3.0 |
| Mavka | 55.8 | 8.3 | 0.2 | 12.5 | 3.4 |
| Podolyanochka | 51.9 | 14.0 | 4.3 | 10.6 | 3.2 |

Therefore, it was established that the height of the plants depends on the variety and sowing methods. In case of Kharkivska shtambova variety, this figure amounted to 68.3-91.6 cm, Nadiya variety – 50.2-58.6 cm, Bukovinka variety– 53.8-64.1 cm, Mavka – 55.8-

66.7 cm, Podolyanochka variety is 51.9-63.4 cm. As we see, with the increase of row spacing, increasing the height of the plants.

As to the height of attachment of the lower bean and distance from the soil surface to the tip of the lower bean it is known that these figures describe the suitability for mechanized harvesting of beans. Our studies revealed that by the usual method of planting with wide row spacing of 15 cm height of attachment of the lower bean this figure was the highest in Nadiya variety and amounted to 15.8 cm; Mavka variety had the lowest – 11.2 cm. Decrease of this indicator was observed with the increase of the width of the rows. By the usual method of planting with wide row spacing of 30 cm height of attachment of the lower bean was the highest in Nadiya variety to 15.1 cm; Mavka variety had the lowest – 9.5 cm. In a wide-row method of planting with row spacing of 45 cm high, these values were in the variety Bukovinka – 15.6 cm, the variety Nadiya – 8.3 cm.


*Figure 1. Form of bush of beans depending on the row spacing (the harvest-2013)*

Observations indicate that the methods of sowing influenced the number of internodes and branches. By the usual method of planting with wide row spacing of 15 cm number of internodes was highest in grade Podolyanochka – 13.8 No, the lowest in the variety of Kharkovska shtambova – 10.1 No. Growth of this indicator was observed when increasing the width of the rows. By the usual method of planting with wide row spacing of 30 cm height of attachment of the lower bean was highest in Bukovynka variety – 16.4 No, Mavka variety had the lowest – 13.2 No. As a result of the wide-row method of planting with row

spacing of 45 cm high, these figures were for the variety of Kharkovska shtambova – 13.4 No, the lowest Podolyanochka variety – 10.3 No.

The number of branches depended on the method of sowing, at sowing in the usual way with wide row spacing of 15 cm and amounted to 1.4-1.8 No, by the usual method of planting with wide row spacing of 30 cm – 2.4-3.1 No, with wide-row method of planting with row spacing of 45 cm 3.0-3.8 No.

Analyzing the biometric characteristic of Podolyanochka variety we found that the sowing methods had an impact on the shape of the bush (fig. 1).

In the process of formation of organic matter it is accumulating in all parts of the plant, however, the maximum accumulation of dry matter does not always prove the effectiveness of the event. This criterion is the yield of the main products. Crop yield is the product of plant productivity and the total number of plants that remained at the time of harvesting.

The set of elements of plant productivity, referred to as the structure of the crop. The main features of the structure of the crop of beans are: the number of beans per plant, seed size, number of seeds from plants, their size (weight of 1000 seeds) and weight of seeds from plant (table 3).

Table 3

*Plant productivity of beans depending on the varieties and sowing methods (Average from 2009-2013)*

| Variety | Quantity, (pieces) | | Weight, (g) | |
|---|---|---|---|---|
| | beans from plant | seeds in the bean | seeds from plant | 1000 seeds |
| Ordinary method of sowing (inter-row spacing of 15 cm) | | | | |
| Kharkivska shtambova | 24,3 | 3,9 | 94,9 | 201,67 |
| Nadiya | 19,0 | 5,0 | 96,1 | 238,27 |
| Bukovinka | 18,6 | 4,7 | 95,7 | 218,91 |
| Mavka | 22,9 | 4,9 | 108,5 | 222,34 |
| Podolyanochka | 22,3 | 4,4 | 98,6 | 224,08 |
| Ordinary method of sowing (inter-row spacing of 30 cm) | | | | |
| Kharkivska shtambova | 28,6 | 3,4 | 97,6 | 285,51 |
| Nadiya | 21,9 | 4,6 | 101,1 | 225,51 |
| Bukovinka | 21,7 | 4,5 | 98,4 | 256,41 |
| Mavka | 25,1 | 5,0 | 124,3 | 207,93 |
| Podolyanochka | 24,5 | 4,5 | 110,6 | 213,58 |
| Wide-row method of sowing (inter-row spacing of 45 cm) | | | | |
| Kharkivska shtambova | 36,2 | 2,9 | 104,5 | 298,71 |
| Nadiya | 23,5 | 4,5 | 106,3 | 228,34 |
| Bukovinka | 23,7 | 4,4 | 103,8 | 232,11 |
| Mavka | 28,3 | 5,2 | 147,2 | 215,09 |
| Podolyanochka | 29,4 | 4,7 | 138,3 | 259,67 |

Thus, the highest number of beans on the plant is set in Kharkivska shtambova – 24.3-36.2 No, the smallest in Nadiya variety – 19.0-23.5 No. Weight of seeds from plants partially depends on the previous value, but largely on the variety characteristics, and the highest was observed in Mavka variety – 108.5-to 147.2 g, the smallest in Kharkivska shtambova variety – 94.9-104.5 g.

Weight of 1000 seeds in the studied varieties depending on the sowing methods also changed. So when sown in the usual way with wide row spacing of 15 cm of Kharkivska shtambova variety, the value was 201.67 g, and the highest in Nadiya variety – 238.27 g. When sown in the usual way with wide row spacing of 30 cm the lowest weight of 1000 seeds was in Mavka variety – 207.93, and the highest in Kharkivska shtambova variety – 285.51. Sowing by wide-row method with row spacing of 45 cm ensured the growth of the weight of 1000 seeds. It was the highest for the variety of Kharkivska shtambova – 298.71 g, the lowest for the Mavka variety – 215.09 g.

The obtained data of harvest suggest that the value of the crop, depending on the variety and sowing methods also differed (table 4).

Table 4

*The yield of seed beans depending on the variety and sowing methods, ($t \cdot ha^{-1}$) (average for the years 2009-2013)*

| The sowing methods / Variety | Ordinary (inter-row spacing of 15 cm) | Ordinary (inter-row spacing of 30 cm) | Wide-row (inter-row spacing of 45 cm) | Average factor A | LSD factor A |
|---|---|---|---|---|---|
| Kharkivska shtambova | 1.66 | 1.58 | 1.64 | 1.63 | |
| Nadiya | 1.73 | 1.69 | 1.74 | 1.72 | |
| Bukovinka | 1.75 | 1.72 | 1.76 | 1.74 | 0.06 |
| Mavka | 1.78 | 1.66 | 1.69 | 1.71 | |
| Podolyanochka | 1.76 | 1.71 | 1.75 | 1.74 | |
| Average factor B | 1.74 | 1.67 | 1.72 | average experience – 1.71 | |
| LSD factor B | | 0.04 | | LSD factor AB – 0.10; Sx – 2.01. | |

The results of the research showed that the yield of seeds depends primarily on the varietal and the weather conditions of the growing season. In the years of research, the bean plants were sufficiently provided with heat and moisture. The highest yield of seeds of 1.78 $t \cdot ha^{-1}$ was formed on the variant of Mavka variety when sown in the usual way with wide row spacing of 15 cm. The lowest yield of bean was obtained on the level 1.58 $t \cdot ha^{-1}$ when sown by the usual way with wide row spacing of 30 cm of Kharkivska shtambova variety. By wide-row method of planting with row spacing of 45 cm higher yields were provided by a variety of Bukovynka – 1.76 $t \cdot ha^{-1}$.

## Conclusions

It was determined that the sowing methods had an impact on the duration of the interphase periods in case of beans varieties. In case of sowing with the usual way with wide row spacing of 15 cm, the length of the growing season was 75-85 days at the average. Sowing by the usual way with wide row spacing of 30 cm extended the vegetation period by 3-5 days, the wide-row method with wide row spacing of 45 cm extended the vegetation period by 4-10 days.

During the increase of the value of row spacing, the increase in individual productivity of bean plants and structure of yield was reported.

As a result, the yield depended on the variety and sowing methods. Sowing in the usual way with wide row spacing of 15 cm have provided the highest yield of Mavka variety on the level of 1.78 $t \cdot ha^{-1}$, and the lowest in case of Kharkivska shtambova variety – of 1.66 $t \cdot ha^{-1}$. In case of sowing in the usual way with wide row spacing of 30 cm the highest yield was for Bukovinka variety – 1.72 $t \cdot ha^{-1}$, the lowest in Kharkivska shtambova variety is 1.58 $t \cdot ha^{-1}$. In case of the wide-row planting method with wide row spacing of 45 cm, the biggest grain yield of bean was in the variants of Bukovynka variety – 1.76 $t \cdot ha^{-1}$, the lowest in Kharkivska shtambova variety – 1.64 $t \cdot ha^{-1}$.

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# WPŁYW CZYNNIKÓW TECHNOLOGICZNYCH NA WZROST, ROZWÓJ I PLON WYBRNAYCH ODMIAN FASOLI ZWYKŁEJ

**Streszczenie.** Niniejszy artykuł przedstawia wyniki badań dotyczących odmian fasoli zwykłej (*Phaseolus vulgaris L.*), wzrostu i rozwoju roślin w warunkach zachodniego lasostepu. Ponadto, określa czas trwania okresu wegetacyjnego, tworzenie się elementów składających się na wydajność roślinną, która dostarcza odpowiedniego poziomu plonu nasion w zależności od odmiany i metod siewu. Siew zwykły z szerokim 15-centymetrowym rozstawem dał najwyższy plon odmiany Mavka i był on na poziomie 1,78 t·ha$^{-1}$. W wyniku siewu zwykłego z szerokim 30-centymetrowym rozstawem, odmiana Bukovynka osiągnęła najwyższy plon rzędu – 1,72 t·ha$^{-1}$ a w wyniku siewu szerokiego z rozstawem wynoszącym 45 cm, plon wyniósł 1,76 t·ha$^{-1}$.

**Słowa kluczowe:** fasola zwykła, odmiana, kwitnienie, dojrzałość, wydajność, plon

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# ANALYSIS OF EFFECTIVENESS OF STORING WASTE HEAT IN THE WATER ACCUMULATOR[1]

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*ballotage, diffuser*

ABSTRACT

The paper presents analysis of the ways in which waste heat collected from the upper space of the plastic tunnel may be used. Warm air sucked from the upper space was pumped to a diffuser located in the process water tank. The assumed method was theoretically analysed and then tests were carried out in a real facility. Air bubbles moving in the liquid layer transferred heat, which they contained. The initial research, carried out according to the assumed method, did not bring satisfactory results. Nonetheless, some relations and possibilities of improvement of the described method by increasing the degree of complexity and the system costs were reported.

## Introduction

The organic and economic factors as well as the threat resulting from the lack of energy resources, enforce new trends in searching for energy sources. Popular, the so-called renewable energy sources not always completely satisfy our expectations. The use is completely justified if we carry out a multi-criteria assessment of their obtaining and use (Rutkowski, 2008; 2009). Sometimes, we should think how to improve energy effectiveness of the existing systems and how to carry out analysis on the existence of sources and possibilities of using the waste energy.

In the horticultural production in crop cultivation under cover considerable heat consumption is reported in the winter season but in the period of early spring and later, the greenhouse effect causes production of great amount of heat, which is wasted in most cases. On the other hand, within the same period, the production process requires heat even for heating the process water or for short-term storage in order to use it at night. We should also remember that the present level of technology allows transformation of energy parameters, which in a new form will find wider application. For example, heat pumps supplied from the source, which has higher temperature, reach high efficiency (Rubik, 2011). Taking

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into account high prices of heat pumps, one should carry out an extended economic analysis on the production activity when making an investment decision. However, before we make investment decisions, we should analyse one of the manners of using waste energy, which is heating the process water with the use of a diffuser.

The object of the research is a plastic tunnel with dimensions 9x16 m, which has a double plastic cover, filled in with air. In the upper part of a tunnel (fig.1) two intakes made of spiro pipes are located. Openings of 35 mm diameter were made in the spiro pipes of 300 mm diameter. The total surface area of openings constitutes 270% of the cross-section of a suction pipe. A suction pipe was connected to a fan, which pumps air to the diffuser located in the process water tank. Performance of the fan could have been arbitrarily changed during the tests. Measurement of the energy parameters was carried out with the use of the available apparatus used for another tests in the analysed facility. Figure 1 presents distribution of the measurement points.

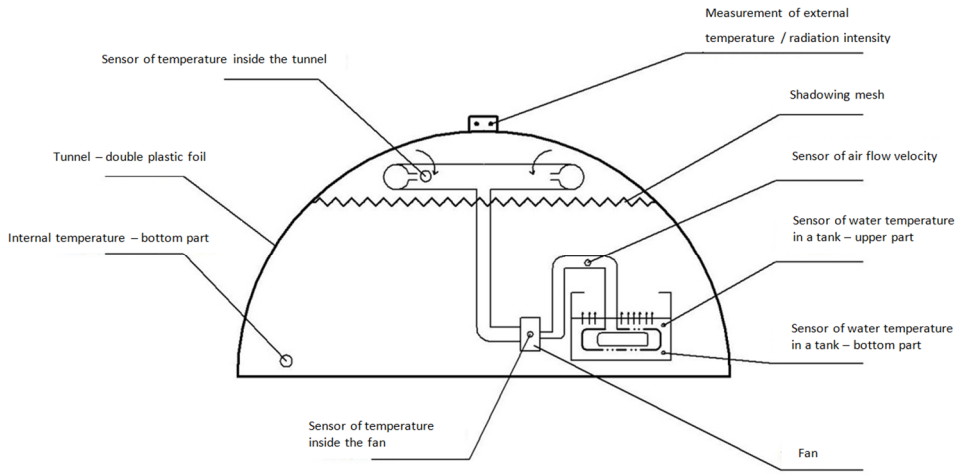


*Figure. 1 Schematic representation of the test rigs*

In the facilities under cover, as a result of solar radiation a great variability of temperatures occurs in the vertical arrangement. When analysing the temperature course inside the facility in the period of research presented in figure 4, we will notice that the temperature in the upper zone of the plastic tunnel in the afternoon is three times higher than in the plant vegetation zone. When using a shadowing mesh in the upper part of the tunnel, we separate this zone, thus obtaining in the system of heat recovery more even, high temperature. Excess of heat, which is collected during the day over the shadowing mesh, may be successfully stored in order to secure heat deficiencies at night in facilities which do not have a continuously operating heating system, or for heating e.g. the process water or supplying the bottom source of the heat pump. In order to find the simplest, economical solution, the system presented in figure 2 was taken into consideration.

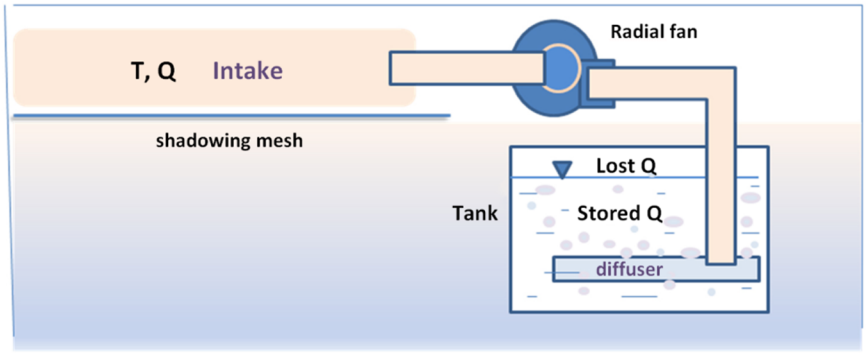


*Figure. 2 Schematic representation of the technical system for recovery of heat waste concentrating over shadowing mesh*

The objective of the paper was to determine effectiveness of the direct heat exchange in the diffused flow in the above-presented technical system

Total energy intake of this system is defined by the fan operation $L_w$.

$$L_w = L_p + L_b$$

where:

$L_p$ – work of shaping the inflow stream to diffuser

$L_b$ – work of forming bubbles in the diffuser openings for performance of ballott (free inflow)

Effectiveness condition requires that:

$$L_w < Q_{mag}$$

where:

$Q_{mag}$ – supply of the collected heat in the accumulator tank

Although the initial theoretical assumptions indicated restrictions related with this method in the aspect of heat exchange, the above method may be taken into consideration and may be improved in case of the recovery of waste energy. Since there are no documented literature assessments in this scope therefore basic research should be carried out. A simple structure of the system did not require financial expenditures and enabled realization of experimental research with the use of standard laboratory equipment.

A simplified theoretical analysis of the system had, in this case, a nature of a simple application of the relation of airing systems generally popular in the field of environmental protection, water physics, floatation etc. The paper includes mainly the patterns and methods provided by (Podgórski, 2012; Kowal et al., 1997; Szyszka, 2004; Weinerowska et al., 2004).

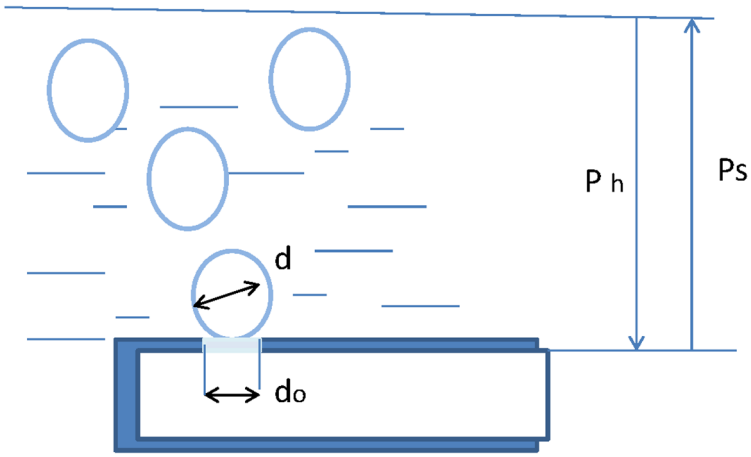


*Figure. 3 Air bubble formation*

According to these relations, the following assumptions were made:

1. Free ballotage or free beading effect begins from the balance state $p_h = p_s$ namely, from the state of pressure balance from the column of liquid over the diffuser and pressure of the supplied air (fig. 3).
2. Diameter of bubbles d depends on the diameter $d_o$ and the surface tension σ. Bubbles do not absorb gases dissolved in water, they do not merge thus they do not considerably change their diameter during the outflow (there is an impact of small pressure decrease along with ascending but simultaneously bubbles are chilled).
3. Velocity of outflow in free ballotage is mainly a function of bubbles diameter d and liquid viscosity. As a result of the buoyant force as well as the viscosity force, air bubbles move along the considerable part of a trajectory with a uniform motion.
4. The number of bubbles in the free ballotage per a time unit is determined by the air flow intensity in $m^3 \cdot s^{-1}$ in connection to the total area of outflow openings.
5. Bubbles with diameter of ≈ 2 mm maintain a rounded shape in water, their velocity in water fluctuates within 0.2 to 0.3 $m \cdot s^{-1}$ (above this diameter, the flow resistance may cause shape deformation).

