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AUTONOMOUS PLATFORM TECHNOLOGY FOR BIOMASS TRANSPORT

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Abstract

The article presents guidelines, developed concepts and the construction of specialized technology tracked vehicle for the transport of biomass on wetlands, implemented within the framework of the development project No. PBS2/B8/11/2013 “Autonomous transport technology of the harvested biomass on protected wetlands” bound removal of unwanted vegetation from protected areas especially national parks, landscape parks and Natura 2000. The design of the new vehicle has been developed by a consortium led by the team of Power Engineering and Dynamics of Agricultural Engineering, BE-PIMR in Poznan. Its task is to find a solution that would significantly increase the efficiency of the process of obtaining biomass, taking into account the autonomy of action of the resulting structure. This technology will be one of the important links of the system built for the maintenance and improvement of biodiversity in protected areas.

KEYWORDS: TRACK VEHICLE, AUTONOMOUS VEHICLE, WETLANDS PROTECTION

1. INTRODUCTION

The model and design of the autonomous platform technology for the transport of biomass on wetlands were developed as part project No. PBS2/B8/11/2013 [1] implemented at the Industrial Institute of Agricultural Engineering (PIMR) [8] in Poznań by the Team for Power Engineering and Dynamics of Agricultural Engineering. The key purpose of the project implemented at the Institute is to develop effective and efficient biomass transport technologies for the Tracked Vehicle Unit [patented] which has been designed to carry out protection activities related to the removal of unwanted plants from national park wetlands, landscape parks and reserves set up to reinstate breeding sites of rare and endangered bird species such as the aquatic warbler [2, 3, 4]. To this end, PIMR, in cooperation with the Military Technical Academy (WAT) [9], Industrial Institute of Technology and Measurements (PIAP) [10] and Hydromega [11], designed a model of specialised Autonomous Biomass Transport (ABT) vehicle.

2. PROJECT PURPOSE AND ASSUMPTIONS

The aim of the project was to develop an alternative technology to manage biomass transport, significantly improving the efficiency of the process, i.e. collecting biomass from the mowing unit and transporting it away from the pasture along planned approach paths to minimise the risk of getting stuck in the mud and shorten travel time. The structure is supposed to be light (up to 7 tonnes of GVW) and generate negligible ground pressure (of up to 10 kPa) thanks to the use of modular delta continuous tracks. The platform is powered by a self-ignition combustion engine.

The system (Fig. 1) works as follows: the working module of the Tracked Vehicle Unit collects biomass on the transport module, reloads it onto the ABT platform and transfers to the collection point.

![Fig. 1. Concept of the Autonomous Biomass Transport (ABT) system [1]](image)

3. SYSTEM DESIGN CONCEPTS

Three options were selected for the pre-defined project assumptions and the preliminary analysis of the process of biomass reloading from the transport module onto the ABT platform:

1. **Option 0** - classic reloading method with the use of a belt conveyor;
2. **Option 1** - reloading biomass containers by replacement;
3. **Option 2** – reloading biomass containers by rotation.

In the Option 0 (Fig. 2), biomass is reloads from the transport module (TM) onto the ABT platform container with the use of a belt conveyor. Reloading can be done when the vehicles are on the move, its total time being dependant on the capacity of the conveyor connecting the transport module with the ABT platform. To make this type of reloading possible, the transport module must be equipped with an extra drive system powering the belt conveyor. The option may be used in two different versions: (a) reloading from the back of the transport module (Fig. 2a) and (b) reloading from the side of the transport module (Fig. 2b).
Reloading biomass from the transport module onto the ABT platform by replacement consists in switching loading containers from the top (full containers from the transport module are replaced by empty ones from the ABT platform and vice versa). The aim of this technique is to shorten the time of unloading which will increase work efficiency. This option requires a rigid connection between the transport module and the ABT platform. Switching loading containers in Option 1 will be considered for two versions: 1 - transporting full containers over empty ones (Fig. 3) and 2 - transporting empty containers over full ones.

In Option 1 (Fig. 3), the ABT platform approaches the transport module, the two units are coupled (Fig. 3a) and a container filled with biomass is transferred onto the ABT platform over an empty container located on the platform by rotation (Fig. 3b). At the same time, the empty container is moved from the ABT platform onto the transport module. After the containers have been moved, the transport module and ABT platform are decoupled and the container with biomass (Fig. 3c) is transported to the point of reloading. Option 2 works in a similar manner, the difference being that the empty container from the ABT platform is moved over the full container from the transport module.

Option 1 is quite complex and requires an additional device which lifts a container filled with biomass to transport it onto the ABT platform. An empty container must be simultaneously moved to the transport module. This poses the danger of the loss of stability during the unloading process and increases the mass of both the transport module and the ABT platform.

In Option 2 (Fig. 4), reloading is done by replacing a container filled with biomass with an empty one brought on the ABT platform with the use of a rotation mechanism. This option is rather complicated and requires an additional mechanism to rotate the platform which should accommodate two containers (empty and full). The rotating platform should also be equipped with a power supply system (combustion engine, hydraulic system) of the ABT platform, a rotating mechanism and a device to move containers. In order to implement this option, the transport module must first be connected to the ABT platform with a coupler consisting of two strands which facilitates the work of the mechanism transporting the container from the ABT platform onto the transport module (Fig. 4a). Next, the rotating platform is moved 180° about the vertical axis. As there is a considerable difference in mass between the container filled with biomass and the empty one, the rotating axis of the platform must be located at the point minimising the risk of overloading the vehicle from any side. This is particularly important given the need to maintain lateral stability of the vehicle during platform rotation (Fig. 4b; 4c; 4d). In the last stage, the empty container is moved from the rotating ABT platform onto the transport module by means of a special mechanism (Fig. 4e).