Initial selection of the input parameters of the suggested system was based on the following assumptions:

1. The set volume of the heated air intake was approx. 60 $m^3$. It was assumed that an hourly average number of exchanges in the investigated period corresponding to the average sun exposure was 6 (in reality from 4 to 8 exchanges due to variable conditions of sun exposure).
2. The height of water surface over the diffuser should not be too low so that a bubble has enough time to give back heat, but it was also too big for the fan to balance pressure.
3. Time of bubble ouflow should enable effective heat exchange. Since "the heat stock" in a bubble is proportional to $d^3$ and the surface area of heat exchange to $d^2$. Shortening the exchange time requires decrease of the bubble diameter.

The above shows that the bubble diameter and the height of the water column over a diffuser decide in this case on the length of the bubble route and the time of heat exchange. These assumptions determined difficulties in the performance of research on the selection of a fan and an appropriate diffuser. According to the recommendations (Gondek, 2000) a fan with low efficiency but good pile-up properties, high-pressure (up to 10, 000 Pa) should be applied. A radial fan with the maximum power of 1.5 kW, efficiency of 300 $m^3 \cdot h^{-1}$, $\Delta p$ = 8,000 Pa, the rotational speed of which was regulated with the use of the electronic system (HPB-F-200-150), ensured similar parameters to the required conditions.

Selection of a diffuser required the following conditions to be met.

1. The area of outlet openings of diffusers should correspond to the cross section of the outlet channel of the fan suggested above with a 100 mm diameter.
2. A diffuser should ensure possibly the lowest diameter of bubbles.

In this case due to the costs of the experiment, minimization of the outlet openings diameter was attempted by wrapping a perforated pipe made of plastic with a high-density cloth. A 2.5 m long diffuser with a cross-section diameter d=50 mm was used. In order to check the condition 1 of the compliance of the area, the measurement of the air speed flow in the outlet channel of the fan was carried out before and after the diffuser was mounted. The applied diffuser did not show suppression of flow. Nonetheless, no bubbles, formed this way, with diameters below 1 mm, were obtained. Diameters remained within 1 to several millimeters.

A tank with volume V=9001, where heat was stored, was made of polyamid and was thermally insulated. The maximum height of water surface from the diffuser axis was 700 mm and corresponded to the possibilities of balancing pressure of the applied fan. For such assumed technical system, initial calculations were made. Calculations were carried out including typical conditions in the possessed experimental greenhouse. Moreover, the author's own computer program, which carried out calculation of the heat exchange, was used in a simulation. This program was created as a part of another research work.

The air flow of 0.1 $m^3 \cdot s^{-1}$ with temperature 30ºC was assumed for calculations. During the beading effect, this stream occurs in the form of $2.4 \cdot 10^7$ bubbles with the total area of 312 $m^2$ and heats a water tank with a complex initial temperature of 15ºC . The simulation proved that the flow process is accompanied by small heat exchange. The temperature increase was estimated as 1ºC after approx. 1 hour of exchange. Despite rather unfavourable results of simulation for verification, a decision was taken to carry out an experiment in the real facility. Since, for the accepted model, the greatest uncertainty was brought along with a thermal transfer coefficient *U* taken from thermodynamic tables Engineering ToolBox. This coefficient is calculated according to the following formula:

$$U = (h_1^{-1} + l\,\lambda^{-1} + h_2^{-1})^{-1}$$

where:

- $h_1$ – coefficient of heat transfer by water from the external side of a buble, $(W \cdot (m^2 \cdot K)^{-1})$
- $l$ – thickness of a membrane which is around a bubble, (m)
- $\lambda$ – heat transfer coefficient of the surface surrounding a bubble, $(W \cdot (m \cdot K)^{-1})$
- $h_2$ – coefficient of heat transfer by air from the inside, $(W \cdot (m^2 \cdot K)^{-1})$

A partition, namely a water layer with specific directed tensions, which surrounds the air bubble, is characterised by uncertainty (but not only the partition). The second factor is an impact of the bubble velocity and the related phenomena (turbulences) on the heat exchange. The obtained results of experiments are presented in figure 4.

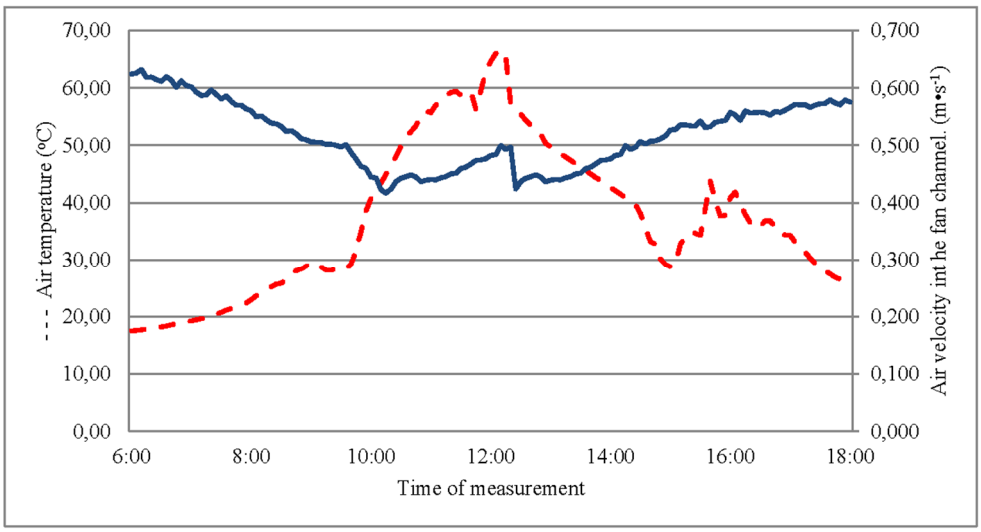


*Figure. 4 Physical parameters of air over the shadowing mesh (exemplary day of research)*

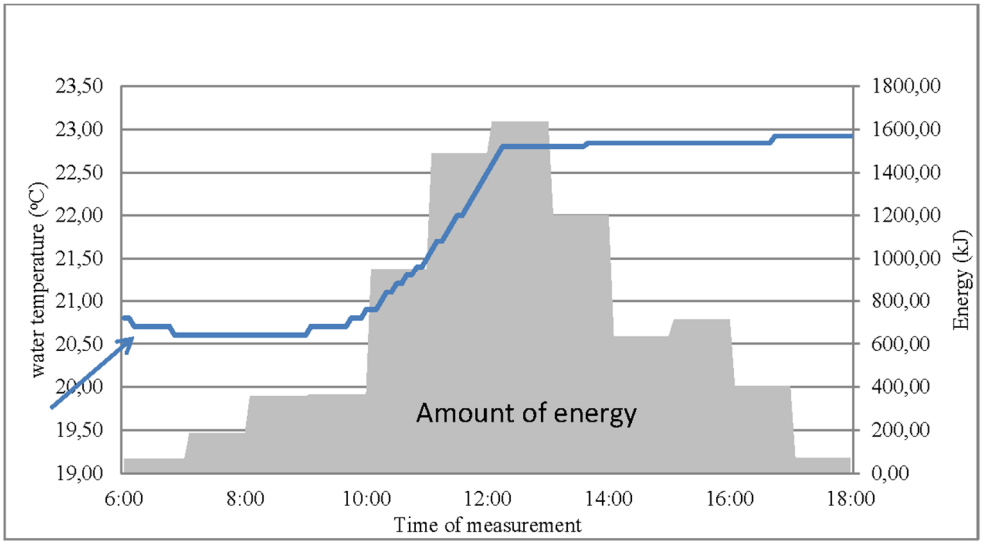


*Figure. 5 Dynamics of heating the process water (exemplary day of research)*

When tracing the amount of energy obtained from the upper space of the investigated plastic tunnel, one may notice that it is not too high; however, in the aspect of the crop technology, the value of the process water temperature has a significant impact on the production efficiency. Raising water temperature in the existing conditions of research by 2-3ºC is not much but it should be emphasised that in relation to the type of the cultivated plants on the investigated surface of the tunnel, demand for process water is as much as 8 times lower in comparison to the tank volume.

In the accepted weekly period of research (3rd decade of February) average values of the obtained results are as follows;

1. In the accepted conditions of research at the average value of the intensity of solar radiation at the level of 185 $W \cdot m^2$ (within 10 hours) in the tank of volume of 900 l water temperature raises at the average by 3.5ºC.
2. In the accepted conditions of research, heat stored in the process water constitutes approx. 50% of the electric energy consumption which serves as the fan drive
3. The obtained value of the heat transfer coefficient (air bubbles - water) is two times lower than the one assumed in simulation calculations (assumed: 0.6 $W \cdot m^{-2} \cdot K^{-1}$, obtained: 0.3 $W \cdot m^{-2} \cdot K^{-1}$)
4. In order to improve the efficiency of heat recovery, the research conditions should be verified.

Raising the average value of air temperature by 17ºC in the intake during a day in comparison to the heated water temperature resulted in raising the water temperature by 3ºC in the accepted research conditions (60 litres of air intake per 1 litre of water in the heater tank).

The above experiments show that the simulation calculations were too optimistic. Compliance of results may be obtained if heat transfer coefficient is corrected. At the beginning the assumed value was U=0.6 $W \cdot (m^2 \cdot K)^{-1}$, corrected 0.2 $W \cdot (m^2 \cdot K)^{-1}$. Thus, heat transfer coefficient values of the air bubble - water are disputable and require specification of the flow conditions.

## Conclusion

The method of direct supply of heat by the air diffuser proved to be ineffective in the considered simple, cheap technical system. In particular, operation of a fan, which maintains proper static pressure, exceeded 3 times the yield of energy which came from the heat exchange.

Facilitation of operation of the heat recovery system according to the described method is possible but through the increase of its complexity and thus costs. One should aim at decreasing diameters of air bubbles and at prolonging the heat exchange time e.g. by prolonging the passage of outflow but at the same time reducing the height of the water column over a diffuser. Orientatively, a diffuser should ensure the beading effect of diameters equal or smaller than a tenth part of a milimeter at the unchanged flow efficiency. Reduction of the particles size causes also reduction of the outflow speed enabling effective heat exchange. However, these solutions bring new technological issues which are theoretically related to the electro-static phenomena, balance of phases and other which are not subject to

simple estimations (Takahashi, 2005). It is not known whether in a general balance of costs they will prove effective for production under cover.

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## ANALIZA EFEKTYWNOŚCI MAGAZYNOWANIA CIEPŁA ODPADOWEGO W AKUMULATORZE WODNYM


**Streszczenie.** W pracy przeprowadzono analizę metody zagospodarowania ciepła odpadowego pobieranego z górnej przestrzeni tunelu foliowego. Ciepłe powietrze zasysane z górnej przestrzeni wtłaczano do dyfuzora umieszczonego w zbiorniku z wodę technologiczną. Przyjętą metodę przeanalizowano teoretycznie a następnie przeprowadzono badania w obiekcie rzeczywistym. Unoszące się pęcherzyki powietrza przemieszczając się w warstwie cieczy przekazywały zawarte w nich ciepło. Badania wstępne realizowane według przyjętej metody nie przyniosły zadawalających wyników. Niemniej zaobserwowano pewne zależności i możliwości doskonalenia opisanej metody na drodze zwiększenia stopnia złożoności i kosztów układu.



**Słowa kluczowe:** obiekty pod osłonami, wymiana ciepła powietrze-woda, balotaż, dyfuzor

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# VALUES OF THE BINDING FORCE OF COMMON SEABUCKTHORN WITH A PLANT

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ABSTRACT

The aim of the study was to determine the effect of selected operating parameters of the two types of orchard sprayers on vertical distribution (expressed as spray percentage share in 50-cm segments) and quantitative changes in the vertical distribution of spray measured on the vertical separator of drops. The study included measurements of the vertical distribution of spray for two different ways of nozzles setting, two types of nozzles and two fan rotation speeds. The vertical distribution of spray depended significantly on spray emission system, the configuration and the type of nozzles and in the slightest degree on the fan rotation speed. The smallest share of liquid fell on the edge segments (≤ 5.22%) and the largest on the middle ones – 29.33%. The change in the configuration of nozzles significantly affected the change in the spray vertical distribution (by the spray displacement between the 50-cm segments). The greatest changes in the vertical distribution of spray – as affected by nozzle configuration change – was observed for the sprayer with the horizontal spray emission with maximum change in one segment of 14.0% (an average of 7 segments: 5.38%).

## Introduction

Herbs cultivation in Poland has over a one-century tradition (Kozłowski, 2000). However, in the past, field crops included mainly herbs, while nowadays more and more growers reach for bushy medical plants. Common seabuckthorn (*Hippophae rhamnoides L.*) is one of them. It is a dioecious species which belongs to the oleaceae family, which can be met in the natural environment in Poland on the Baltic shore as well as in the cultivation on production plantations. Usually it occurs in the form of a highly branched bush, which with its habit and leaves resembles bushy forms of a willow tree. It has small soil requirements, a strong root system and the ability to bind atmospheric nitrogen. It is used as a pioneer species during soil erosion (Vescan et al., 2010). Its berries are rich in elements, in particular with vitamin C and E (Kallio et al., 2002; Zeb, 2004). Oil from seeds and berry pulp is particularly known (Zadernowski et al., 1997; Yang and Kallio, 2002; Cenkowski et al.,

2006). Common seabuckthorn has a great therapeutic potential (Yang et al., 2000; Suleyman et al.., 2001; Geetha et al., 2002; Cheng et al., 2003; Negi et al., 2005). Research carried out by Piłat et al. (2012) indicates high variability of the chemical composition of berries from various varieties. Interest in this plant in various countries is great (Vernet, 2006). According to the survey data (Niesteruk et al., 2013) in Poland it is still not popular. According to the quoted research, over half of the respondents have never heard of this plant and over 80% have never met the products, which contained common seabuckthorn berries. It results from the fact that fruit are undoubtedly hard to harvest due to thorns and density along branches. Thus, in order to popularize this unusually valuable plant, analysis of various possibilities of harvest mechanization is indispensable (Fu et al., 2014).

The objective of the paper was to determine and compare the bonding force of berries with a shoot for two varieties of common seabuckthorn. The obtained measuring data may be helpful for development of structural assumptions of working elements of a machine for harvesting common seabuckthorn berries.

## Material and methodology of research

Berries of common seabuckthorn *Hippophae rhamnoides* L. constituted the research material. They came from the plantation located within the Department of Production Engineering and the Power Industry in Krakow. Two varieties Botaniczeskaja and Augustinka were covered by the analysis. The tests were carried out within 2012-2013. During the harvest maturity in the second half of August, common seabuckthorn branches were cut of with berries and then mounted in the attachment for extending biological material on the testing machine MTS Insight 2. Single berries were picked according to the agreed procedure recorded in the "Test Works 4' programme. Schematic representation of the picking device was presented in figure 1.

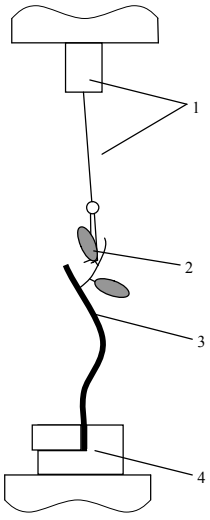



*Figure 1. Schematic representation of the test rigs: 1– tensometric head of the testing machine along with a tie rod which picks berries, 2 – common seabuckthorn berry, 3 – seabuckthorn branch, 4 – attachment which mounts samples in the testing machine*

In quasi-static tests for plant material, the speed is within 1 to 20 $mm^{-1}$ (Stropek and Gołacki, 2005; Bochat and Zastempowski, 2009). Since, it is a first stage of research concerning the process of separating berries of seabuckthorn from a plant (in real conditions it is a dynamic process), the value of the test speed was determined in the upper applied range of the value and was 120 $mm \cdot min^{-1}$. Berries bonding force with a plant was tested in two zones of bushes, central and bottom, picking 100 berries from each zone.

Statistical analysis of the obtained results was carried out with the use of a computer program Statistica 9, analysis of variance was carried out and after showing differences between the considered variables – Duncan test at the significance level of p=0.05.

## Results of the research

Figure 2 presents an exemplary characteristic of the course of changes of the value of the force separating berries from the central part of Botaniczeskaja variety. The A point means a critical force which separates berries from a plant.

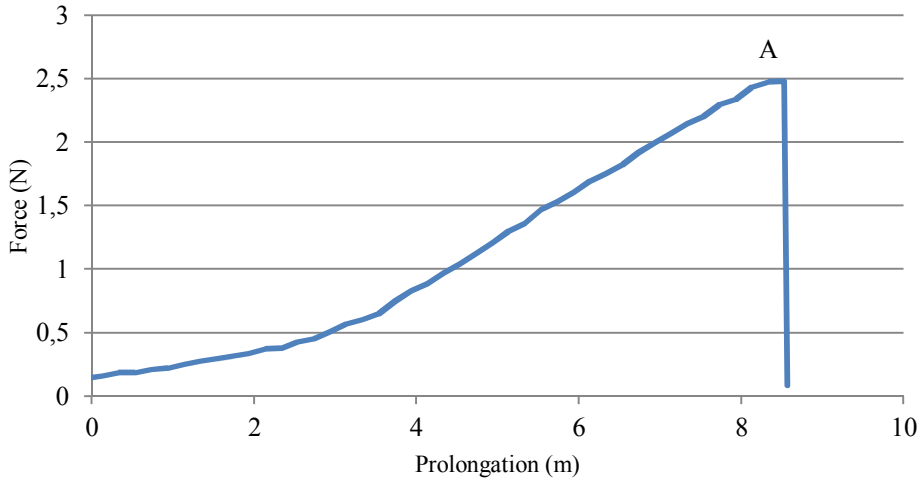
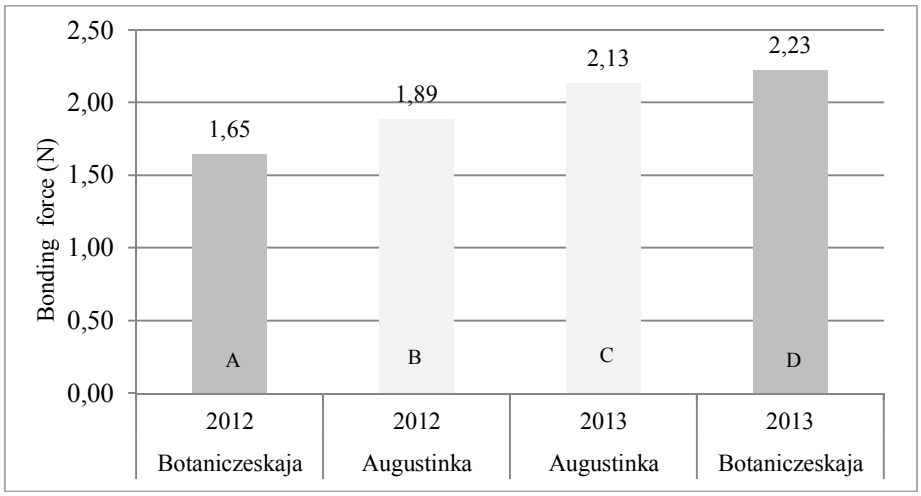



*Figure 2. An exemplary course of changes of the bonding force value for Botaniczeskaja variety in the central zone*

The research carried out on raspberries shows that the bonding force of berries is a varietal property and mainly depends on the size and shape of the receptacle, degree of berries maturity and the course of atmospheric conditions (Rybczyński et al., 2001). Thus one may assume that there has been a variability of this property over many years.

Results of the presented research confirm the thesis that the analysis of variance (ANOVA, MANOVA) proved relation of the bonding force of berries of particular varieties to the years of research. Berries of Botaniczeskaja variety had the weakest bonding in 2012; however in the following year of research, at the average by 0.58 N higher values were reported for this variety, thus these results were in the different uniform group (fig. 3).

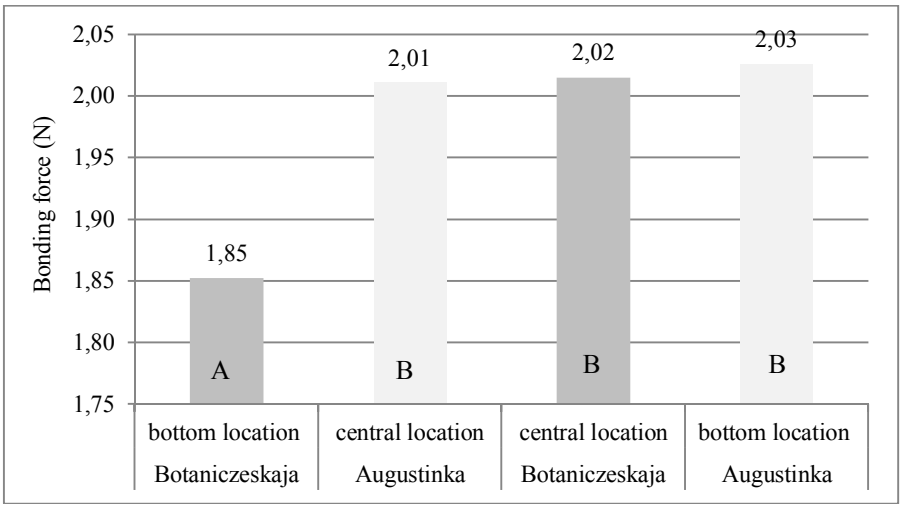



A, B, C, D – uniform groups acc. to Duncan test

*Figure 3. Mean values of the bonding force of berries of the investigated varieties of common seabuckthorn in particular years*

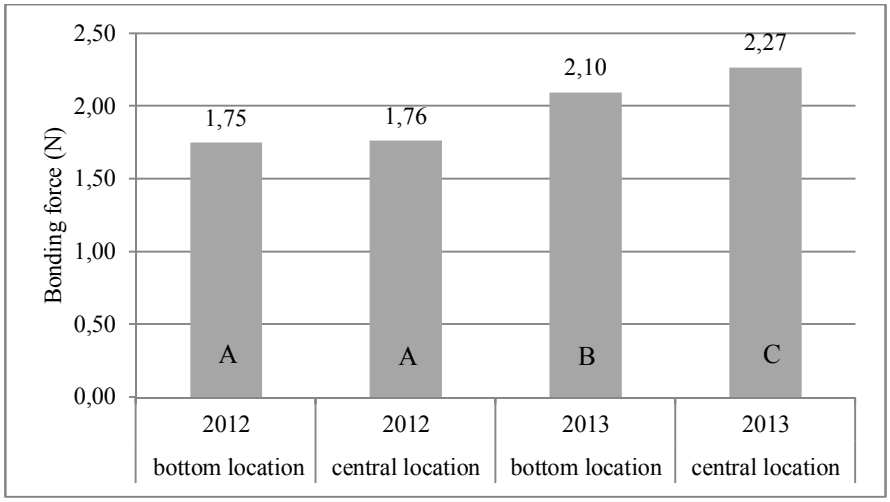
The statistical analysis which was carried out proved also simultaneous impact of berries varieties and location on a plant on the bonding forces. The lowest values were determined for Botaniczeskaja variety in the bottom location, at the average 1.85 N.Whereas values of bonding forces of berries of this variety from the central part were similar to the values determined for Augustinka variety in both investigated zones, thus these values were in the common homogenous group (fig. 4).

In 2012 interaction of the bonding force of berries in particular zones with the years of research were also determined. In 2012, lower values of bonding forces were reported for berries from the bottom as well as from the central part. Inter alia, no statistical differences were determined; the obtained results were in the common homogenous group. While in 2013, such differences occurred and berries from the bottom part of the bush had slightly weaker bonding with a plant. The presented mean results of the bonding force are within 1.75 N in 2012 to 2.27 N in 2013 (fig. 5). Such increase in the bonding force values may cause deterioration of the efficiency of combine harvesting, similarly to variability of the bonding forces values of raspberries, presented in the Rabcewicz's and Danek's research (2010), resulted in deterioration of the combine harvesting of these berries.




A, B – uniform groups acc. to Duncan test

*Figure 4. Mean values of the bonding force of berries of the investigated varieties of common seabuckthorn in particular years*




A, B, C – uniform groups acc. to Duncan test

*Figure 5. Mean values of bonding forces of common seabuckthorn berries in relation to location and years*

It seems that the differences obtained in the bonding forces values of seabuckthorn berries between particular years of harvesting and bushes zones may be related to slightly different course of climatic conditions in those years. When comparing meteorological data

from 2012 and 2013 from the region of research, differences in the amount of precipitation are particularly visible. Observed during the August harvest in 2013 higher values of berries bonding forces in comparison to the last year, were preceded by humid May and June as well as dry July and August. The research carried out by Guo et al (2007) indicates changes in the seabuckthorn architecture under the influence of the water stress, although its tolerance to drought is well known. It should be assumed that the changes in architecture are followed by modifications in its anatomical structure, which may result in changes of the bonding forces of berries.

However, the relations, observed in the presented results, require to be confirmed in the following years of research and constitute an introduction for the deeper analysis of this subject.

## Conclusions

1. Variability of the bonding force values of the investigated common seabuckthorn berries in relation to the year of research was reported. Difference between 2012 and 2013 for Botaniczeskaja variety was at the average 0.58 N, and for Augistinka variety it was 0.24 N. Higher values of bonding force were obtained in 2013.
2. Values of the bonding forces of berries with a plant were variable in relation to the applied variety and location of berries on a bush. Discrepancies in the bonding force values of berries of the investigated varieties from particular zones of bushes were reported. Botaniczeskaja variety had particularly low bonding forces at the average 1.85 N in the bottom zone whereas such relation was not observed in Augustinka variety.
3. Relation of the bonding force values of common seabuckthorn berries to location of berries on a bush and the year of research. In 2012 lower bonding force values of fruit, not related to their location were determined. On the other hand, in 2013 berries located in the lower part had slightly weaker bonding.

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# WARTOŚCI SIŁ WIĄZANIA OWOCÓW ROKITNIKA ZWYCZAJNEGO Z ROŚLINĄ

**Streszczenie.** Rokitnik zwyczajny to krzewiasty gatunek rośliny z rodziny oliwkowatych o owocach zasobnych w składniki aktywne biologicznie. Jest wciąż mało rozpowszechniony w Polsce, co związane jest w dużym stopniu z trudnościami zbioru niewielkich i gęsto osadzonych owoców na ciernistych gałęziach. Celem pracy było wyznaczenie i porównanie wartości sił wiązania owoców z pędem dla dwóch odmian rokitnika zwyczajnego, Botaniczeskaja i Augustinka. Materiał badań pochodził z własnej plantacji doświadczalnej. Badania prowadzono na maszynie wytrzymałościowej MTS zrywając owoce z dwóch stref krzewów, środkowej i dolnej. Stwierdzono zależność statystyczną wartości sił wiązania owoców poszczególnych odmian od lat badań, a także umiejscowienia owoców na krzewie. Najsłabiej związane były owoce odmiany Botaniczeskaja zbierane w 2012 roku, charakteryzujące się średnią wartością siły wiązania wynoszącą 1,65 N. Mniejsze wartości sił wiązania dla tej odmiany obserwowano w przypadku owoców znajdujących się w dolnej części krzewu.

**Słowa kluczowe**: owoce rokitnika, zbiór mechaniczny, siła wiązania

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# HIGH-FREQUENCY TRADING OF AGRICULTURAL COMMODITIES AS A SOURCE OF ADDITIONAL INCOME IN AGRICULTURE[1]

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ABSTRACT

The paper verifies usefulness of the high frequency trading model developed by Marco Avellaneda and Sasha Stoikov, used in simulation of turnover with futures contract securities of one of agricultural commodities on the selected commodity stock exchange. Accuracy of provided signals of purchase and sale signals was verified on authentic quotations – the futures contract for coffee prices of the London Stock Exchange. Results of ten subsequent session days was analysed in detail. Quality of the assumed investment algorithm was determined with the use of stock exchange ratios: Information Ratio and Maximum Drawdown. A short discussion was conducted, which compared a standard investing method and the analysed model of algorithmic trading. In conclusion, all most important statements and conclusions were made, which confirmed usefulness of the HFT model developed by Marco Avellaneda and Sasha Stoikov for turnover of futures contract securities for agricultural commodities.

## Introduction

Algorithmic trading originates in non-complex applications which allow division of big orders into few smaller ones and to perform them optimally. Development of this technique was possible only when the internet stock exchange market with orders sent through e-mails got popular and transaction applications became widely available. At the beginning it was a program, which realized strictly determined orders, in situations, when specific conditions for their conclusion were met. Present programs use complex algorithms, which include mathematical tools, in particular for statistics, optimization or calculus of probability. Transaction programs following quotations and other information sources, which have direct impact on stock exchange markets, give suitable investment signals.

Presently, as a result of dynamic development of IT services and easy access to the internet, access to algorithmic trading is not reserved only to big and significant inventors but is also available for individual investors. The newest solutions for persons, who want to invest in the stock exchange without acquainting with its complexity of functioning, is

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offered by some economic subjects investing through financing robots. These robots operate on algorithmic trading models, without disclosing their operations and only informing the investor on the worked out profit. Moreover, companies, which make such type of software available, compete between each other on many planes. First of all, they try to work out as high profits for clients as possible (and thus increase its nominal provision through the increase of the number of licenses and capital). Secondly, they try to indicate improper conduct of competition automatons. Finally, probably the most important, they modify operation of their algorithms on account of moves and assumed strategy through alternative algorithms. Thus, details of algorithms used by robots may be rarely used in literature. If yes, then in decisive majority, these are publications concerning the use of artificial intelligence, the so-called "black boxes", Thus, Chang et al. (2011) used artificial neural networks for detecting signals of purchase and sale on the securities market. Technical analysis combined with tracing plots of prices/volume of sale was presented by Chavarnakul and Enke (2008), where artificial neural networks were used to the moment of purchase and sale. Gradojevic and Gencay (2013) adapted fuzzy logic for assessment of the investment risk and selection of strategy. Fuzzy sets were also used by Tan et al. (2011) for cyclic stock investments. Analysis of clusters with Support Vector Machine (SVM – machine teaching method) was, on the other hand, the subject of research carried out by Choudaury et al. (2014). Indications for genetic algorithmic (GA) which support strategies based on the technical analysis were presented by Esfahanipour and Mousavi (2011). Genetic algorithms were also the subject of research by Mabu et al. (2013) but papers of this team were guided towards the use of GA for the needs of decision trees. On the other hand, Kluger and McBride (2011) showed implementation of the agent system for discovering investment patterns in intraday investments. The transaction model with high frequency analysed in the paper (High Frequency Trading) is also one of examples of using solutions of algorithmic trading.

Rising requirements of investors, who more often use programmes of algorithmic trading, on the Polish stock exchange market in 2013 forced Warsaw Stock Exchange to change the transaction system WARSET, operating since 2000 into UTP system – Universal Trading Platform. The present system meets the most excessive requirements of investors ensuring suitable environment for concluding transactions, where milliseconds count.

In the world literature one may find publications concerning the use of algorithmic trading models on the securities market (shares, bonds) – Aragon and Dieckmann (2011), Li et al. (2009) – or FOREX stock exchanges (currencies) – Evans et al. (2013), Kozhan and Salmon (2012). There is no common knowledge on analogous models on commodity markets, which decisively differ in its characteristic (liquidity and percentage differences in quotations). Commodity exchanges are characterized with low liquidity and more stable securities prices. It is conditioned by more fixed prices of commodities, quotations of which do not drop drastically or do not increase to few dozen percent during one session as in case of shares of smaller companies. Thus, verification of the algorithmic trading model on the agricultural commodities market is justified.

## The objective and the scope of the study

The objective of the paper is to verify usefulness of the high frequency trading model developed by Marco Avellaneda and Sasha Stoikov, used in simulation of turnovers with futures contract securities of one of agricultural goods on the selected commodity stock exchange.

Accuracy of signals to perform alternatively respectively transactions of purchase and sale on authentic quotations of futures contract was investigated. A number of simulations at various values of parameters which influence calculation of threshold values of purchase and sale prices were carried out. Possibility of working out income and the rate of return with engaged capital and the condition of a wallet within subsequent 10 session days was calculated and imaged in the form of plots.

Financial instrument in the form of futures contract for agricultural goods is an object of the research. Selection of contract commodity was guided with high liquidity i.e. number of transactions in a session, necessary for the analysed model. After analysis of available futures contract, futures contract for coffee was selected from data of London Stock Exchange, the type of quotations of which is constant and is characterized with liquidity at the level of approx. 542 quotations during one session. The quotation unit is GBP·tonne-1, i.e. value of one tonne of a commodity expressed in pound sterling. A tick, that is a minimal jump in quotation for this contract is 1.00 GBP.

Data to simulations, which were carried out concerning quoting from subsequent 10 session days (number of session days selected arbitrary), were downloaded from London Stock Exchange through OpenQuant application with IQFeed. Session days included constant period of session days 14 – 17, 22 – 25 and 28-29 April 2014. Additionally it was assumed that 15 minutes before the end of session, conclusion of purchase transaction is not possible. This solution aimed at avoiding the situation of freezing capital to the following session day.

## Methodology of work

### Stochastic model of investment

It was assumed that the price of a particular commodity S (t) is subject to decomposition Ito

$$dS(t) = b\big(t, S(t)\big)dt + \sigma\big(t, S(t)\big)dW(t), \tag{1}$$

where: W(t) is a standard Brownian motion.

Additionally through $p^b(t)$ and $p^a(t)$ respectively the price of purchase and sale, for which the investor is prone to conclude a transaction, has been determined. At these symbols, price spread for purchase and sale was described as:

$$\delta^b = p^b(t) - S(t) \tag{2}$$

and

$$\delta^a = S(t) - p^a(t) \tag{3}$$

Moreover, two dynamic processes Q (t) were considered – number of securities in a particular moment in time possessed by an investor and X (t) – cash available after transaction.

The investor aims at maximization of the expected value of a portfolio

$$u(t,s,q,x) = \max_{\delta^a,\delta^b} E_{t,s,q,x}\left[-exp[-\gamma(X(T) + Q(T)\cdot S(T))]\right] \tag{4}$$

where:

$t \in [0,T]$ – time,

$s = S(t)$ – present price of a given good,

$x = X(t)$ – cash designed for investment,

$q = Q(t)$ – present level of engagement in a given security.

Parameter $\gamma$ is a feature, which characterizes the market (liquidity) whereas $\delta^a$ and $\delta^b$are the only sizes, which can be influenced by an investor.

## Optimization of offered purchase and sale prices of commodities

For determination of a strategy, optimal from the point of view of an investor, Hamilton-Jacob-Bellman equation was used. According to Ho and Stoll (1981) function u meets the following relations:

$$u_t + \frac{1}{2}\sigma^2 u_{xx} +$$
$$\max_{\delta^b} \lambda^b(\delta^b)[u(s,x-s+\delta^b,q+1,t) - u(s,x,q,t)] + \max_{\delta^a} \lambda^a(\delta^a)[u(s,x+s+\delta^a,q-1,t) - u(s,x,q,t)] = 0 \tag{5}$$

$$u(s,x,q,T) = -exp[-\gamma(x+qs)] \tag{6}$$

It allowed determination of purchase and sale offer of a particular security in any moment in time:

$$r^a(s,q,t) = \theta_1 + 2q\theta_2 + \frac{1}{\lambda}\log\left(1+\frac{\lambda}{k}\right) - 2\theta_2 \tag{7}$$

$$r^b(s,q,t) = \theta_1 + 2q\theta_2 - \frac{1}{\lambda}\log\left(1+\frac{\lambda}{k}\right) + 2\theta_2 \tag{8}$$

The above calculations decisively simplify assuming the final time horizon. Then, the best investment strategy is reserving cash under the purchase sale order respectively as:

$$r^a(s,q,t) = s + (1-2q)\cdot\frac{\gamma\sigma^2(T-t)}{2} \tag{9}$$

$$r^b(s,q,t) = s + (-1-2q)\cdot\frac{\gamma\sigma^2(T-t)}{2} \tag{10}$$

## Research results and discussion

In order to better present effects of operation of the investment algorithm, results were divided into two parts

I. effect of operation for single session day,
II. effect of operation for the whole considered period

**First session day**

Data which characterize the first session day were presented in table 1, whereas on plot 1-3 respectively quotations of the futures contract for coffee, portfolio condition and the condition of possessing securities by an investor, were presented.