The ABT options described above were tested under simulation conditions for a pre-defined dynamic model of the system (Fig. 5) [1]:

- shifts of the centres of gravity for the continuous tracks
- loading of individual continuous tracks
- longitudinal tilt of the modules
- forces and moments in the coupler connecting the ABT vehicle with the transport module.
Based on the results of these tests, Option 1 was selected - the empty container is moved over the top whilst the ABT vehicle and the transport module are rigidly coupled. This solution ensures the shortest time of the reloading cycle with relatively small shifts of centres of gravity for vehicle axles (Fig. 6). In this option, the maximum authorised axle weight is 45 kN (Fig. 7). Rigid connection between the modules ensures that their longitudinal tilt is reduced to below 0.5° (Fig. 8), but also requires greater docking precision and, consequently, a more advanced control unit.

The vehicle body (Fig. 10) is a welded spatial structure made of rectangular closed profiles as well as sheets of metal and open profiles. The body is a weight carrying structure with other units attached to it such as the self-ignition engine of the main drive, continuous track axles, reloading unit and vehicle coupler. It is 7,100 mm long and 2,980 mm wide. The axle base amounts to 4,300 mm. The front of the body is equipped with a coupler which makes it possible to attach the transport module of the mowing unit and unload the container. The axles of the continuous track unit are mounted on the lower part of the body. The mid area is designed for a self-ignition engine of the main drive together with a hydrostatic pump unit. The unloading unit is mounted onto the upper part of the body.

The continuous track of the ABT vehicle comprises two axles - front and rear - bearing rotating track units (Fig. 11). Continuous track units [6] transfer loads from the body onto the surface enabling vehicle movement through the integrated executive elements of the drive and steering units. Each track unit is driven by a hydrostatic engine via a driving wheel. Rotation is enforced by hydraulic servos. Continuous track units consist of a bogie with load, tension and steering wheels. The bogie is fitted with a stub axle yoke with a hydrostatic engine. The driving wheel mounted on the hub transmits drive power onto the track belt. Direct contact with the surface and transmission of the drive power onto the surface is ensured by lugs made of steel with increased abrasion resistance (such as Raex 400).
To comply with requirements for reloading the biomass-full container from the transport module of a mowing vehicle onto the ABT vehicle and the empty container in the reverse direction, a reloading unit (Fig. 12) has been developed consisting of empty container transfer, full container pulling and full container unloading systems.

Due to the specific structure of the ABT vehicle, containers have been specially designed (Fig. 13). An indentation is made all along the container. This allows the driving engine of the main vehicle to be placed directly under the container. As a result, the loading capacity of containers is reduced. Following all the modifications to the container’s structure introduced so that the ABT vehicle could achieve the required parameters, the load it can carry amounts to 7.3 cubic metres.

According to the selected project solution, containers are reloaded when the ABT platform (receiving biomass) and the transport module of the mowing vehicle are connected by the coupling unit. The coupling unit (Fig. 14) automatically positions the transport module of the mowing vehicle in relation to the ABT platform. Thanks to two movable arms topped with hooks, the ABT vehicle may be preliminarily connected with the transport module [5].

The hooks also level out the ABT vehicle and the transport module. When the two are preliminarily aligned, the ABT platform and the transport module are moved closer together (pulled). In the final stage of the coupling process, both units are positioned by wedges located in the frames of both vehicles. The connection makes it possible to replace containers safely.

The control system consists of two parts: hardware (sensors, antennas, on-board computers) and software, which is responsible for the selection of software modules for the implementation of different tasks given by the ABT - planning transport routes, supervising work mode, planning subsequent unloading, recognising the mowing vehicle, docking etc. Following the analysis of scenarios, four basic cases of using the system by an operator where identified:
- map edition,
- automatic control,
- teleoperation,
- cleaning optical devices.

In addition, the team identified two more cases which are indispensable for the system (and are independent of the operator):
- ensuring connection
- security analysis

Based on the developed architecture and operating scenario for the ABT system [1], the system was broken down into its logical sub-systems (Fig. 15). After the selection of the task to be carried out, the architecture will be further simplified and adapted to the needs of a specific mission/task.
5. CONCLUSION

Virtual models of the ABT vehicle made it possible to reach the following conclusions:

1. The selected solution ensures the shortest time of unloading which will increase work efficiency.
2. The designed vehicle meets all the project requirements. Due to the expanded structure, the total mass of the vehicle increased from 4 to 7 tonnes, i.e. by 75%, compared to the mass assumed before 3D modelling. It is necessary to optimise subassemblies of the structure in terms of mass and resistance so that allowable ground pressure of the vehicle does not exceed 10 kPa. The process is possible, however, after field tests which will verify the actual loading of the structure.
3. Average unit ground pressure for the current mass of the vehicle amounts to 14.3 kPa which complies with the standard of 10-15 kPa recommended by the Biebrza National Park even though the mass of the vehicle has increased.
4. The real-life model of the vehicle will be tested during field tests planned for 2016/2017.

6. LITERATURE

[4] Research project No. WND_POIG.01.03.01-00-164/09: “Integrated Technology for the Protection of wetlands from vegetal succession leading to the deepening degradation of the natural element”, project is headed by dr inż. Krzysztof Zarembowski.
At present the agricultural sector of the Republic of Kazakhstan in the cultivation of crops applying No-till techniques and direct seeding drills of various abroad firms "Amazone", «John Deere», «Gherardi», «MASCHIO-GASPARDO», «Kuhn», «Köckerling», «Horsch» and others are widely used. Drills are equipped with disk, chisel and tine coulter and neighboring countries seeders mainly are equipped with disk openers. Chisel and tine chisel coulters are reliable and easy to set planting depth, well-maintained and deepened at constant planting depth either [1]. But, they badly cut the plant remains, leading to clogging of interploughshare space.

Practice shows that the single-disc coulters do not always cut crop residues and not completely hide the furrow, and in the wet and heavy soils a packed furrow is formed. Double disc coulters although don’t have the above drawbacks, but in drought periods have uneven progress of the working parts and deepening the working part to the desired depth of seeding the soil requires effort up to 200 kg. This in its turn requires the installation of the individual cylinder for each coulter, which leads to an increase in mass of the drill and to its expensiveness.

Based on a search of experimental and theoretical assumptions we offer direct sowing with the following configuration options for openers:

- **Option 1** installation disk and chisel openers in two rows: one of them is chisel, and in another - disc, ensuring high throughput and low tractive resistance at work after cereal raw backgrounds;
- **Option 2** - installation disc and tines with distribution of seeds for sowing a wide belt (belt drill seeding), providing high throughput, low driving resistance and high yields.

According to the programming and methodology of research in view of the proposed options experimental samples disk and chisel coulters with suspension mechanisms were made, Figures 1 and 2.

For the energy assessment of working parts the theoretical research was done and the traction resistance of the structural and technological parameters of chisel and disc coulter dependences are set. Thus, the traction resistance of chisel coulter is defined as [2, 3]:

\[
R_{\chi f} = \left( B_\phi \cdot h + h_{sp}^2 \cdot \tan \psi_{ck} \right) \left( K_{\psi T} + K_{\psi P} + K_{\psi K} \right)
\]

Where

- factors that take into account the cost of energy to overcome the pressure of the soil layer at the bit opener;
- \( K_{\psi T} = 0.5 \cdot m_v \cdot A_{\alpha o} \cdot A_{1} \cdot \psi \cdot h \cdot g \) - coefficient taking into account the energy costs of the destruction of the soil layer at the bit opener \( ( A_{\alpha} = A_{\alpha o}) \);
- \( K_{\psi P} = m_v \cdot A_{\alpha} \cdot A_{1} \cdot C \cdot \cos(\phi) \) - coefficient taking into account the energy cost of the informing and change of the movement speed direction along the chisel opener \( ( A_{\alpha} = A_{\alpha o}) \).
Components of disc coulter resistance are determined by taking into account the soil cutting resistance forces by the blade of a flat disk $F_p$, the horizontal components of the soil deformation resistance force is defined by the disk tip $F_{\text{tip}}$, force of dynamic resistance of soil formation $F_k$, soil friction forces $F_m$ and effort on the ground crumbling $F_c$.

As a result, the traction resistance of disc coulter is defined as [4]:

$$F_T = F_{Xm} + F_{Xp} + F_{Xk}$$

Where $F_{Xm} = K \cdot h \cdot b (\cos \beta + \cos \gamma + \frac{g \cdot \rho \cdot V}{h} \cdot \cos \beta)$, $F_{Xp} = K_p \cdot h \cdot b \cdot \rho \cdot V^2$.

$F_{Xk} = 0.5 \cdot g \cdot h^2 \cdot b$ - resistance, respectively, to overcome friction and soil formation pressure on the opener, the destruction of the reservoir and to the informing and change the speed of the formation direction of movement along the wedge.

Analysis of the obtained formula (1) and (2) shows that the tractive resistance of the coulter depending on the depth and processing speed varies depending on the parabolic dependence.

For research with experimental openers laboratory apparatus was made and highly technical measuring instruments and equipment were used.

To verify the theoretical calculations to determine the traction resistance of chisel opener in accordance with the established methodology, laboratory experiments in the soil at a depth of sealing channel from 4 to 7 cm. and with moving at a speed of 0.87 to 3.1 m/s were conducted.

The results of theoretical and experimental research in the form of dependency change of the traction resistance of the chisel opener speed at a depth $h = 4cm$ are presented in Figure 3.

**Figure 3** - The theoretical $R_{\text{th}}$ and experimental $F_e$ dependences of the resistance of the traction of the chisel opener speed $V$ when working at depth $h = 4$ cm.

Similarly laboratory experiments in soil channel for disc coulters were conducted. Tests at different depths seed and fertilizer from 4 to 10 cm were carried out with a change in movement speed from 0.87 to 3.1 m/s. The results of theoretical and experimental research in the form of dependency change of the traction resistance of the speed of the disc coulters are shown in Figure 4.

**Figure 4** - Theoretical and experimental $F_x$ depending on the traction resistance of the disc coulter speed $V$ when working at depth $h = 7$ cm.

According to the schedule 4 we have that an increase in speed from 0.87 to 3.1 m/s theoretical $F_{th}$ and experimental $F_e$ dependences increase depending on a parabolic pattern. In addition, the disc coulter parameters are justified which are: disc diameter of 375 mm, the angle between the discs $\alpha = 100$, the position of the vanishing point drives $\beta = 400$ and the distance between axes of 155mm discs. For chisel opener with the mechanism of suspension the following parameters are justified: length of leashes $l_{CD} = 300$ mm and $l_{CF} = 300$ mm, width 20 mm chisel. Although experimental values exceed the theoretical but in general, they are supported by common methodological research position. In order to obtain reliable results and findings on the justification of parameters of working bodies are planned for further laboratory and field studies using experimental working bodies and drills with combined openers.