Table 1
*First session day – summary*

| Property | Values |
|---|---|
| Date: | 14-04-2014 |
| Time of first quoting | 10:00:36 |
| Time of last quoting | 18:29:48 |
| Opening price | 2 135.00 |
| Closing price | 2 136.00 |
| High | 2 154.00 |
| Low | 2 119.00 |
| Change of the opening price in comparison to the closing price of the previous session | - 10.00 i.e. -0.47% |
| Change of the closing price in comparison to the opening price | 1.00 i.e. 0.05% |
| Number of quotations | 613 |
| Number of signals / Number of purchase transactions according to the model | 115/69 |
| Number of signals / Number of sale transactions according to the model | 131/69 |
| Number of signals for sale in the period of purchase blocking | 8 |
| Condition of a portfolio at the opening of the session day | 100 000.00 |
| Condition of a portfolio at the closing of the session day | 101 595.00 |
| Daily return rate of the invested funds | 1.60% |

Comparing quotations of the contract on fig. 1 and the condition of a portfolio on fig. 2, it should be stated that although the quotation has dropped from opening the session to 2:26:52 p.m. by 0.755 the condition of a portfolio gradually increased. Transactions carried out at slight fluctuations of quotation allowed working out the increase of the portfolio value by 0.66%. The reported sudden decrease of quotation between 4:33:39 – 4:53:58 p.m. by -0.79 influenced the decrease of a portfolio by -0.46%. Whereas, quite fast increase of the quotation between 4:53:58-5:55:53 by 0.94% caused the increase of a portfolio by 0.75%. The condition of a portfolio presented in fig. 3 at the beginning of a session allowed purchase of 46 securities at 10:17:16 through the increase of its value to £ 100 138.00 and decrease of securities quotation by £ 6.00 allowed purchase on a one-off basis as much as 47 securities, which allowed more effective use of possessed funds on a hypothetically owned brokerage account.

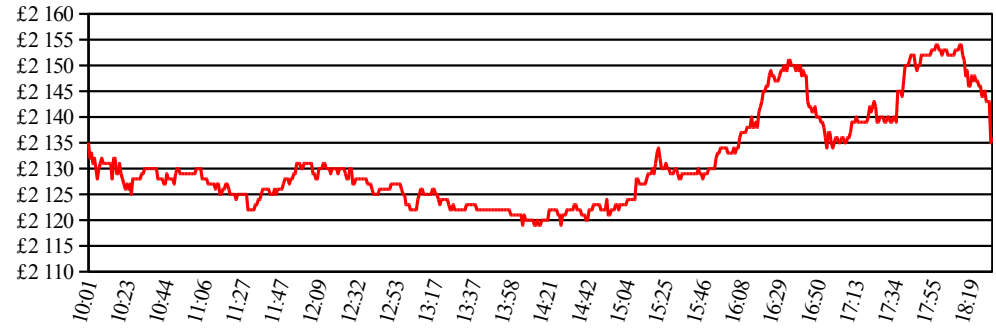


*Figure 1. Quotation of the futures contract on the first session day*

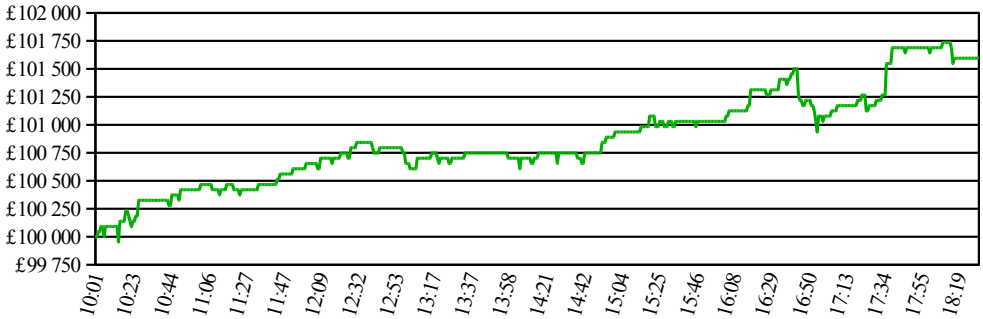


*Figure 2. Condition of a portfolio on the first session day*

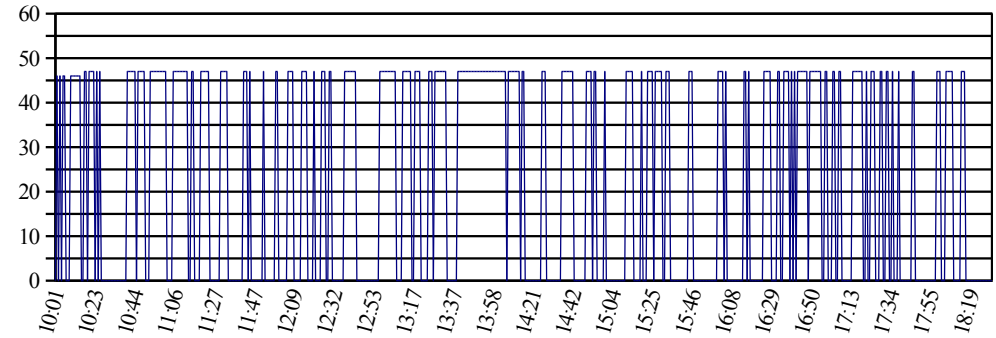


*Figure 3. Condition of possessing securities on the first session day*

**Full analysed period of investment**

In order to better reflect differences of quotations and the condition of a portfolio of subsequent ten session days, they were presented in tables 2 and 3.

Table 2
*Differences of opening and closing prices and the value of a portfolio of ten session days*

| Session day | Price | | Portfolio | | Differences | |
|---|---|---|---|---|---|---|
| | of opening | of closing | at the opening | at the closing | in prices | of a portfolio |
| 1 | 2 135.00 | 2 136.00 | 100 000.00 | 101 595.00 | 0.05% | 1.60% |
| 2 | 2 142.00 | 2 126.00 | 101 595.00 | 101 972.00 | -0.75% | 0.37% |
| 3 | 2 097.00 | 2 068.00 | 101 972.00 | 103 759.00 | -1.38% | 1.75% |
| 4 | 2 069.00 | 2 124.00 | 103 759.00 | 105 603.00 | 2.66% | 1.78% |
| 5 | 2 136.00 | 2 161.00 | 105 603.00 | 107 699.00 | 1.17% | 1.98% |
| 6 | 2 179.00 | 2 178.00 | 107 699.00 | 107 993.00 | -0.05% | 0.27% |
| 7 | 2 164.00 | 2 171.00 | 107 993.00 | 109 139.00 | 0.32% | 1.06% |
| 8 | 2 174.00 | 2 155.00 | 109 139.00 | 109 189.00 | -0.87% | 0.05% |
| 9 | 2 117.00 | 2 132.00 | 109 189.00 | 109 550.00 | 0.71% | 0.33% |
| 10 | 2 118.00 | 2 145.00 | 109 550.00 | 110 213.00 | 1.27% | 0.61% |

When analysing difference of the portfolio values in table 2 one may observe that the analysed model did not cause any loss within ten years. In seven cases out of ten, the model of algorithmic trading gave better results than quotation differences. It should be emphasised that calculations were made without including price fluctuations between subsequent sessions, that is the so-called reference price.

For the assessment of the accepted investment algorithm, Information Ration (IR) – of one of the most popular ratios for comparison of the level of risk of various investment strategies was additionally determined.

$$IR = \frac{\sum_{i=1}^{m} \frac{R_i - R_m}{n}}{\sqrt{\sum_{i=1}^{m} \frac{(R_i - R_m)^2}{n-1}}}, \tag{20}$$

where:

$R_i$ – rate of return from the analysed model in the period i

$R_m$ – rate of return from benchmark (reference rate) in this case it concerns quotations

n – length of the analysed period.

IR values lower than 0.5 should be recognized as unfavourable. IR values within $[0.50; 0.75]$ are recognized as good. After exceeding the level of 0.75 the investment should be recognized as particularly favourable. The value of ratio was calculated at the level of 0.52 which proves that the analysed model brought good results.

Maximum Drawdown was the second ratio, determined by authors; size, which describes the highest percentage loss in the analysed period.

$$MD = \min_{i=1,\ldots,t;t=1,\ldots,N} \sum_{j=1}^{t} R_j \,, \tag{21}$$

Upon the data analysis of this ratio for two variants of investing (traditional model - HFT model), it proved that HFT model characterizes with considerably lower risk of drawdown. It is reflected in data in table 3.

Table 3
*Maximum Drawdown rates and accompanying data for two investing variants*

| Property | Describing data | |
|---|---|---|
| | Standard manner of investment | Analysed HFT model |
| Moment of purchasing securities | 18:12:38 14-04-2014 | 11:35:41 23-04-2014 |
| Moment of selling securities | 14:54:40 17-04-2014 | 15:22:24 23-04-2014 |
| Capital up | 100 000.00 | 108 385.00 |
| Capital down | 95 400.00 | 106 621.00 |
| Drawdown | - 4 600.00 | - 1 764.00 |
| Value of ratio | -4.60% | -1.63% |

Comparison of effects and some features of two methods within 10 session days is presented by data in table 4. The analysed HFT model did not cause loss in the entire period as well as on any particular day.

Table 4
*Differences between a standard investing model and the analysed model of algorithmic trading*

| Property | Standard manner | Acc. to the analysed model |
|---|---|---|
| Invested funds | 100 000.00 | 100 000.00 |
| Profit | 460.00 or 3174.00 | 10 213.00 |
| Loss | - 3 726.00 or - 4 600.00 | Not reported |
| Rate of return | 0.46% or 3.17% or -3.73% or -4.60% | 10.21% |
| Number of transactions made | 2 | 1.454 |
| Price risk | High | Minimized |
| Availability of funds out of session | Lack | Available |

Investor using the standard method may sell securities in the moment, when he/she finds it appropriate. A human factor, in the form of emotions, has a great impact on the possibility of great loss in the standard investing. The investor, who incurs losses, still hopes that quotations will come back to the level, at which, at least, he bought securities. Usually, it is not like that and further adjournment of selling securities deepens the loss. There is a great probability that the investor might decide on the sale of securities only when they reach the most unfavourable price. Model of algorithmic trading eliminates the factor of emotions which accompanies taking up decisions on a transaction, which mainly allows limiting losses. It is very important from a clearly arithmetic point of view, because the amount, which should be made up, rises considerably faster than the incurred loss (Zaremba, 2010).

## Conclusions and statements

As it was presented in the paper, the model of algorithmic trading suggested by Avellaneda and Stoikov based on High Frequency Trading, may be successfully used in the agricultural and derivative commodities trading assuming considerably high market liquidity. It may cause obtaining additional profits by farmers, who may thus get advantage over competition.

At the use of stock ratios Information Ratio and Maximum Drawdown, it was confirmed that the analysed model of algorithmic trading is a good tool for investing in comparison to standard methods and is characterised with lesser risk of drawdown.

Analysis of particular days proved that in seven out of ten cases this model is a better method and, what is more important, did not cause any loss on any particular day. The calculated theoretical profit at the level of 10.21% worked out within ten session days at a low risk, as proved by the model, even after including provision of the brokerage house for carrying out a transaction, it would be satisfactory for each investor.

Through the use of author's blocking of securities purchase15 minutes before the end of the session, funds, out of session hours, may be invested on other stock exchanges, FOREX markets, which operate 24 hours a day or on overnight deposits, where they are invested in countries with other time zone. Thus, due to this blocking, the value of a portfolio was made non-dependent of the price fluctuations between sessions.

In order to improve the model suggested in the paper, sensitivity analysis of strategy on arbitrally assumed parameters such as e.g. liquidity and considerably extend time interval included in the research. Investigation of execution of orders is an open problem, which was not discussed, i.e. verification of the time from the moment of confirmation of an order to its execution and how it influences the summary volume of orders on shaping the sale price. Verification of behaviour of the described algorithm, which would have to compete with other investment robots, would also be an interesting cognition aspect.

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# HIGH FREQUENCY TRADING W HANDLU TOWARAMI POCHODZENIA ROLNICZEGO JAKO ŹRÓDŁO DODATKOWEGO DOCHODU W ROLNICTWIE

**Streszczenie.** W pracy sprawdzono przydatność modelu szybkiego kupna i sprzedaży (High Frequency Trading) Marco Avellanedy i Sashy Stoikov'a, użytego w symulacji obrotu walorami kontraktu terminowego na towar pochodzenia rolniczego na wybranej giełdzie towarowej. Zbadano trafność podawanych sygnałów transakcji kupna i sprzedaży na autentycznych notowaniach - kontrakt terminowy na ceny kawy londyńskiej giełdy papierów wartościowych (London Stock Exchange). Szczegółowo zanalizowano wyniki dziesięciu kolejnych dni sesyjnych. Jakość przyjętego algorytmu inwestycyjnego określono za pomocą wskaźników giełdowych: Information Ratio oraz Maximum Drawdown. Przeprowadzono krótką dyskusję porównującą standardową metodę inwestowania oraz analizowany model handlu algorytmicznego. Na zakończenie zebrano najważniejsze stwierdzenia i wyciągnięto wnioski potwierdzające przydatność modelu HFT Marco Avellanedy i Sashy Stoikov'a do obrotu walorami kontraktów terminowych na towary pochodzenia rolniczego o dużej płynności oraz możliwość jego praktycznego zastosowania.

**Słowa kluczowe:** arbitraż statystyczny, High Frequency Trading, giełda towarowa, handel algorytmiczny.

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# EFFICIENCY IN THE USE OF AGRICULTURAL TECHNIQUE

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ABSTRACT

The objective of the paper was to determine appropriate relations between efficiency and effectiveness of implementing the scientific and technical progress and work organization with the use of the EU funds. In 2004-2009 70 selected family farms from the province of Biłgoraj, which benefit from the EU funding for technical modernization, were investigated. The period prior to and after obtaining the aid was analysed. Efficiency of using agricultural engineering referred to the amount of aid and the net commodity production was the highest in farms, which were big with respect to the area and economy. The costs of obtaining grain units (GU) were decreasing along with the increase of the economic size of farms, while the net commodity production was rising in these farms. Efficiency of using the EU funds for technical modernization was presented in each investigated group of farms, but these funds were the most effectively used in farms with the area up to 70 ha of AL, which is mainly determined by the AL area, economic size, level of the obtained farming effects and the level of providing the work station with infrastructure. In farms with smaller areas, a high level of the employment infrastructure, at the simultaneous loading with high costs of mechanization means, was proved. Modernization of farms, considerably influences the production process, all mechanization rates increase including: the replacement value of mechanization means, the level of technical infrastructure of employment, installed power, objectified work inputs, human labour expenditures, employee infrastructure, energy infrastructure of employment, mechanization degree and the net commodity production ($GU \cdot ha^{-1}$ AL).

## Introduction

Various projects, also called the EU funds, related to funding economic activity with regard to the production technology quality or social and environmental activities are the most frequently used form of aiding agriculture, next to extensive forms of counselling (Program rozwoju…, 2007). These operations aim at the improvement of the agrarian structure of rural areas, shift in the production organization, limitation of work tiresomeness, maintaining biodiversity in the natural environment and even vocational retraining of agricultural producers. Majority of these activities may be carried out through the improvement

of organization and mechanization of work processes in agriculture (Malaga-Toboła, 2006). Technical and scientific progress in the commodity and developing farms (businesses) results in the increase (Δ) of specific effects (advantages). Most often these are the production effects ($+\Delta GU \cdot ha^{-1}$ AL), energy effects ($-\Delta MJ \cdot GU^{-1}$), economic effects ($-\Delta$ PLN$\cdot GU^{-1}$) and ecological effects ($-\Delta$ of the environment degradation) (Wójcicki, 2008). The manner of the production organization, which is expressed in the increase of its intensity ratio is a factor, which enables smaller farms to obtain a family income (Sawa, 1998). Family farms, as a rule, intensively organize the production process and along with the increase of the farm area decrease of intensity of production business activity takes place. Efficiency of technical modernization of farms is related to the farming system, which includes rationality and effectiveness in the use of the production factors (external and internal) in order to increase the production size (Encyklopedia..., 1984). Provided that efficiency is related to minimization of costs or maximization of effects, then effectiveness of operation, which is understood as the ability to achieve aims in a rationally determined time, is a factor that favours this process. Efficiency and effectiveness of operations are elements of the management process and influence production capacities e.g. of a family farm. The increase of manufacturing capacities results from the efficient management and implementation of the mechanized production technologies, which shape appropriate work and living conditions of agricultural population, enabling reduction of differences in the technical and economic conditions of production between regions, group of farms and branches of agricultural production branches but limiting negative ecological threats resulting from agricultural production processes. The dynamics of this process, defined as efficiency of operations is expressed with realization of the objectives (in the rationally determined period of time) with the use of available capital resources, which allow increase in the level of infrastructure and the degree of the work process mechanization. Presently, access to the EU funds enables technical modernization of the process in family farms, but the problem consists in ensuring efficiency in the realization of those modernization processes (Wójcicki, 2009; Szeląg-Sikora, Kowalski, 2010). Increase of productivity in agriculture enables mechanization of production processes, which also causes improvement of working conditions (Pawlak, 2010; 2011). However, in order to decrease the costs of agricultural production, attention should be paid to the rational and effective use of the possessed machinery park.

The objective of the paper was to determine appropriate relations between the efficiency and effectiveness of implementing a scientific and technical progress and work organization with the use of the EU funds.