**References**

THEORETICAL SUBSTANTIATION OF TOPPING PARAMETERS WITHOUT SUGAR BEET HEAD COPYING

ТЕОРЕТИЧЕСКОЕ ОБОСНОВАНИЕ ПАРАМЕТРОВ СРЕЗА БОТВЫ САХАРНОЙ СВЕКЛЫ С ГОЛОВОК КОРНЕПЛОДОВ БЕЗ ИХ КОПИРОВАНИЯ

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Abstract: Nowadays topper machines which cut beet tops without copying root heads via rotary topper and only after this heads are cut individually by passive knife widely used in the world. However, with using this topping method significantly increases sugar-bearing plant material losses. Taking into account that sugar beet tops is effective raw material for receiving biogas, its collecting without loss is actual beet industry problem. However, when cutting tops from sugar beet heads with individual copying and collecting tops from each root crop head the top productivity is significantly reduced, the design of the topping device becomes complicated, operational expenses considerably increase. Methods of mathematical modeling, programming and calculations on PC are used in the course of research. As a result of the conducted research the mathematical model of a cut without individual copying of root crop heads as well as algorithm are developed. This algorithm enables to determine the rational height of installation of the cutting device over the level of soil surface that in this turn provides minimum losses of beet tops. Dependence of sugar-bearing plant material losses and residues of beet tops on cut height without individual copying of root crops heads was experimentally defined. Comparison with theoretical calculations showed that in the range of working heights of a cut of 20-60 mm deviation does not exceed 1%.

KEYWORDS: SUGAR BEET, ROOT CROP HEADS, TOPS, MATHEMATICAL MODEL, CUT WITHOUT COPYING.

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1. Introduction

Currently the toppers carrying out beet tops cutting without individual copying of root crops heads are widely spread in the world. This is due to the fact that the modern industrial production technology of sugar beet suggests that at the harvesting time sugar beet heads are the same size and shape and also they located at same level above the soil surface. However, studies found that these circumstances are not always observed, even at careful compliance of all modern technologies requirements. Natural factors, which occur even in the most favorable areas of cultivation of sugar beet presuppose: various size and shape of root crops heads; different shape and height of the tops bunch; obligatory presence of dry and laid tops (which during the growing season certainly appear) and various arrangement of heads above level of the soil surface.

When accurately trace the global development of harvesting mechanization of beet tops, then it can be seen what mechanized process of cutting the tops inside sugar beet harvester was replaced on individual copying of each head of root crop in a row and their topping on a root. However, reducing the cleaning performance, the complexity of the designs, significant operating costs have led to the fact that the individual copying of root crops heads during topping process has been substituted by cutting without copier, despite the obvious and significant losses of sugar-bearing mass and tops.

Furthermore, modern toppers which carry out a cutting without copying are not always adjust on a optimum working height for cutting unit. These units mostly have working body of rotary type [1]. Adjusting the topper on the desired cutting height is done by visual assessment of the cut tops quality. This can lead to unreasonable losses of sugar-bearing mass or to increasing tops residues on root crops heads. Moreover, after setting the desired cutting height, typically adjustment of its value in most cases is not done.

At this time, there are no methods for determining rational height of cutting tops without copier, which would be based on the losses sugar-bearing mass and residues of uncut tops meeting established requirements.

In general, this fact is a significant problem for beet industry, since reducing the losses of sugar-bearing mass at the cut directly reduces losses but at the same time increases the content of tops that being to reducing of sugar yield when processing.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

Such researchers as A.O. Vasilenko, P.F. Volk, V.M. Bulgakov, N.M. Zuev, L.V. Pogorelyiy, N.V. Tatyanko, N.M. Boris et al. found a linear dependency found that between heads height above the soil surface and dimensional characteristics of root crops.

2.2. Purpose of the study

Finding opportunities for effective cutting without copier of sugar beet tops with minimal losses.

2.3 Materials and Methods

Methods of mathematical modeling, programming and calculations on PC are used in research.

3. Results and discussion

To reduce the sugar-bearing mass losses it is necessary to develop a method for determining the rational height of cutting without copier of beet tops from root crop heads. To solve this problem a mathematical model of the cutting without copier process was used [2]. Dependences of sugar-bearing mass losses and the tops residues on root crops from height of cutting without copier will be determined theoretically as well as experimental verification of the obtained results will be carried out.

The model of the head of root crops of sugar beet, which can be approximated by a conically shaped body was developed (Fig. 1). Main geometric parameters of the root crop head are shown in Fig. 1.
Using simple geometric dependencies between parameters of sugar beet head and tops following dependencies were developed:

\[
\begin{align*}
\hat{h}_{g.l.} &= ah + b, \\
\hat{d}_1 &= mh + n, \\
\hat{d}_{g.l.} &= d_1 + 2\hat{h}_{g.l.}\cdot \tan \alpha.
\end{align*}
\] (1)

where: \( \hat{h}_{g.l.} \) – distance from the upper part of the head to the bottom of green leaf area; \( h \) – head height above the soil surface; \( d_1 \) – diameter of the upper part of the root crop; \( \hat{d}_{g.l.} \) – diameter of tops bunch; \( a, b, m, n \) – constants.

Six groups of heads arrangement of sugar beet roots and tops with respect to the soil surface were distinguished (Fig. 2).

Sugar-bearing mass losses and tops residues of root crops of the given interval of head height above ground are determined by the following formula:

\[
M_i = F(h_i; h_{i+1}) \cdot P(h_i; h_{i+1}) \cdot N_i,
\] (2)

where:

\[
\begin{align*}
F(h_i; h_{i+1}) &= V_b \cdot \rho, \\
F(h_i; h_{i+1}) &= V_l \cdot \rho_l,
\end{align*}
\] (3)

where: \( V_b \), \( \rho \) and \( V_l \), \( \rho_l \) – accordingly volume and density of root crops and beet tops; \( N_i \) – amount of root crops of given interval per unit area.

The integral in (5) is not determined in quadratures, therefore the appearance probability of root crops of given interval of height above ground heads of root crops is defined by the formula:

\[
P(h_i; h_{i+1}) = \frac{1}{\sqrt{2\pi} \sigma} \int_{h_i}^{h_{i+1}} \exp \left(\frac{(h - h_i)^2}{2\sigma^2}\right) \, dh.
\] (5)

The results of the comparison of theoretical and experimental studies are shown (Fig. 4).
Defining of the quality indicators was conducted by well-known methodology. This methodology is relatively precise but is labor-consuming that limits the number of experiments.

Theoretical calculations are compared with experimental studies (Table 2) deviate as follows:
- sugar-bearing plant material losses – from -0.3% to +1.8%;
- tops residues from -0.3% to 0.7%.

Table 2. The absolute deviation of the theoretical calculations results and experimental data

<table>
<thead>
<tr>
<th>h2, mm</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar-bearing plant material losses, %</td>
<td>1.8</td>
<td>0.9</td>
<td>0.3</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.3</td>
</tr>
<tr>
<td>Tops residues, %</td>
<td>-0.3</td>
<td>-0.2</td>
<td>-0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

One of the reasons for deviation of the results of theoretical and experimental studies is not taken into account in the mathematical model of the additional tops cleaning and root crops damage of inside sugar beet harvesting machine.

When the sugar-bearing plant material losses make up from 1% to 5%, which are close to the agro-technical requirements, the deviation of the results of theoretical and experimental studies does not exceed 0.7% for the tops residues and 0.5% for the sugar-bearing plant material losses.

Comparing the results of experimental and theoretical studies, we can conclude that the theoretical model with sufficient accuracy displays trends dependency sugar-bearing plant material losses and tops residues from the height of cutting without copier. Therefore, this mathematical model can be used to predict the sugar-bearing plant material losses and tops residues of different varieties of sugar beet. Using these dependencies that are shown in Fig. 3 it is possible to determine the height of cutting without copier with predictable losses on sugar-bearing plant material and residues of the tops.

4. Conclusion

1. Model of sugar beet head and mathematical model of sugar-bearing plant material losses and tops residues when cutting without copier depending on the setting of the cutting height was developed.
2. Numerical simulation on the PC allowed to calculate of sugar-bearing plant material losses and tops residues depending on the height of cutting without copier under appropriate agrophysical characteristics of field and sugar beet roots.
3. Comparing the results of theoretical and experimental studies have established that discrepancy of sugar-bearing mass losses and tops residues do not exceed 1 ... 2%, which is fully correspond with the methodology of research and used in research experimental devices.
4. The proposed mathematical model can be used to predict the sugar-bearing plant material losses and tops residues under different varieties of sugar beet cultivation, harvesting techniques and tools to predict the quality indicators of cleaning.

5. Literature

The studies established the main causes of losses of harvest of rice and the factors affecting its collection of completeness: simultaneity maturing panicles, were killed, and the density of stems; thickness unevenness roller (coefficient of variation 38.5%); different density of packed roll; overload in a tough regime threshing associated with unprepared pile of rice biomass to threshing. Formulated scientific and methodical bases of creation of reducing the loss of harvesting machines, consisting of the following series of mechanical and technological principles: reduction of losses of seeds and their injuries by pre-allocation of free seeds from the sloping mass fruitful; to the threshing destruction due to mature seed stalk; mechanical vibration in the orientation of the seed flow corrugated seed collecting surface by detecting the properties of self-orientation relatively free of seeds orienting elements; combined mechanical action on the moving bed of crop by shaking her layers on mutually perpendicular planes; violation ties preliminary seed bearing surface of seed collection in order to reduce the energy intensity of their collection; mechanical orientation of the tips of the plants when applying them scratching area; the formation of the twin rolls and supply is not threshed heads on the roll for further ripening; the impact of different types of radiation to produce a combine threshing when harvesting. This situation determined the need for improved threshing-term technology and design combine harvester Figure [1-5 et al.].

Considered in the review of the study did not allow to solve the problem of performing alignment in a single process alignment high-yielding biomass of rice and a continuous supply of them in the rice grain harvester combine. But they were the basis for selecting areas of theoretical and experimental studies, as well as the technological scheme of the device for the alignment of the biomass of rice (Figure 1).

A device for aligning biomass placed in the rice grain combine comprises a housing 1 with a bottom 2 sections of corrugations 3 in the bottom located between them with different frequency range in length feeder rice combine harvester, the distance between the corrugations 3 of the bottom 2 feeder rice combine harvester performed with greater frequency in the receiving part feeder, 3 wherein the corrugations have a V - shaped profile, slat conveyor 4.