## Material and methodology of research

In 2004-2009 70 agricultural farms from the province of Biłgoraj, which benefit from the EU funding for technical modernization, were investigated. The investigated group of farms was divided acc. to the criterion of the aid amount, the AL area and the economic size unit (ESU). It was assumed that the technical effectiveness is expressed by the net commodity production for technical equipment of farms. Whereas presenting the value of its equipment referred to the aid amount expresses the economic effectiveness. Grouping farms acc. to the AL area allowed assessment of the production scale effectivenessand acc. to the ESU - the allocation effectiveness. The effectiveness ratio is determined by the pro-

duction level (P) and the amount of the incurred expenditures (N) (Pawlak and Wójcicki, 1993). Proportions between elements of the effectiveness ratio ($E = P \cdot N^{-1}$) depend on the production factors. In the research, which was carried out, the amount of the aid is a production effect, strictly related to the level of the net commodity production. Evaluation of the effectiveness of the technical modernization of family farms was based on the technical and economic ratios including: the replacement value of the mechanization means, the level of technical infrastructure of employment, installed power, inputs of the objectified work, expenditures of human labour, the employee infrastructure, energy infrastructure of employment, mechanization degree acc. to Zaremba (1985) and the net commodity production ($GU \cdot ha^{-1}$ AL). Particular technical and economic indexes describe the family farms modernization efficiency fractionally. In order to verify whether it is high or low, whether is is improving or deteriorating, the basis for referral is necessary. In the investigated farms, the period before purchase of mechanization means was assumed as a basis (before funding - the basic year).

## Research results

Analysis of efficiency in the agricultural engineering referred to the amount of aid and the net commodity production proved that it is the highest in farms, which are big with respect to the area and economy. However, there is a great difference between the level of the obtained net commodity production ($GU \cdot ha^{-1}$ AL) and the amount of the incurred production expenses, which mainly consist in production circulating assets and the costs of using mechanization means. The costs of obtaining GU (fig. 2) were dropping along with the increase of the economic size of farms (from 48.9 to 25.7 $PLN \cdot GU^{-1}$). Whereas, net commodity production in those farms increased (from 46.5 to 148.4 $GU \cdot ha^{-1}$ AL).

The research show that the highest commodity production is obtained when the ratio of the costs of using mechanization means to the expenditures on production circulating assets does not exceed 40% (Sawa, 1998). Agricultural engineering enables their better use. The level of production is strictly related to the efficiency ratio of using the agricultural engineering, which is visible in farms with the highest economic viability. The production scale and the production system of a farm as well as its rational engagement in the production process have a considerable impact on the efficiency of agricultural engineering (Lorencowicz, 2005). Efficiency of mechanization of the agricultural production process is determined with efficiency of using the EU funds, which increases the net commodity production (Wasąg, 2011).

Efficiency of technical modernization of the investiagted farms (table 1) was described including the AL area. In the targeted year, the replacement value of the mechanization means increased in all groups of farms divided acc. to the AL area. The biggest difference in comparison to the base year (before funding) was reported in the smallest farms with regard to the area (18%) and the biggest farms (32%). It proves more rational use of machines by farms with bigger AL area (Wasąg, 2011). The ratio of the level of technical infrastructure of employment was increasing proportionally to the area (AL ha) and the highest value in comparison to the base year achieved in farms with the area of 70 ha AL

(61.7%). The highest increase of power installed was reported in farms up to 10 and from 10-30 ha AL (46.4 and 35.5%) and above 70 ha AL (26.1%).

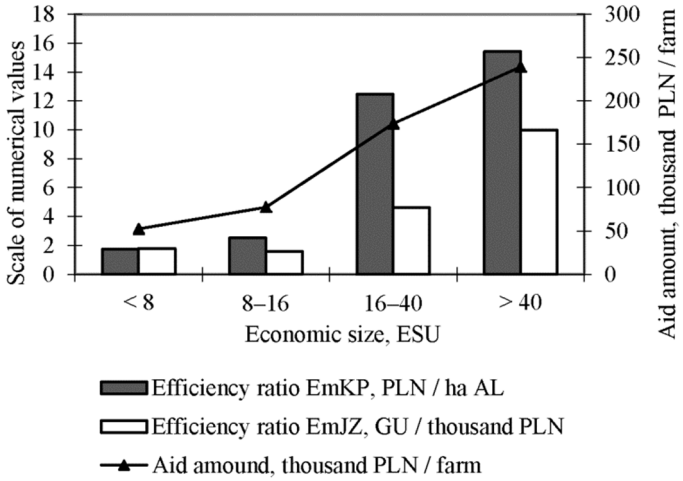


*Figure 1. Efficiency in the use of agricultural engineering with reference to the aid amount*

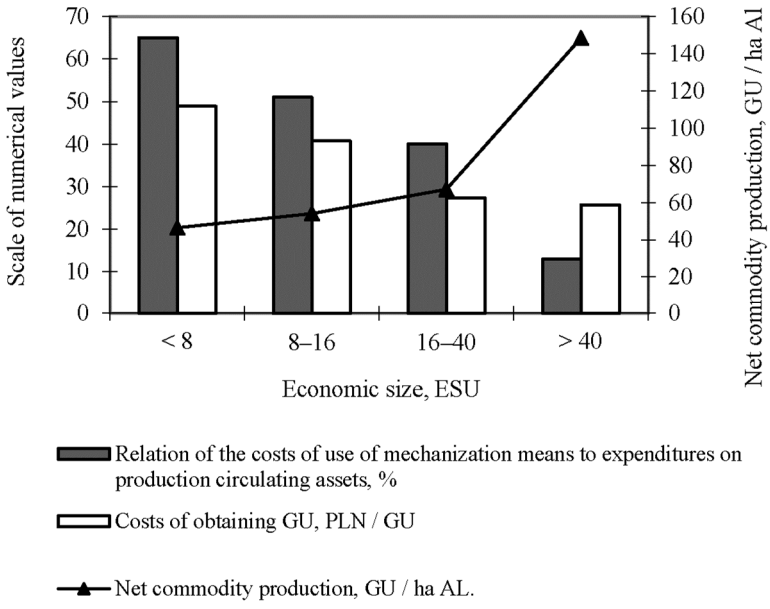


*Figure 2. Efficiency in the use of agricultural engineering with reference to the net commodity production*

Table 1
*Efficiency and effectiveness of technical modernization of the investigated family including their area*

| Specification | Measure unit | Farm area (ha AL) | | | | | | | | | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | < 10 | | 10–30 | | 30-50 | | 50-70 | | > 70 | | | |
| | | by. | ty. | by. | ty. | by. | ty. | by. | ty. | by. | ty. | by. | ty. |
| Number of farms | number | 11 | | 41 | | 6 | | 3 | | 9 | | 70 | |
| Replacement value of mechanization means | (thousand PLN · ha$^{-1}$ AL) | 43.9 | 52.0 | 32.6 | 39.4 | 19.3 | 20.3 | 16.3 | 16.9 | 11.4 | 15.1 | 24.7 | 28.7 |
| Changes in the replacement value of mechanization means | (%) | | 118.5 | | 121.1 | | 104.8 | | 103.3 | | 131.9 | | 116.3 |
| Index of the technical level of work infrastructure | (PLN · manhour$^{-1}$) | 6.6 | 9.0 | 11.5 | 14.9 | 12.2 | 17.8 | 13.8 | 20.0 | 14.3 | 23.2 | 11.7 | 17.0 |
| Change of technical level of work infrastructure | % | | 137.0 | | 129.8 | | 145.6 | | 144.5 | | 161.7 | | 145.2 |
| Installed power | (kW ·100 ha$^{-1}$ AL) | 848 | 1241 | 673 | 912 | 461 | 526 | 472 | 424 | 360 | 454 | 563 | 712 |
| Change in the installed power | % | | 146.4 | | 135.5 | | 114.0 | | 89.8 | | 126.1 | | 126.4 |
| Inputs of the objectified work | (kWh·ha$^{-1}$ AL) | 2562 | 3197 | 1735 | 2033 | 1285 | 1151 | 1425 | 999 | 880 | 1398 | 1577 | 1756 |
| Change of the inputs of the objectified work | % | | 124.8 | | 117.2 | | 89.6 | | 70.1 | | 158.8 | | 111.3 |
| Inputs of human labour | (manhour·ha$^{-1}$ AL) | 475 | 477 | 227 | 207 | 109 | 95 | 122 | 77 | 77 | 68 | 202 | 185 |
| Change of the inputs of the objectified work | (%) | | 100.5 | | 91.1 | | 87.0 | | 63.3 | | 87.8 | | 91.5 |
| Infrastructure provided to an employee | (thousand PLN·opz$^{-1}$) | 262 | 359 | 460 | 597 | 488 | 711 | 553 | 799 | 573 | 927 | 467 | 679 |
| Change in the infrastructure provided to an employee | (%) | | 137.0 | | 129.8 | | 145.6 | | 144.5 | | 161.7 | | 145.2 |
| Energy infrastructure of work | (kWh·manhour$^{-1}$) | 9.2 | 12.3 | 14.5 | 18.0 | 20.6 | 25.7 | 27.9 | 32.8 | 33.8 | 51.5 | 21.2 | 28.0 |
| Change in the energy infrastructure of work | (%) | | 133.4 | | 123.6 | | 124.4 | | 117.5 | | 152.2 | | 132.1 |
| Index of the mechanization degree acc. to Zaremba | (% acc to Zaremba) | 47.8 | 57.7 | 59.4 | 66.8 | 69.5 | 71.2 | 67.4 | 73.2 | 70.8 | 75.3 | 63.0 | 68.8 |
| Change in the index of the mechanization degree acc. to Zaremba | (%) | | 120.6 | | 112.5 | | 102.4 | | 108.5 | | 106.4 | | 109.3 |

by. – the basic year (before funding) = 100% ty. – the targeted year (after funding)

The inputs of the objectified work were shaping similarly to the replacement value of the mechanization means. However, farms with the area 30-50 and 50-70 ha AL, were in comparison to the base year (before funding) lower respectively by 10.4 and 29.9%. Whereas, the human labour expenditures in both periods were the highest in the smallest farms and decreased along with the increase of the AL area. Technical infrastructure of an employee and the energy infrastructure of employment increased propotionally to the increase of the area (ha AL) and the aid amount (thousand PLN·farm$^{-1}$). It was stated that in the targeted year, the index of the mechanization degree (which characterizes the work process), except for farms below 10 ha AL (57.7%) was at the high level (from 66.8 to 73.2%). It was the highest in the biggest farms with respect to the area, and in each investigated group (ha AL) its increase was reported in comparison to the base year.

## Conclusion

Efficiency in the use of agricultural engineering referred to the amount of aid and the net commodity production is the highest in farms, which were big with respect to the area and economy. The costs of obtaining grain units (GU) were decreasing along with the increase of the economic size of farms, while the net commodity production was rising in these farms. Efficiency of using the EU funds for technical modernization was presented in each investigated group of farms, but these funds were the most effectively used in farms with the area up to 70 ha of AL, which is mainly determined by the AL area, the economic size, the level of the obtained farming effects and the level of the work station infrastructure. Technical infrastructure considerably influences the agricultural production process since it enables better use of the production circulating asset. In farms with smaller areas, a high level of the employment infrastructure, at the simultaneous loading with high costs of mechanization means, was proved. Modernization of farms considerably influences the production process, all mechanization rates increase, including: the replacement value of mechanization means, the level of the employment technical infrastructure, installed power, objectified work inputs, human labour expenditures, employee infrastructure, energy infrastructure of employment, the mechanization degree and the net commodity production (GU·ha$^{-1}$ AL).

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## EFEKTYWNOŚĆ STOSOWANIA TECHNIKI ROLNICZEJ

**Streszczenie.** Celem pracy było określenie właściwych relacji pomiędzy sprawnością a skutecznością wdrażania postępu naukowo-technicznego i organizacji pracy, przy wykorzystanie funduszy UE. W latach 2004-2009 przebadano 70 wybranych gospodarstw rodzinnych z powiatu biłgorajskiego korzystających z dofinansowania UE na modernizację techniczną. Analizowano okres przed i po otrzymaniu pomocy. Efektywności stosowania techniki rolniczej w odniesieniu do kwoty pomocy i produkcji towarowej netto była najwyższa w dużych obszarowo oraz ekonomicznie gospodarstwach. Koszty uzyskania jednostek zbożowych (JZ) malały wraz ze wzrostem wielkości ekonomicznej gospodarstw, natomiast produkcja towarowa netto w tych gospodarstwach wzrastała. Efektywność wykorzystania funduszy UE na techniczną modernizację wykazano w każdej z badanych grup gospodarstw, ale środki te były najskuteczniej wykorzystywane w gospodarstwach do 70 ha UR, co jest determinowane przede wszystkim powierzchnią UR, wielkością ekonomiczną, poziomem uzyskiwanych efektów gospodarowania oraz poziomem uzbrojenia stanowiska pracy. W mniejszych obszarowo gospodarstwach wykazano wysoki poziom uzbrojenia pracy, przy jednoczesnym obciążeniu wysokimi kosztami środków mechanizacji. Modernizacja gospodarstw rolnych znacząco wpływa na proces produkcji, wzrastają wszystkie wskaźniki mechanizacji, w tym: wartość odtworzeniowa środków mechanizacji, poziom uzbrojenia technicznego pracy, moc zainstalowana, nakłady pracy uprzedmiotowionej, nakłady pracy ludzkiej, uzbrojenie pracownika, uzbrojenie energetyczne pracy, stopień mechanizacji i produkcja towarowa netto ($JZ \cdot ha^{-1}$ UR).

**Słowa kluczowe:** gospodarstwo rodzinne, technika rolnicza, sprawność, skuteczność, powierzchnia UR, wielkość ekonomiczna, kwota pomocy

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# THE USE OF THE SCILAB SOFTWARE WITH A RTAI EXTENSION FOR PROTOTYPING A TEMPERATURE CONTROLLER OF THE THERMAL BIOMASS PROCESSING INSTALLATION

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ABSTRACT

The objective of the paper was to design and test various variants of the thermal biomass processing controllers. The process took place in a batch reactor consisting of a metal chamber into which thermal energy was supplied through a diaphgram with the use of a 2 kW power ceramic band heater. The chamber of the reactor along with the heater was thermally insulated. A classic solution of a PID controller and its variety - a robust PID controller, resistant to the object parameters fluctuations was selected for tests. The Linux Debian system and the SciCosLab environment, consisting of graphic SciCos environment were used for the operation of the stand. The system kernel was modified for operation in real time through a RTAI module (Real Time Application Interface). Analysis of the results shows that, a robust controller ensures better quality, which besides a shorter time of response, behaves better in case of the object parameters fluctuations.

## Introduction

Research on prototyping a controller for temperature control of the thermal biomass processing resulted from the necessity to develop an effective system of maintaining stable temperature in the batch reactor, which is the control object. The control object was designed for research on the thermal biomass processing. A reactor is a complex thermodynamic system, in which phase changes and heat exchange phenomena take place. Due to the process complexity and many unknown physical coefficients, creating a mathematical model of the thermal biomass processing in a batch reactor is very difficult based on the physics law. In order to determine the process model, which is indispensable for setting a controller, identification tests were carried out by a "black box" method. The black box method consists in the input and output signals analyses and the obtained parameters are physically senseless. In the research on modelling the process, parametric identification was applied and the model structure was accepted as an inertial object with a transport delay. Then, parameters of the accepted model structure were determined from the object step

response. The presented method of obtaining the process model is an efficient method for inertial objects with a transport delay and enables fast prototyping of controllers.

## The objective and scope of the paper

The objective of the paper was to select a temperature controller in the thermal biomass processing reactor, which would ensure resistance to the object parameterschanges, which mainly result from an endothermic reaction inside it. For this purpose, a classic PID controller and a robust PID controller were designed and tested and then a comparative analysis of the obtained controllers concerning heating and maintaining temperature in the reactor was carried out. An industrial computer with x 86 platform operating under the Linus Debian control, whose kernel was modified to work inreal time through the RTAI module (Real Time Application Interface) was used for the research. The SCILAB environment with a graphic extension SciCosLab for simulation, measurement and testing inreal time was installed.

The control object consists of a metal chamber and a ceramic heater which encircles the reactor chamber, the power of which is 2 kW. The reactor chamber along with the heater was thermally insulated by aluminosilicate insulation. Identification research and tests of the selected controllers were carried out on the presented reactor. A classic solution was selected, namely a PID controller and a robust PID controller. A very popular binary controller was not used in the tests on account of great thermal volume of the metal casing, which would have resulted with considerable readjustments in comparison to the set value.

Programming environment, as well as an operational system, used in the construction process of the stand, was selected due to the open source. The Linux Debian and SciCosLab environment, which includes the graphic environment SciCos, was applied. The system kernel was modified for operation in real time through the RTAI module (Real Time Application Interface). The COMEDI controllers, which combine a programmer layer with expansion cards connected to the ISA or PCI buses, are significant factors.

Implementation of temperature controllers of the pyrolysis reactor in Linux x86 system with the installed RTAI module.

Figure 1 presents a schematic representation of the control system used for controlling the process temperature in the reactor. It is an example of the control system in the closed system, which performs the task of stabilization of the controlled size in the HIL technology (English: Hardware In The Loop) – the HIL simulation technology which consists in connecting a part of a real object to the feedback loop.

Thermal biomass processing temperature control takes place through a computer equipped with the Linux-RTAI system. Suitable controllers implemented on the above mentioned platform are the process controllers.

Model identification, construction and tests of controllers, as well as their later research took place in the open source software available in Linux-SciCosLab. A description of the programming foundations and particular blocks is included in the available literature (Campbell et al., 2006; Bucher et al., 2008; 2010).

Based on Brzózka's publication (2002) it was determined that the sampling period for temperature control systems should be within 10 to 20 s. Controllers should be prepared for the sampling time of 10 s. Unfortunately, restrictions of the SciCosLab software and the

RTAI-Lab software caused the need to set the controllers for a shorter sampling time of 1 s, which resulted only in the necessity to increase the calculation power of the computer.