The role of the machine-building industry, both in manufacturing and in the economy of Kazakhstan as a whole is increasing every year. At the same time, a key task of the industrial policy of the state is to develop high-tech and export-oriented industries, namely machinery have the necessary capacity and resources to solve this problem. The strategy of technological development of the Republic of Kazakhstan provided to increase grain production to 25 ... 30 mln. tons. Performing tasks can be achieved through the further modernization of agricultural production and rational use of the available technology in the farms.

The above analysis technology of cultivation and harvesting rice in Kazakhstan established the main causes of losses of harvest of rice and the factors affecting its collection of completeness: simultaneity maturing panicles, were killed, and the density of stems; thickness unevenness roller (coefficient of variation 38.5%); different density of packed roll; overload in a tough regime threshing associated with unprepared pile of rice biomass to threshing. This situation determined the need for the development of advanced technology and design threshing rice harvester.

On the basis of the system analysis of objects production line cleaning rice established the need to incorporate additional operations into the process of preparation to the threshing heap of biomass with advanced time-sampling of grain, which increases the separation of grains, reduces the injury, creating a stable operation threshing and separating device combine. Analysis of the levels of exposure of objects on a production line of rice biomass dynamic model and move it possible to assess the uniformity of the roll width to the desired degree of leveling biomass heap before entering the MCU. Presented tilt camera is a new generation (energy efficiency) feeder for transporting the plant matter from the header or the pick-up in the threshing and separating device self-propelled combine harvester. When compared with existing samples tilt cameras for the transportation of plant matter, this development offers significant advantages, among which the main ones: a significant increase in energy efficiency, reduction of the quantity and quality of grain losses during harvesting, and others. Tests feeder in paddy fields showed that it ensures stable reliable operation without overload rice harvester.

Theoretical, methodological and practical results of the studies were used in carrying out research work undergraduates, PhD students and formed the basis for the development of training programs in the preparation of bachelors in technical professions.

2.1. Preconditions and means for resolving the problem

Rice is one of the most valuable food (diet), organic food, and holds a special place in dealing with issues of food security of the country. First, in 2012 rice production in Kazakhstan increased when in 2014, crops accounted for 199.466 hectares, in 2015 - cultivated area amounted to 227, 656, ie, an increase of 28.19 thousand. ha. The concept of agro-industrial complex of Kazakhstan in the future provides the maximum increase in productivity, through innovative operations included in the technology of cultivation and harvesting of rice.

Figure 1 - Diagram of the layout device for aligning biomass rice combine harvester and thresher rice grain harvester.

A-reaper, B-spacer, C-tilt camera rice combine harvester, 1-inspection cover, 2- the lower shaft, 3-the device for aligning, 4-biomass conveyor.
housing rice grain combine harvester. The sloping lower chamber (slave) is installed in the drum grooves that provide technological gap between the conveyor 4 and the bottom 2 at the inlet. The direction of movement of the conveyor 4 is set so that the biomass stream moving between the conveyor 4 and the bottom 2. The biomass enters the inclined chamber where it is captured by the conveyor 4 slats and is pulled on the bottom 2. Due to the fact that the bottom 2 is satisfied corrugated shaped surfaces, where the profile of the corrugations 3 on the bottom 2 are arranged to each other by different frequency distances along the length of feeder rice combine harvester, and the distance between the corrugations 3 of the bottom 2 is formed with greater frequency in the receiving part feeder, and the apex away from the grind, the biomass of rice tends to occupy space, ie, it moves from the middle of the bottom 2 to its edges. This delivers a smoother and smoother leveling the flow of biomass rice 4 slats and 2 bottom. Due to the fact that the stream moving between the conveyor 4 and the bottom 2. The direction of movement of the conveyor 4 is set so that the biomass flow over the width of the feeder, ie width on the grind. The corrugations 3 directionally distribute weight across the width of the chamber, rubbing the panicle rice biomass ribbed edges 3 to the edges, and then evenly fed into the mass of rice thrasher combine harvester.

2.2. Solution of the given problem

Stable-quality rice threshing process provides a consistent work flow line combine mechanisms [6]. Available in rice combine harvester’s production line process preparation and threshing consists of tools and devices designed to ensure quality performance of the following operations:
- the collection and transportation of rice biomass;
- uniform flow distribution of biomass for threshing;
- separation of the maximum number of commodity grain biomass with a minimum of crop losses and energy costs.

It was found that the value of second feed roller threshing rice is one of the key control parameters that have influence on the stability and sustainability of the process of threshing rice combine harvesters. A second feed conditions, characterized by continuous and unstable oscillations in time portions of the biomass, depends on numerous factors.

Subject to a constant rate of movement combine the value of second feed remains approximately constant. However, in reality, the second inning, and change is the sum of an infinite number of oscillations, the micro of various sizes. Investigations revealed that the continuity of the process when the rice combine harvester, are strongly influenced by low frequency vibrations, since they correspond to different values of second filing.

The explanation for this - different periods of maturation and the heterogeneity of the crop in the rice fields. Changing the second feed, depending on the yields shown only at considerable length harvester passage.

The control device [7] drawing - 1, with a certain yield and working width of the combine header, generates the supply of rice biomass, defined by the equation:

\[ q_i = 0.01Q_i B_i \vartheta_i \nu_i, \]  \hspace{1cm} (1)

where: \( q_i \) - feed rice combine harvester thrasher biomass per time unit, kg / s; \( Q_i \) - yield rice \( i \) ha; \( B_i \) - cutting bar width, m; \( \nu_i \) - combine forward speed, m / s; \( \nu_i \) - the ratio of the mass of grain to the entire biomass entering the thrasher.

Having considered the elementary layer heap of biomass in the section A-A before it enters the feeder and after exposure to the control device in cross-section B-B drawing - 1, define, taking into account the shrinkage of the roll, the second feed \( q_{ip} \), according to the formula (2)

\[ q = \rho bh_{cp2} k_{ep} \vartheta_T, \]  \hspace{1cm} (2)

Where: \( \rho \) – the density of rice stalk weight per unit, kg / m³; \( b \) – the average width of the biomass piles, m; \( h_{cp2} \) – layer thickness at the outlet of the control device m; \( k_{ep} \) - coefficient reflecting the degree of alignment of rice biomass, depending on the profile, number, placement and angle of attack rate of working bodies; \( \vartheta_T \) - conveyor speed, m/s.

Assume that the flow of piles of biomass and its similarity with the control device implemented uniformly, then equating the right sides of equations (1) and (2) we get:

\[ 0.01B \vartheta_u Q / \nu = \rho L h_{cp2} k_{ep} \vartheta_T, \]  \hspace{1cm} (3)

at a certain speed of movement of the conveyor, the thickness of the layer of rice biomass is determined by:

\[ h_{cp2} = 0.01B \vartheta_u Q / (\nu L k_{ep} \vartheta_T). \]  \hspace{1cm} (4)

Redistribution heap of biomass in the control device takes place in the process of moving it to the threshing drum and the uniformity of a heap of rice biomass threshing drum width is estimated coefficients leveling and shrinkage (figure 1, A-A, b-b) [2]. Uniformity coefficient \( k_{p1} \) heap of biomass at the entrance to the tilt camera is given by

\[ k_{p1} = \frac{\sum (h_{i1} - h_{cp1})^2}{n - 1}, \]  \hspace{1cm} (5)

and the uniformity coefficient \( k_{p2} \) when leaving piles of biomass of feeder:

\[ k_{p2} = \frac{\sum (h_{i2} - h_{cp2})^2}{n - 1}, \]  \hspace{1cm} (6)

where \( h_{cp1}, h_{cp2} \) - average thickness of the layer at the entrance \( (h_{cp1}) \) and output \( (h_{cp2}) \) of the feeder house.

In view of the above, the uniformity heap of biomass attained control device in the feeder housing is determined by the alignment factor - \( k_{qp} \):

\[ k_{qp} = \frac{k_{p1} - k_{p2}}{k_{p1}}, \]  \hspace{1cm} (7)

The best quality is achieved by aligning \( k_{p2} \rightarrow 0 \) or when \( k_{qp} \rightarrow 1 \) and limits \( k_{qp1}, 1, ..., n \).

The average shrinkage factor \( k_{sc} \) biomass during the passage of it through the feeder is determined by:

\[ k_{sc} = \frac{h_{cp1}}{h_{cp2}}, \]  \hspace{1cm} (8)
Where \( x \) - the width of the tilt camera; \( h \) – the thickness of the biomass layer. \( x_i = 1, 2, 3, 4, 5, 6, 7, 8, 9 \) - height control point roll. A-A – section at the entrance to the roller control device; B-B – outlet.

Picture 2. Driving leveling and shrinkage heap biomass passing through the inclined combine camera

For the coordinated work of the production line necessary process control. System control will present the function critical in a changing environment, the following tasks:
- ensuring the sustainability of the process of threshing rice biomass;
- the achievement of a coherent operations of all devices and combine the mechanisms;
- uniform feed to the threshing piles of biomass.

2.3 Results and discussion

To determine the rate leveling biomass rice developed a new method and conducted laboratory tests on an experimental laboratory setting [7.8]. Methods of determining the coefficient of leveling the biomass of rice realize by the device shown in figure 3.

\[
\mu = \frac{\sum x_{\text{max}} - \sum x_{\text{min}}}{\Sigma x_{\text{max}}} \quad (9)
\]

where: \( \sum x_{\text{max}} \) - the maximum displacement of colored stems, mm; \( \Sigma x_{\text{min}} \) - minimum displacement colored stems, mm; \( \mu \) - leveling factor is calculated numerical value of the coefficient of leveling the biomass of rice.

An parametric mathematical models of working parts for feeder rice combine harvester having the form:
- multiple regression equation unfolded for the process indicators leveling biomass rice depending on the angle of attack \( x_1 \), height \( x_2 \) frequency and placement of working bodies \( x_4 \), the feed rate of biomass rice \( x_3 \):

1. The coefficient of leveling biomass rice \( \mu, \% \)

\[
\mu = 71.51 + 1.18906 x_1 - 1.49493 - 4.36088 x_2 - 0.66959 + 1.86027 x_3 - 0.90464 + 2.08086 x_4 - 1.67166 + 0.66586 x_1 x_2 - 0.25 x_1 x_3 + 1.63912 x_1 x_4 + 2.6675 x_2 x_3 + 1.60656 x_2 x_4 + 0.9175 x_3 x_4 \quad (9)
\]

2. Branch grains from panicles, m,\%

\[
m = 3.75 - 0.4459 x_1 + 0.69893 - 0.35672 x_2 + 0.04502 - 0.18537 x_3 - 0.22008 - 0.02973 x_4 - 0.32612 - 0.26723 x_1 x_2 + 0.3125 x_1 x_3 - 0.46922 x_1 x_4 - 0.2625 x_2 x_3 + 0.3666 x_2 x_4 - 0.3375 x_3 x_4 \quad (10)
\]

3. The extent of damage to the rice seed during threshing, \( \Pi, \% \)
II = 3,15 - 0,08918 x1 + 0,24856+ 0,53508 x2 + 0,16019– 0,21766 x3 + 0,19554– 0,20809 x4 + 0,2839– 0,27059 x1 x 2+0,0375 x1x3 + 0,07258 x1 x 4 – 0,4625 x2 x 3 – 0,45168 x2 x 4 – 0,0125 x3 x4

(11)

Tests tilt cameras in rice fields (Figure 4) shows, that it provides a stable solid without overloading the work of a combine harvester.