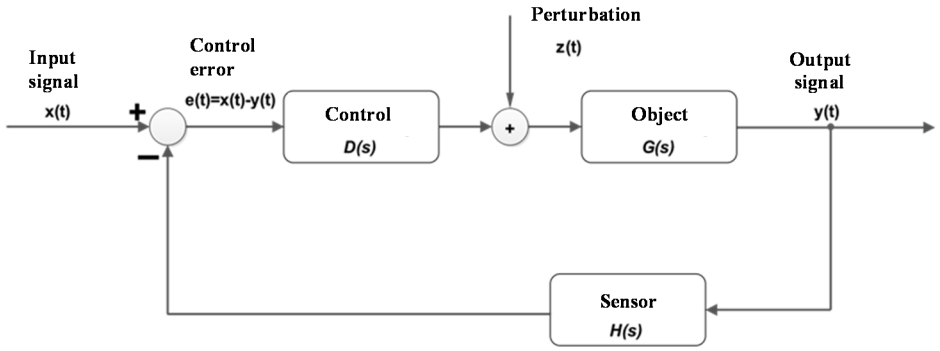


*Figure 1. A schematic representation of the stand for control of the pyrolysis process temperature*

**Model identification**

Each dynamic linear model is characterized with transmittance expressed with a general formula:

$$G(s) = \frac{L(s)}{M(s)} \tag{1}$$

in the case of the first degree inertial delay model:

$$G(s) = \frac{k}{sT+1} e^{-sT_0} \tag{2}$$

where:

$G(s)$ – operator transmittance,
$k$ – reinforcement,
$T$ – time constant,
$T_0$ – transport delay time

The object of the paper was to construct a temperature controller of biomass thermal processing. Thus, a parametric identification method was selected. It assumes linearity of the control object in the entire scope of the control signal. This assumption is correct in the case when the heated reactor is not filled with batch material. Such object defines then a multi-inertial structure, which the most frequently, is modelled as a first-degree inertia with a transport delay. A parametric method of identification consists in determination of the object parameters, the structure of which is known based on the analysis of the step response course for a step or impulse function (Łysakowska and Mzyk, 2005; Ogata, 2002).

The first step in the step response analysis of the system was to find a point of inflection of the step response (fig. 2). The point of inflection is in the place, where the first derivative reaches the maximum and the other derivative equals zero (Bronsztejn et al., 2009;

Orzydłowski and Łobodziński, 2001). Figure 2 presents three plots: the upper plot presents the course of the step response of the system, the central – the course of the first derivative value, and the lower one presents the course of the second derivative value. Common point of all plots, which determines the point of inflection has been marked with a black line.

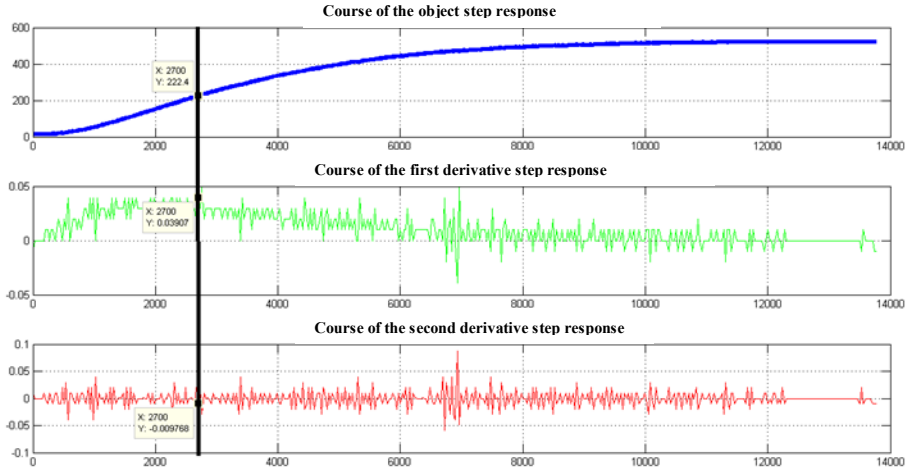


*Figure 2. Determined point of inflection*

In the point of inflection, a tangent to the course of step response was determined. The object reinforcement was determined as a relation of the temperature increase to the increase of the control signal value at the analogue output of the card. For the considered object this are respectively: 505℃ and 3.4V.

The approximate model data were read out from the plot (fig. 3):

reinforcement – k=148,5294, time constant – T = 4250s. delay – $T_o$ = 890.

In order to increase the preciseness of determination of the model parameters, optimization methods for searching for such parameters, which ensure the highest compliance with the real data, were applied. For this purpose, optimization of the function with the derivative- free optimization DFO was applied (Palczewski, 2014). This method consists in searching for the minimum of functions in the set range. The algorithm assumes a division of the segment into smaller parts and searching for the minimum in the vicinity of the centre of the selected segment.

As a result of optimization, new model values were obtained:
reinforcement – k=150,5294, time constant – T = 2670 s. delay – $T_o$ = 1294.

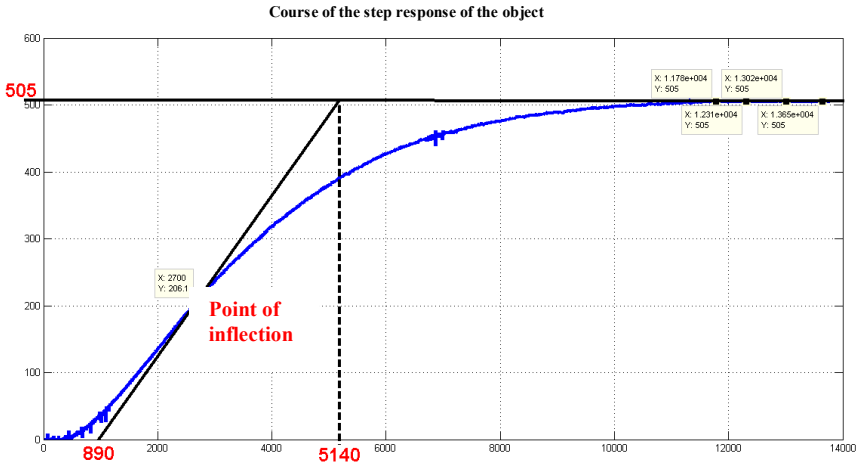


*Figure 3. Step response of the object with marked parameters: time constant, delay, reinforcement*

The obtained model served for setting controllers and their simulation tests. Transmittance of the constant model according to the above values and pattern (2) is:

$$G(s) = \frac{150.5294}{2670s+1} e^{-1294s} \tag{3}$$

**Construction and implementation of the PID controller**

Tunings of the PID controller (Brzózka, 2006) were presented in a discreet variant and calculated from Ziegler-Nichols formulas (Brzózka, 2006) in the following manner:

– proportional term: $$K = \frac{1}{k}\left(\frac{1{,}2T}{T_0+\frac{T_S}{2}} - \frac{0{,}3TT_S}{\left(T_0+\frac{T_S}{2}\right)^2}\right) = 0.016439, \tag{4}$$

– integrator: $$\frac{T_S}{T_i} = \frac{0{,}6TT_S}{K\left(T_0+\frac{T_S}{2}\right)^2 k} = 0.0003863, \tag{5}$$

– derivative term: $$\frac{T_d}{T_S} = \frac{0{,}5T}{KT_S k} = 539.4792, \tag{6}$$

where:

$k$ – reinforcement is: 150.5294,
$T_0$ – delay is: 1294 s,
$T$ – time constant is: 2670 s,
$T_s$ – sampling time is: 1 s.

The determined controller tunings controlled the temperature quite well. The only drawback of these tunings is a very long time of control which is approximately $7 \cdot 10^4$ s. The principles of the tunings selection with Ziegler – Nichols method provide only approximate, pictorial values of particular terms, at the same time they are the starting point for finding such tunings at which regulation takes place in a satisfactory manner (Ogata, 2002). Thus, it was decided to select manual tunings which ensure a more precise regulation. The tunings were selected with a trial and error method and the values of particular terms present as follows:

– proportional term: old value: 0.016439, new value: 8.0639,
– integrator: old value: 0.0003863, new value: 0.002563,
– derivative term: old value 539.5, new value 539.5

After the parameters are adjusted, the value is regulated with a greater precision and is obtained in a shorter time of $1.4 \cdot 10^4$-$1.5 \cdot 10^4$ s, which was presented in figure 4.

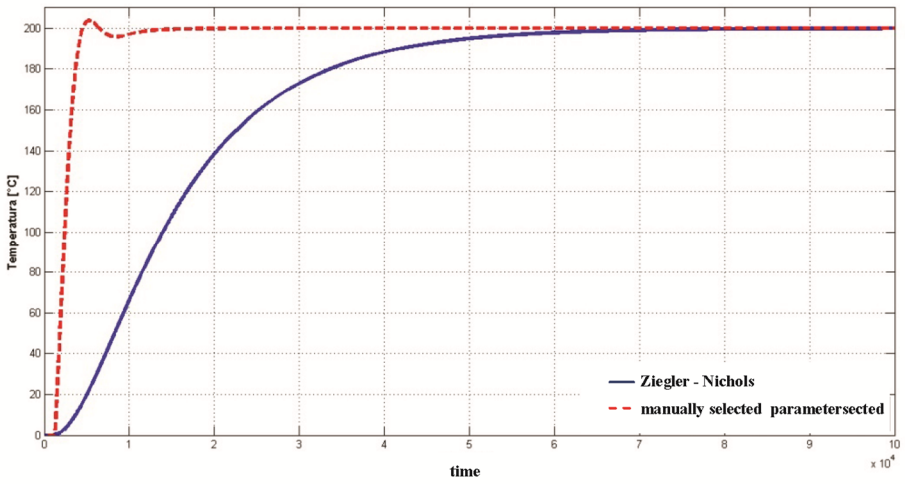


*Figure 4. The course of the value regulated by the discreet PID controller with the calculated values of tunings and manually selected parameters*

The Saturation block is a significant part of the PID controller. It limits values within 0 to 10, provided for the object. It prevents the effect of the controller tuning.

The PID controller design with the object model must have included input/output of the measurement card. Figure 5 presents the design appearance of the PID controller with a feedback loop in the HIL technology.

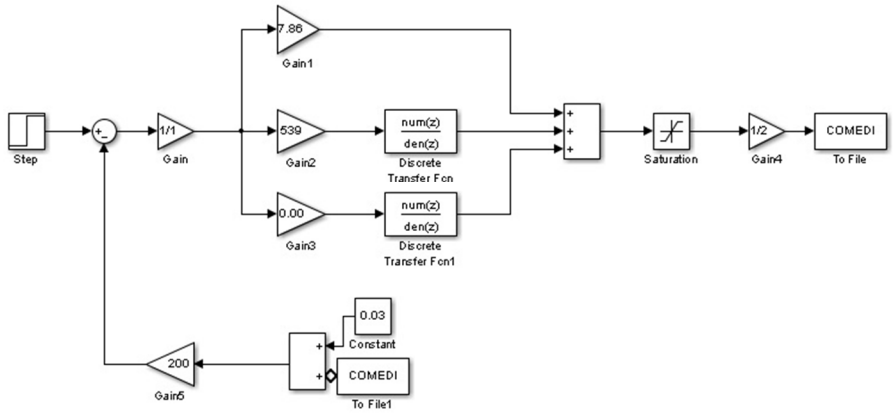


*Figure 5. Appearance of the PID controller with a feedback loop in the HIL technology made in SciCos programme with operation of the input/output cards with COMEDI controllers*

**Design and implementation of the robust PID controller**

A robust controller is such a discrete control system, which is not sensible to perturbations of the object parameters (Brzózka, 2002). Two connected controllers are used for its construction. One of them is responsible for regulation of the value set according to the introduced mathematical model parameters, whereas the other is responsible for regulation of the set value based on the real object. Such combination causes that the unit becomes insensible to big deviations of the object parameters.

The first PID loop assumes model values pursuant to the ones obtained during the identification process, whereas values of the PID controller correspond to the values described above. The second loop is related to the real object, the parameters of which may change during the process. In the designed model, perturbations in the form of changing model values (insulation is burnt, inaccuracy of reflecting the model parameters towards the real object, etc.) were included: time constant from the valueof 2670 s to the value of 2550 s, reinforcement changes from 150.5294 to 155, delay changes from 1294s to 1400 s.

Figure 6 presents the course of control of the value controlled by the described controller. This value was set with the PID controller response to the same signal. The robust controller showed greater readjustment which is related to the introduced perturbations in the form of model parameters changes. However, despite high parameters deviations, the controller in the time of approximately $1 \cdot 10^4$ s worked out the set point.

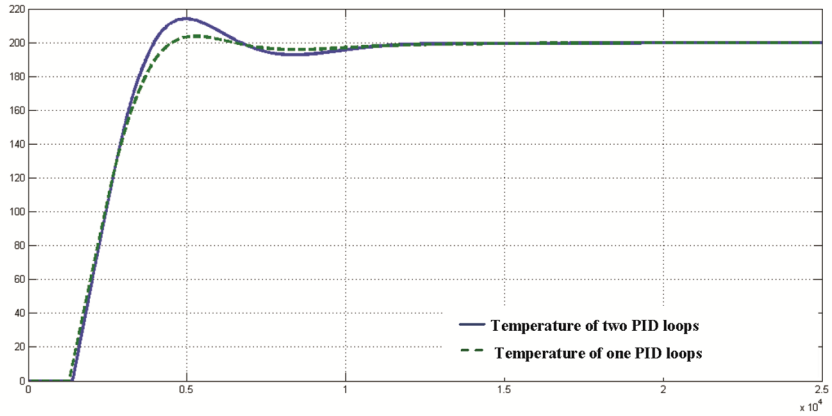


*Figure 6. The course of the value regulated by the discrete robust controller PID*

Like, in the case of the PID controller, it was necessary to adjust the PID robust controller to the operation with the COMEDI controllers. A schematic representation of such a controller is presented in figure 7.

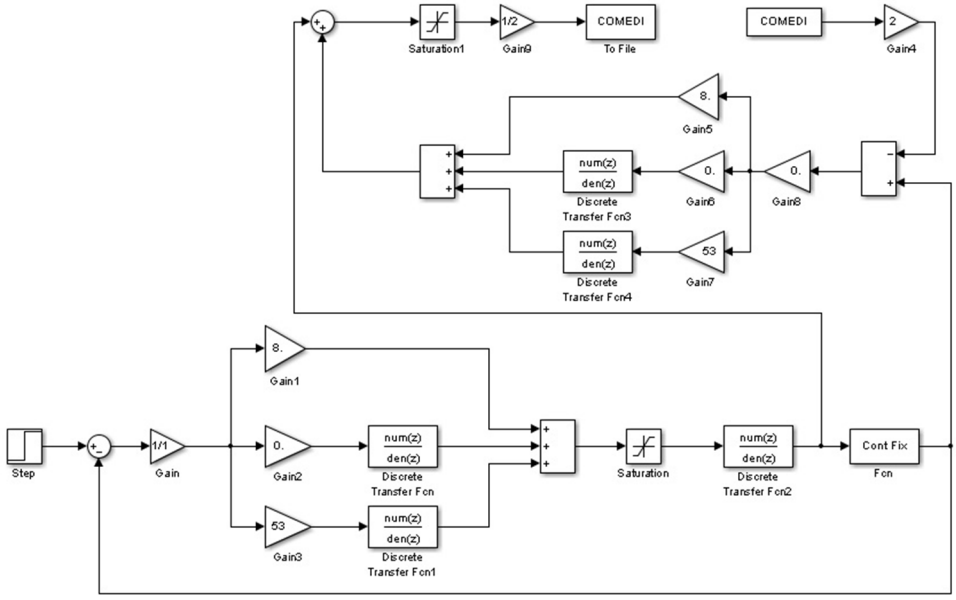


*Figure 7. Appearance of the PID controller with a feedback loop in the HIL technology made in the SciCos programme with operation of input/output cards with COMEDI controllers*

## Research results

Tests of the designed control system on the real object consisted in determination of dynamic properties of controllers with regard to the step function of the set point. The objective of the designed controllers was to achieve the set point in possibly the shortest time and with the possibly the smallest control error. In tests of both controllers, the set point was changing in a step manner from zero to the temperature of 200°C. The designed PID controller reflected very well the set temperature without readjusting in time, which was 7000s (less than 2 hours). Then, the value was within the limits198.3℃-200.2℃, which is in a possible control error and the readout error of thermocouple and conversion of its signal into a standardized signal within the tension standard 0-10V. Then, the second of the tested controllers, the robust PID controller was implemented. Temperature stabilization took place after 5700 seconds (approx. 1.5 h). The signal was within 198 -201°C which is within an admissible measurement error. Figure 8 presents the course of the controlled value (temperature) when using controllers on the real object- thermal biomass processing installation.

According to the comparison, the robust PID controller (green colour) worked out a signal in approx. 5700 s, whereas the PID controller (blue colour) worked out the same signal value in 6800 seconds. This difference is approx. 110 s, that is, almost 20 minutes. It should be emphasised that the robust controller started control from the temperature lower by approx. 7°C, which in the beginning of control may be crucial. Temperature courses in the reactor obtained from measurements characterize with small (at the level of the measurement error) deviations from the set point.

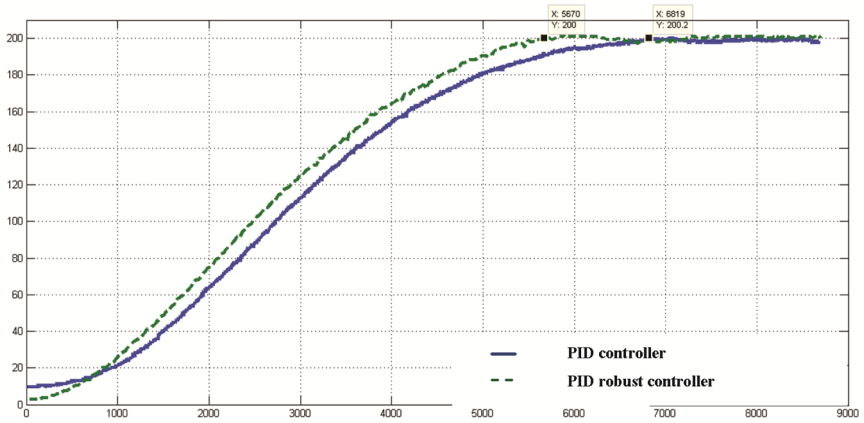


*Figure 8. Comparison of temperature control courses by: the PID controller and the robust PID controller*

## Conclusion

Temperature control in thermal biomass processing is a significant issue particularly in batch reactors, whose operation characteristics is not determined. Such situation causes high variability of the controlled object mainly due to endothermic reactions, which take place with various intensities and in various process stages. The tests, which were carried out on the real object allowed verification of practical realizations of controllers and their usefulness in temperature control in batch processes. The tests covered the PID classic controller tuned on the model obtained as a result of parametric identification of the non-batch object and the robust PID controller. Better parameters of operation were obtained for the robost controller especially with regard to the control time. Besides, it better reacted in the case of parameters changes caused by reactions in the reactor. However, advantages of the PID controller, on the basis of which the robust controller has been constructed, should be emphasised. It has a simpler structure than the robust controller and simultaneously a simpler implementation because it does not require implementation of the discrete process model, which translates into lower demand of machines for computing power and the reduction of implementation costs.

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# WYKORZYSTANIE OPROGRAMOWANIA SCILAB Z NAKŁADKĄ CZASU RZECZYWISTEGO RTAI DO PROTOTYPOWANIA REGULATORA TEMPERATURY INSTALACJI DO TERMICZNEGO PRZETWARZANIA BIOMASY

**Streszczenie.** Celem pracy było zaprojektowanie i przetestowanie różnych wariantów sterowników procesu termicznego przetwarzania biomasy. Proces odbywał się w reaktorze wsadowym składającym się z metalowej komory do której poprzez przeponę dostarczana była energia cieplna za pomocą grzałki ceramicznej opaskowej o mocy 2kW. Komora reaktora wraz z opasującą ją grzałką była zaizolowana termicznie. Do testów wybrano klasyczne rozwiązanie regulatora PID oraz jego uodpornioną na zmiany parametrów obiektu odmianę – regulator odporny PID. Do obsługi stanowiska, wykorzystano system Linux Debian oraz środowisko SciCosLab, w którego skład wchodzi środowisko graficzne SciCos. Jądro systemu zostało zmodyfikowane do pracy w czasie rzeczywistym poprzez moduł RTAI (Real Time Application Interface). Analiza wyników wskazuje, iż lepszą jakość regulacji zapewnia regulator odporny, który poza szybszym czasem odpowiedzi, lepiej się zachowuje w przypadku zmian parametrów obiektu.

**Słowa kluczowe:** reaktor, termiczne przetwarzanie, identyfikacja, regulacja temperatury, PID, regulator odporny, SCILAB

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# IMPACT OF THE VARIABLE LEVEL OF POTASSIUM FERTILIZATION ON FRAGILITY OF A RACHIS OF THE SELECTED SPELT VARIETIES

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ABSTRACT

The objective of the research was to determine and compare values of forces necessary to separate a rachis of four selected varieties of spelt at the use of two levels of potassium fertilization. The tests were carried out with a testing machine MTS Insight 2. Measurements were carried out separately for upper, central and bottom zone of a rachis. Based on the obtained results, it was stated that the researched varieties of spelt show a considerable variability on account of rachis strength in particular rachis zones. In the upper zone, the level of the applied potassium fertilization did not influence the rachis strength. It was related to all the researched varieties and the force values, at which separation of the rachis segment occurred, were within 1.09 to 1.67 N in relation to the variety. In the lower zone of rachis, its strength in all varieties was the biggest regardless the applied potassium dose.

## Introduction

Spelt (*Triticum aestivum ssp. spelta*) is a subspecies of common wheat, which on the territory of Europe has been known and cultivated from approx. 3000 years. This grain has become popular in cool climate regions: in Scandinavia, in mountainous regions of Germany, Switzerland and in Poland. As early as in the beginning of the 20th century, in some regions of Germany and Switzerland, acreage of its cultivation was bigger than other bread wheat. Later, spelt has been finally driven out form cultivation by introduction of new wheat varieties, which characterize with better crop and simpler threshing (Sulewska et al., 2008; Tyburski and Babalski, 2006). Only in the end of the 20th century, another increase of spelt popularity, related to organic food production has taken place. Investigation on the chemical composition of seeds of this wheat showed its precious nutritional values. Literature data prove that within this subspecies of wheat, there are forms, characterizing with more advantageous biochemical composition of seeds in comparison to the cultivation forms of common wheat (Piergiovanni et al., 1996; Ranhortra et al., 1996; Campbell, 1997; Danutė Jablonskytė-Raščė et al., 2013). This wheat has also a particular meaning in or-

ganic agriculture and for cultivation on areas with higher organic requirements. It distinguishes with low requirements concerning environmental and agrotechnical conditions, natural resistance to diseases and pests (Wiwart et al., 2004; Kordan et al., 2007) and thus with good adjustment to extensive cultivation system (Eusterschulte and Kahnt, 1995). However, the spelt cultivation is related to a serious problem, which has been insolvable so far, concerning separation of seeds from ears. Caryopses are strictly surrounded by chaffs and glumes and a fragile rachis which breaks down during threshing, makes this variety non-threshable. During the grain combine harvesting, whole non-threshed ears get to a tank and further treatment is necessary in order to separate seeds (Tyburski and Babalski, 2006). The undertaken tests were to prove, whether the phenomenon of spelt rachis fragility may be limited through the change of the level of potassium fertilization of this plant. A stronger rachis would allow prolonging the time of impact of a batten of a threshing machine drum on ears and make the seeds separation process more efficient. Differentiation of the potassium dose is justified with nutrient requirements of spelt. According to Tybusrski and Babalski (2006) spelt requires very good supply in potassium because of long stalks, for formation of which, greater amount of this element is required. After a good forecrop, which very often consists of papilionaceous plants, especially perennial, an increased potassium dose may also prevent the lodging phenomenon.

The objective of the research, which was carried out was to determine and compare forces values, necessary to separate the segment of the spelt rachis, cultivated in conditions of variable level of potassium fertilization.

## Material and research methodology

Ears of four winter spelt varieties constituted the research material, which according to the literature data (Konvalina et al., 2013) belong to the group of the most frequently cultivated in Poland. These were: Franckenkorn, Oberkulmer Rotkorn, Schwabenkorn and Ostro. Material came from the field experiment, placed on the good rye complex soil. Spelt was fertilized with minerals with the use of the following doses of a clean component: N – 70 kg·ha$^{-1}$, $P_2O_5$ – 60 kg·ha$^{-1}$, whereas the potassium dose was verified with the use of 75 and 150 kg·ha$^{-1}$ $K_2O$. Ears were manually collected in the stage of full maturity of plants, separately for each variety and the level of potassium fertilization. Humidity of ears determined with the balance desiccators method was at the level of 8%. In order to determine the value of force required for separation of the rachis segment with an ear, tests of rachis segment separation of the testing machine MTS Insight 2 were carried out. Ears were divided into three equal parts marking their borderlines and thus separating 3 zones. Ears along with the rachis segments were separated individually from the lower part of an ear and the record of the ear zone, where measurement was carried out, was conducted. 100 ears for each variant of fertilization within each variety were analysed. 3 small spikelets from each zone were separated from each ear. The measurement ending of the testing machine was combined with an ear with the use of a plastic jaw chuck with high friction coefficient, which allowed reduction of its pressure on the investigated material. Manner of mounting an ear in the testing machine was presented in figure 1 below. In order to enable recording of the moment of stripping the rachis segment a tensometric head for the force measurement with

the scope up to 120 N was applied. Measurements of force values were carried out with precision up to 0.01 N.

*Figure 1. Measurement head of the testing machine MTS Insight 2 with a mounted ear*

In the process of rachis separation, two stages may be distinguished. The first stage (A) is related to fighting flex stresses in a rachis and deviation of its segment from the ear axis. During the second stage (B) stretching of rachis takes place, which finally leads to separation of its segment – point "z" in figure 2.

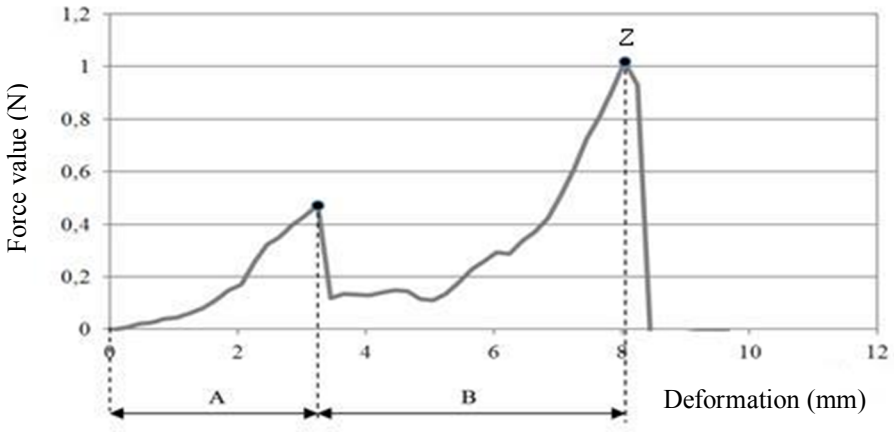


*Figure 2. An exemplary course of force values changes during separation of the rachis segment*

## Research results and discussion

One of the factors, which are significant in the process of cereals threshing, is a binding force of a seed with an ear. According to the literature data, its values for spring wheat are within 0.96 to 1.79 N for winter wheat from 1.02 to 2.09 whereas for rye are within 0.81 to 1.31 N (Rezniček, 1971). In case of wheat spelt, a fragile rachis hinders determination of the binding force of a grain with an ear. Its division into segments takes place at the values of forces lower than those, which are necessary to separate a caryopsis from a spikelet. Rachis fragility is a genetic property, typical for tetraploid and diploid wheat species. Origin of wheat spelt (*Triticum spelta* L.) has not been entirely explained yet. Based on the genetic tests of the material, it was established that it was created, most probably, by cross-breeding of hexaploid and tetraploid common wheat, from which, they probably inherited this property (Gąsiorowski, 2004; Tyburski i Babalski, 2006).

The investigated varieties of wheat spelt were varied on account of rachis strength, expressed with the value of force necessary to separate its segment with a spikelet. Reaction of varieties on the variable level of potassium fertilization was analysed separately for each from the distinguished three zones of an ear, because the flowering and ripening process of caryopses in each of them takes place in a slightly different time, which may cause the variability of mechanical properties of the rachis fragment, which is within them.

Statistical analysis of the obtained results proved that in the upper zone of an ear, a variable level of potassium fertilization did not influence the rachis strength and it concerns all investigated varieties (table 2). In case of varieties: Oberkulmer Rotkorn, Ostro, Schwabenkorn, the rachis of the upper zone of an ear characterized with strength and the average value of the force which causes separation of its segment was 1.58 N (table 1). In the discussed ear zone, Franckenkorn variety differed significantly from the remaining ones. Its rachis was divided into segments at the force of 1.17 N (table 2).

Table 1
*Average values of forces required for separation of the rachis segment with a spikelet in particular ear zones for the investigated varieties of wheat spelt*

| Variety | Ear zone | Uniform groups | | | | | | The force of stripping the rachis segment (N) | SD (N) |
|---|---|---|---|---|---|---|---|---|---|
| | | a | b | c | d | e | f | | |
| Franckenkorn | upper | | | | | | x | 1.17 | 0.62 |
| Franckenkorn | central | | | | | x | | 1.59 | 0.51 |
| Franckenkorn | lower | | x | | | | | 2.60 | 1.26 |
| Oberkulmer Rotkorn | upper | | | | | x | | 1.57 | 0.77 |
| Oberkulmer Rotkorn | central | | | | x | | | 2.13 | 0.95 |
| Oberkulmer Rotkorn | lower | x | | | | | | 3.29 | 1.67 |
| Ostro | upper | | | | | x | | 1.62 | 0.54 |
| Ostro | central | | | x | x | | | 2.25 | 0.59 |
| Ostro | lower | x | | | | | | 3.50 | 1.90 |
| Schwabenkorn | upper | | | | | x | | 1.56 | 0.72 |
| Schwabenkorn | central | | | | | x | | 1.60 | 0.55 |
| Schwabenkorn | lower | | x | x | | | | 2.42 | 1.37 |

SD – standard deviation
a,b,c,d,e,f – uniform groups acc. to Duncan test

Table 2
*Average values of forces required for separation of the rachis segment with a spikelet in the upper ear zone for the investigated varieties of wheat spelt*

| Spelt variety | Dose of $K_2O$ ($kg \cdot ha^{-1}$) | Uniform groups | | | The force of stripping the rachis segment (N) | SD (N) |
|---|---|---|---|---|---|---|
| | | a | b | c | | |
| Franckenkorn | 75 | | | x | 1.09 | 0.58 |
| Franckenkorn | 150 | | | x | 1.25 | 0.66 |
| Oberkulmer Rotkorn | 75 | | x | | 1.49 | 0.73 |
| Oberkulmer Rotkorn | 150 | x | x | | 1.65 | 0.80 |
| Ostro | 75 | x | x | | 1.56 | 0.54 |
| Ostro | 150 | x | x | | 1.67 | 0.53 |
| Schwabenkorn | 75 | x | x | | 1.53 | 0.62 |
| Schwabenkorn | 150 | x | x | | 1.59 | 0.81 |

SD – standard deviation
a, b, c – uniform groups acc. to Duncan test

In the central zone, rachis of the following varieties: Franckenkorn, Oberkulmer Rotkorn and Ostro was the strongest in comparison to the upper zone. It was reflected in the values of the registered forces, which regardless the level of the applied potassium fertilization had higher values (table 1). In the analysed zone, the highest value of the force, leading to the rachis division into segments, was registered in case of Ostro variety at both fertilization variants and Oberkulmer Rotkorn variety which was fertilized with potassium in the doze of 150 $kg \cdot ha^{-1}$. Average value of this force was 2.27 N (table 3). The lowest rachis strength was reported in Franckenkorn variety with the potassium dose of 75 $kg \cdot ha^{-1}$.

Table 3
*Average values of forces required for separation of the rachis segment with a spikelet in the central ear zone for the investigated varieties of wheat spelt*

| Variety | Dose of $K_2O$ ($kg \cdot ha^{-1}$) | Uniform groups | | | | | The force of stripping the rachis segment (N) | (SD) (N) |
|---|---|---|---|---|---|---|---|---|
| | | a | b | c | d | e | | |
| Franckenkorn | 75 | | | | | x | 1.49 | 0.54 |
| Franckenkorn | 150 | | | | x | | 1.69 | 0.47 |
| Oberkulmer Rotkorn | 75 | | | x | | | 1.93 | 0.52 |
| Oberkulmer Rotkorn | 150 | x | x | | | | 2.32 | 1.21 |
| Ostro | 75 | x | x | | | | 2.29 | 0.59 |
| Ostro | 150 | | x | | | | 2.20 | 0.59 |
| Schwabenkorn | 75 | | | | x | x | 1.59 | 0.60 |
| Schwabenkorn | 150 | | | | x | x | 1.59 | 0.50 |

SD – standard deviation
a, b, c, d, e – uniform groups acc. to Duncan test

The central zone showed also significant differences concerning rachis strength in relation to the potassium dose. They concerned two varieties: Franckenkorn and Oberkulmer Rotkorn. At a higher level of potassium fertilization which was 150 kg·ha$^{-1}$, forces, at which a rachis segment with an ear was separated in case of the mentioned varieties, were respectively 13.4 and 20.2% (table 3). However, due to considerably high variability of this property and small differences in its values in relation to the level of potassium fertilization, one may not clearly determine that the rachis strength increase was caused only by a varied potassium fertilization.

The lower ear zone registered the highest values of forces, at which a rachis was divided into particular segments. It relates to each investigated varieties (table 1). The biggest rachis strength in the lower zone with an average force value of 3.46 N was reported in case of Ostro variety at both levels of potassium fertilization and Oberkulmer Rotkorn variety at the higher potassium dose (table 4). The lowest rachis strength in the discussed zone was determined in case of Schwabenkorn variety at both potassium fertilization levels and it was at the average of 2.42 N (table 4). In the lower zone, also significant differences in the rachis anti- breaking strength were determined in relation to the potassium dose, but only in case of Oberkumler Rotkorn variety. The increase of the potassium fertilization level resulted, in case of this variety, the increase of the force value necessary to separate the rachis segments. This value at the increase of the potassium dose from 75 to 150 kg·ha$^{-1}$ increased from 3.19 to 3.38 N i.e. by 5.9% (table 4). This small increase in the rachis strength at quite high variability of this property in the discussed variety, particularly in the lower zone, does not allow explicit statement whether it was only caused by a variable level of potassium fertilization. It requires confirmation during further research.

Table 4
*Average values of forces required for separation of the rachis segment with a spikelet in the lower ear zone for the investigated varieties of wheat spelt*

| Variety | Dose of $K_2O$ (kg·ha$^{-1}$) | Uniform groups | | | | The force of stripping the rachis segment (N) | SD (N) |
|---|---|---|---|---|---|---|---|
| | | a | b | c | d | | |
| Franckenkorn | 75 | | | x | | 2.62 | 1.30 |
| Franckenkorn | 150 | | | x | | 2.58 | 1.21 |
| Oberkulmer Rotkorn | 75 | | x | | | 3.19 | 1.60 |
| Oberkulmer Rotkorn | 150 | x | | | | 3.38 | 1.73 |
| Ostro | 75 | x | | | | 3.51 | 2.17 |
| Ostro | 150 | x | | | | 3.48 | 1.54 |
| Schwabenkorn | 75 | | | x | x | 2.45 | 1.43 |
| Schwabenkorn | 150 | | | | x | 2.40 | 1.32 |

SD – standard deviation
a, b, c , d – uniform groups acc. to Duncan test

## Conclusions

1. The wheat spelt varieties, which were investigated, showed a considerable variability on account of rachis strength in particular ear zones.
2. A varied level of potassium fertilization did not significantly influenced the rachis strength in the upper zone, it concerns all investigated varieties. Values of forces, at which rachis segment was separated in this zone, were formed in relation to the variety within 1.09 to 1.67 N.
3. In the lower zone of an ear, regardless the potassium dose, rachis in case of all varieties was the highest and it was from 2.40 to 3.51 N.

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# WPŁYW ZMIENNEGO POZIOMU NAWOŻENIA POTASOWEGO NA ŁAMLIWOŚĆ OSADKI KŁOSA WYBRANYCH ODMIAN ORKISZU PSZENNEGO

**Streszczenie.** Celem podjętych badań było określenie i porównanie wartości sił potrzebnych do oddzielenia segmentu osadki kłosa czterech wybranych odmian orkiszu pszennego, przy zastosowanych dwóch poziomach nawożenia potasowego. Badania wykonano za pomocą maszyny wytrzymałościowej MTS Insight 2. Pomiary wykonywano oddzielnie dla górnej, środkowej i dolnej strefy kłosa. Na podstawie otrzymanych wyników stwierdzono że badane odmiany orkiszu wykazują znaczną zmienność pod względem wytrzymałości osadki w poszczególnych strefach kłosa. W strefie górnej poziom zastosowanego nawożenia potasowego nie miał wpływu na wytrzymałość osadki. Dotyczyło to wszystkich badanych odmian a wartości sił przy których następowało oddzielenie segmentu osadki kształtowały się w zależności od odmiany w zakresie od 1,09 do 1,67 N. W dolnej strefie kłosa wytrzymałość osadki wszystkich odmian była największa niezależnie od zastosowanej dawki potasu.

**Słowa kluczowe:** orkisz pszenny, dawka potasu, wytrzymałość osadki kłosa.

# PAŃSTWOWY OŚRODEK MASZYNOWY (POM) – WSPOMNIENIA Z DZIECIŃSTWA

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Zachęcając Prezesa Kluby Seniora Mechanizacji Rolnictwa, p. profesora Rudolfa Michałka, do podjęcia się redakcji monografii o POM-ach (wcześniejsza nazwa brzmiała chyba GOM – Gminny Ośrodek Maszynowy) i napisania wspomnień o nich miałem zamiar przypomnieć i utrwalić w pamięci ten fragment mechanizacji rolnictwa, który odszedł do historii - na naszych oczach.

Nie znam książkowego opracowania, jakie utrwaliłoby w pamięci te zakłady, tj. POM-y, mimo że nasz uniwersytet (wcześniej Wyższa Szkoła Rolnicza, a następnie Akademia Rolnicza) współpracowała z nimi badawczo i dydaktycznie (praktyki studenckie, staże pracowników). Skoro więc z generacji pracowników POM-ów nikt, jak do tej pory, nie napisał wspomnień o nich próbujemy utrwalić ich historię przynajmniej w takim zakresie na ile ją znamy i zachowana jest w naszej pamięci.

Moje wspomnienia dotyczą Państwowego Ośrodka Maszynowego w Brzęczowiach k. Dobczyc, gdzie mój ojciec pełnił obowiązki dyrektora, od 1953 roku aż do niespodziewanej śmierci w 1970 roku. Wcześniej był dyrektorem POM-u w Szreniawie (1951-1953), przeniesionego później do Opatkowic. Tuż obok POM-u w Brzączowicach, może nie więcej niż 50 metrów od ogrodzenia zakładu, mieszkała nasza rodzina w dwurodzinnym budynku, który stoi jeszcze dzisiaj. Moje wspomnienia obejmują okres od chwili najwcześniej zapisanych w pamięci 4-5 letniego chłopca, aż do 1965 roku, kiedy przenieśliśmy się do Myślenic, gdzie rodzice wybudowali nasz dom rodzinny. Miałem wówczas 14 lat i właśnie ukończyłem szkołę podstawową – wówczas jeszcze 7-letnią. Wspomnienia moje obejmują zatem okres ok. 12 lat.

O tym, że POM w Brzączowicach jest jednym z wielu w bliższej i dalszej okolicy wiedziałem – mogę tak powiedzieć – zawsze. Pamiętam bowiem, jak ojciec, wraz z współpracownikami, wyjeżdżał służbowo do innych POM-ów. Zdaje się, że niekiedy byłem też przez niego zabierany do służbowej „Skody", a później „Warszawy" – pamiętam to słabo i nie potrafię odtworzyć z własnej pamięci, jakie to były POM-y. Z przekazu mojej matki wiem dzisiaj, że były to jeszcze POM-y w Jawiszowicach, Kacicach (dyrektor Stanisław Rubiś), Kleczy Dolnej, Kopalinach, Kryspinowie (dyrektor Handzlik), Limanowej (dyrektor Bogacz), Lubaszu, Tarnowcu, Trzyciążu i Podegrodziu. Być może przyczyną moich „służbowych" wyjazdów była nie tyle chęć pokazania mi innego zakładu, lecz kontrola nad niesfornym chłopcem, który nie chodził do przedszkola … . Wiem, że ojciec był także odwiedzany przez dyrektorów innych POM-ów – niestety ich nazwisk nie zapamiętałem, choć wiem, że bywali także w naszym służbowym mieszkaniu. Tak więc wiedziałem już wówczas, że „nasz" POM nie jest jedynym i podobno są jeszcze inne, gdzieś w zasięgu służbowego samochodu ojca, a także gdzieś dalej.

Jak wyglądała sieć tych POM-ów w regionie warto by opisać dla upamiętnienia tego fragmentu historii inżynierii rolniczej w Polsce. Nie zrobią tego już Dyrektorzy „Zjednoczenia" POM (siedziba tego Zjednoczenia mieściła się przy Placu Szczepańskim): pp. Warkowski i Andrzej Starowieyski, gdyż odeszli na zawsze…

Charakterystyczne dwa, „pomowskie"* dźwięki pamiętam do dziś: syrenę, wzywającą rano (chyba o 6:30) pracowników do zakładu i ogłaszającą koniec pracy (godz. 15.00 od poniedziałku do piątku i o 13.00 w soboty), oraz hałas uruchamianych silników ciągników Ursus C45.


Jak wiadomo silniki te (jednocylindrowe, z tłokiem pracującym poziomo, wzdłuż osi podłużnej ciągnika) uruchamiano przy pomocy kierownicy (demontowanej ze stanowiska pracy), podgrzewając wcześniej świecę żarową umieszczoną z przodu ciągnika. Wibrujący dźwięk syreny i charakterystyczny hałas – niczym kolejne, coraz szybsze wybuchy – pamiętam zapewne nie tylko ja, ale wszyscy mieszkający wówczas w promieniu co najmniej jednego kilometra. Jeśli dodam, że POM w Brzęczowicach zlokalizowany był na wzgórzu – z jednej strony od południa podnóżem była dolina rzeki Raby, a od północy dolina potoku zwanego Walnica - to szczególne środowisko akustyczne tego miejsca będzie bardziej zrozumiałe. Dziś wzgórze oblane jest z trzech stron wodami zbiornika wody pitnej dla Krakowa i innych miejscowości – spiętrzonej zaporą w Dobczycach.

Sam POM zlokalizowany był w budynkach jakby podworskich. Nie znam historii przejmowania tych budynków i terenu od przedwojennych właścicieli – chociaż warto byłoby ją poznać. Nie jest wykluczone, że przejęcie (nacjonalizacja) odbywało się z krzywdą i niesprawiedliwością, o której dopiero od niedawna wolno głośno mówić i bliżej ją poznawać. Nie pamiętam żadnych rozmów, które wówczas dotyczyły tej sprawy, tj. nacjonalizacji terenów i budynków. Wiedziałem tylko, że niektórzy pracownicy, np. wozacy**, wcześniej pracowali w tym miejscu – choć nie w POM-ie, bo przecież przed wojną go nie było.

* Wyraz: „pomowskie" (tzn. i wszystkie budynki i ciągniki należące do POM-u), „pomowcy" (ludzie pracujący w POM-ie) były w powszechnym zastosowaniu i jednoznacznie zrozumiałe dla ludzi także spoza branży „pomowskiej".

** W POM-ie prowadzono początkowo także, chów zwierząt. Były konie pociągowe i trzoda chlewna. Najpierw zniknęły z POM-u konie, później – chyba w połowie lat 60-tych zaprzestano chowu trzody chlewnej.

Pamiętam także, że magazyn części zamiennych nazywany był spichlerzem (bo taką funkcję wcześniej spełniał), a magazyn paliw i olejów wcześniej był magazynem lodu (wydobywanego z pobliskiego stawu i gromadzonego podczas zimy). W najbardziej okazałym 1-piętrowym dworku mieściły się biura, a w przyziemiu stołówka pracownicza. Mieściła się tu też centrala telefoniczna, na korbkę, gdzie telefonistka wciskając wtyczki do tajemniczej (wtedy dla mnie) skrzynki łączyła rozmówców.

Na południowym stoku „pomowskiego" wzgórza był sad wiśniowy (nazywany „winnicą" – dlaczego, nie wiem do dziś), a obok stare sady jabłoniowe i rzędy orzechów włoskich. Niewielkie zagajniki leśne, zwane powszechnie „potokami", choć nie płynęły tam żadne strumienie, dopełniały uroku tego miejsca. Mechanizacja rolnictwa, tj. wszelkiego rodzaju technika, otoczona była piękną przyrodą, którą wspominam dziś z nostalgią, którą Czytelnik zna dobrze z wersów Mickiewicza (…dziś piękno twe widzę w całej ozdobie…) .

POM pełnił funkcję produkcyjną i usługową. Zdaje się, że każdy z POM-ów miał wyznaczony asortyment produkcji: w Brzączowiach wytwarzano rozkładane drewniane drabiny, a później (w latach 70-tych) lakierowano błotniki ciągników „Ursus". Wytłoczone błotniki skądś przywożono do Brzączowic samochodami ciężarowymi, a po lakierowaniu odwożono – bodajże do Ursusa k. Warszawy. Czy coś więcej wytwarzano – oprócz wspomnianej wcześniej wieprzowiny – tego nie pamiętam. Być może był jeszcze jakiś inny asortyment produkcji, bo każdy z POM-ów, poprzez tzw. Wojewódzkie Zjednoczenie Państwowych Ośrodków Maszynowych, uczestniczył w ówczesnej państwowej gospodarce planowej. Te plany były udręką dyrekcji i pracowników, gdyż ich wykonanie było tematem rozmów jakich, mimowolnie, byłem słuchaczem w domu. Wiem także, że spontanicznie i dobrowolnie pracownicy pracowali niekiedy dłużej – to jest ponad 8 godzin dziennie – aby „wykonać plan". Czy otrzymywali za to dodatkowe wynagrodzenie? – chyba nie. Mogę jednak zaświadczyć, że dostrzegłem – wówczas nieświadomie – entuzjazm do pracy, jaki dziś jest u niektórych doznaniem jakby obcym … . Wspominam o tym dlatego, że żarty, dowcipy, nawet „psikusy" i widoczna jakby radość życia była powszechna – jak mi się zdaje. Dłuższy czas pracy nie pozbawiał pracowników humoru. Może pamięć okropieństw wojennych w konfrontacji ze spokojną jednak pracą i pewnym zatrudnieniem (wówczas obowiązkowym) tak ludzi usposabiał?

Na placu, gdzie parkowały ciągniki (samochody stały w zamykanych garażach), były także jakieś maszyny, ale w latach 60-tych używano sporadycznie tylko pługi. Zasadniczo ciągniki wykorzystywane były do transportu, przede wszystkim leśnego, a także żwiru wydobywanego z doliny Raby do budowy dróg. Ciągniki, z przyczepami wyjeżdżały rano, a wracały wieczorem lub niekiedy nocą. Grupa traktorów była dość liczna – bodajże było ich o ponad 10.

Oddzielną grupą pracowników byli elektrycy, jak ich nazywano, a w rzeczywistości pracownicy prowadzący tzw. elektryfikację wsi. Było to montowanie słupów, przewodów elektrycznych i instalacji elektrycznych. Wydaje mi się, że grupa tych pracowników nie przychodziła do pracy do POM-u lecz, przebywała na tzw. „delegacji", tam gdzie daną wieś elektryfikowano. Wiem, że tą grupą pracowników kierował następca mojego ojca w Brzączowicach, p. Dyrektor Stanisław Kowalcze. Później utworzono bodajże grupę ds. zaopatrzenia wsi w wodę (wodociągi), ale tego nie jestem pewien.

W warsztatach, miejscu dla dziecka wyjątkowo interesującym, miałem okazję widzieć pracę spawaczy, ślusarzy, mechaników, elektryków i innych specjalistów. Każdy z nich, w ubraniu roboczym, zawsze zwracał uwagę tym, że ręce – a niekiedy i twarz – ubrudzone

były smarami. Technologie napraw ciągników i samochodów były wówczas niezwykle brudzące.

Naprawy prowadzono także przy pomocy mobilnego warsztatu, jakim był samochód marki „Lublin" zwany – nie wiem dlaczego – „czołówką". W metalowym nadwoziu mieścił się komplet narzędzi do napraw, łącznie z wiertarką słupową. Pamiętam dwa szczegóły tego samochodu: charakterystyczne kierunkowskazy przy kabinie kierowcy (świecące „rączki" wychylające się na bok, po włączeniu) i piecyk do ogrzewania zimą (na węgiel). Mechanicy uchodzili wówczas, obok kierowców, za elitarną grupę pracowników.

W brzączowickim POM-ie pracowało wówczas chyba ok. 100 osób (w połowie lat 60-tych – raczej mniej niż powyżej tej liczby) i jak mi się wydaje to była typowa skala zatrudnienia w każdym z POM-ów. Gdyby zatem policzyć wszystkich „pomowców" z ówczesnego województwa krakowskiego (w Polsce było wówczas 17 województw), łącznie z pracownikami „Zjednoczenia" w Krakowie, zapewne byłoby to ok. 1000-1500 osób. Niestety, są to tylko moje przypuszczenia, gdyż nie znam skali zatrudnienia w tych czasach, które wspominam – jak dziecko wówczas przecież.

POM-u strzegł dozorca (wartownik), nie wiem czy początkowo – przełom lat 50/60-tych – nawet nie uzbrojony w broń długą. Wjazd na teren zakładu odbywał się poprzez bramę, gdzie wypisywano przepustki. Opuszczenie zakładu przez osoby postronne też było odnotowywane przez wartownika. Wiem, że po godzinach pracy – zwłaszcza jesienią i zimą – dozorcówka (rodzaj cyrkowej budy, stojącej na słupkach, z półokrągłym dachem) było miejscem spotkań pracowników, którzy nie wiedzieli co robić z wolnym czasem. Kłęby tytoniowego dymu unosiły się zawsze w powietrzu i nikomu to nie przeszkadzało – prawie wszyscy mężczyźni palili papierosy (przede wszystkim marki „Sport"). Telewizji jeszcze nie było – przynajmniej w Brzączowicach.

POM miał także swoją świetlicę, którą potem (przełom lat 60/70-tych) przemianowano na „klubokawiarnię". Było to miejsce, gdzie gromadziła się młodzież (jako uczeń grałem tam nawet jakąś rolę w sztuce teatralnej), a także dorośli. Życie, jak się to mówi – towarzyskie - pracowników kwitło, jakby to ująć nieco poetycko. Telewizji, jak już wspomniałem, nie było, więc świetlica była miejscem, gdzie przychodzono chętnie by porozmawiać, a niekiedy potańczyć (przy muzyce odtwarzanej z płyt). Tu odbywały się pracownicze „sylwestry", karnawałowe zabawy, itp. Gdy POM zakupił pierwszy telewizor oglądano szczególnie „dziennik" i inne programy. Pamiętam jedynie, że kategorycznie zabraniano nam – dzieciom - oglądać czwartkowej „Kobry" (teatr telewizji z kryminalnymi spektaklami), co młodszym Czytelnikom może wydawać się dziś zakazem śmiesznym i niezrozumiałym. Dla mnie też było to niezrozumiałe, choć nieśmieszne, bo zakazy dorosłych dzieci odbierały wówczas jak najbardziej poważnie.

POM był także wówczas – jak by to dzisiaj nazwać – sponsorem grupy sportowców. Byli to pracownicy, którzy po godzinach pracy, w LZS (Ludowy Zespół Sportowy), uprawiali piłkę nożną, siatkówkę i podnoszenie ciężarów. Zwłaszcza w podnoszeniu ciężarów POM w Brzączowiach (LZS) osiągał znaczące sukcesy; bodajże nawet rangi międzywojewódzkiej.

Powracam do mechanizacji rolnictwa w POM-owskim wydaniu. Gdzieś w połowie lat 60-tych POM otrzymał (chyba tak to trzeba nazwać bo ciągników nie kupowało się jak dzisiaj u „dilera", lecz otrzymywał w ramach gospodarki planowej – oczywiście płacąc: komu, gdzie? – nie wiem), nowy ciągnik „Zetor". Nazywano go „Zetor-major" i był, w porównaniu z Ursusem C45, obiektem jakby z innego świata. Względnie cichy, urucha-

miany rozrusznikiem, szybki w jeździe i jakiś w ogóle: elegancki. Patrzyliśmy na niego z zachwytem: my dzieci i pracownicy. Przywilej jazdy ciągnikiem uzyskał najlepszy z dotychczasowych kierowców ciągników „Ursus C 45". Potem przyszły kolejne, nowe ciągniki, ale ten pierwszy podziwialiśmy – pamiętam – z podobną ciekawością, jak pierwszy telewizor.

Pamiętam też, że POM – a zwłaszcza jego pomieszczenia gościnne – były miejscem noclegowym kierowców z Warszawy (zwanych tutaj „warszawiakami"). Była jakaś umowa, która pozwoliła garażować, bodajże samochód „Nysa", i nocować raz w miesiącu (?) dwóm wesołym, dowcipnym kierowcom. Co było celem ich przyjazdów - nie wiem. Wiem tylko, że ich przyjazd był zawsze mile oczekiwany, a zarazem pretekstem do spotkań i wesołych rozmów o tym, co się dzieje w świecie (w stolicy przecież).

Z moich dziecięcych wspomnień POM wyłania się więc nie tylko jako miejsce pracy ludzi dorosłych i miejsce nieco tajemniczych maszyn i urządzeń. To także miejsce, które łączyło pracujących tam ludzi, czymś więcej niż tylko pracą. Ponieważ byli to mieszkańcy Brzączowic i okolicznych miejscowości (Droginia, Stojowice), a rzadko tylko stażyści spoza tych okolic, niejako naturalnie ludzie ci łączyli pracę zawodową z życiem towarzyskim, by nie powiedzieć rodzinnym – bo pracowały tam niekiedy całe rodziny.

Drogi Czytelniku, nie znalazłeś w mych wspomnieniach opisu POM-u, jako zakładu pracy. Dziecko nie może przecież dostrzegać z zakładzie przemysłowym tych wszystkich zawiłości techniczno-organizacyjnych jakie widzi osoba dorosła. Moje wspomnienia zapewne wywołują nostalgię bardziej u mnie niż u Ciebie, który być może POM kojarzysz z niewiele mówiącym skrótem. Napisałem te słowa jednak nie tylko z nostalgii; także dlatego, że z POM-ami z dzieciństwa połączyło mnie dalsze życie zawodowe – już jako osoby dorosłej. Ale to już inna historia i inne wspomnienia…