Due to design changes in-line biomass preparation for threshing and technology process in MCY rice combine is conditions controlled resource. The changes helped to stabilize the constancy of the angular speed of the drum, and therefore, significantly reduced the number and size of additional acceleration, providing shock effects on panicle. Timely dealing figure hypophyseal weight to the drum reduced power consumption in its drive to 15%, no doubt a result of the passage of biomass through improved tilt camera, where the bulk of the stems had preliminary deformation. Decreased not thrashing to 6%, 8% fragmentation and microdamages grain to 13%, increase the capacity of MCY to combine 15% [9-11].

2.4. Conclusion

Modern rice combine harvesters do not meet the agronomic requirements, as the principle of their threshing and separating devices it does not meet the physical and mechanical properties of the rice. On the basis of theoretical and experimental research technology work threshing grain combine harvester determined that, orientation to the threshing rice hypophyseal weight the width of the threshing threshing rice can improve the quality. The proposed innovation tilt camera it provides a more even distribution of the weight of rice transported along its perimeter with a preliminary allocation of free seeds of rice hypophyseal fruitful mass. In addition, the load reduction achieved on the threshing-separating device harvester by reducing the thickness of the applied layer of the rice and ensuring a more uniform supply rice hypophyseal mass harvester thresher. Theoretical, methodological and practical results research used in the performance of research works undergraduates, PhD students and formed the basis for the development of training programs in the preparation of bachelors in technical professions.

2.5. Literature

1. Sadykov J. S. and others. Inclined camera rice combine harvester // Description of the invention to the patent before №19347. KZ. Publ. 15.05.2008, newsletter №5. (in Russian).
RESEARCH ON THE IMPACT OF EXTENDING THE USE OF THE MACHINES ON THE COST OF SPARE COMPONENTS TO MAINTAIN THEIR EMPLOYABILITY

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Abstract: The degree of extending the service life of the machines is crucial in planning the amount of inventory of spare components to maintain their employability. The paper displays the analytical dependence for taking into account the impact of extending the service life of the machines over the cost of spare components needed to maintain their employability.

This paper examines the influence of pre-repair resource, between-the-repair resource and coefficient of variation of the resource of spare elements over their quantity that is necessary to maintain the efficiency of the machines when increasing their service life.

Продължението на работоспособността на машините предполага създаване на запаси от резервни елементи / части, въз, агрегати/ и материали. Големината им зависи от множество фактори, като натоварване, равнище на надеждност, срок на ползване и т.н.

Естествено, ако се увеличи експлоатационният срок на машината без да се изменят надеждностните й показатели, ще се увеличи и разходът на резервни елементи за поддържане й в работоспособно състояние. Точното отчитане на влиянието на удължаването на експлоатационния срок върху разхода на резервни елементи е от съществено значение за планирането на складовите запаси от тях [1].

Целта на разработката е да се изведе аналитична зависимост за отчитане на влиянието на удължаване на експлоатационния срок на машините върху разхода на резервни елементи необходими за поддържане на работоспособността им.

Аналитът на влиянието на удължаването на експлоатационния срок върху разхода на резервни елементи, извършваме въз основа на аналитичната формула за H(t) [2]:

\[ H(t) \approx (t-T_g)/T_m+(v_m+1)/2, \]

където \( T_g \) е доремонтният ресурс на елементите;

\( T_m \) - междуремонтният ресурс на елементите;

\( v_m \) - коeficientът на вариация на междуремонтния ресурс на елементите.

Оттук необходимият фонд от резервни елементи за поддържане на работоспособността на машините за срока им на използване може да се определи по асимптотичното уравнение на вида:

\[ H(t) \approx (T_c-T_g)/T_m+(v_m+1)/2, \]

където \( T_c \) е средният експлоатационен срок на машината.

При удължаване на показателя нормативен експлоатационен срок с \( \Delta T_c \) години (или друга единица календарно време) и постоянни стойности на останалите надеждности показатели на машината, необходимо е да се определи по асимптотичното уравнение на вида:

\[ H(T_c^+) \Delta T_c = (T_c + \Delta T_c - T_g)/T_m + (v_m + 1)/2, \]

където \( \Delta T_c \) е средното удължаване на експлоатационния срок на машините от даден вид.

Тогава измененият на годишния фонд от резервни елементи за поддържане на работоспособността на машините ще бъде

\[ K = [H(T_c^+ + \Delta T_c) - H(T_c^+)]/H(T_c^+ + \Delta T_c) \]

или \( K = \Delta T_c /[1 + \Delta T_c + 0,5\eta(v_m + 1) - K_g] \),

където \( \Delta T_c \) е относителното удължаване на експлоатационния срок на машините; \( K_g \) - относителният дял на доремонтния ресурс на елементите; \( \eta \) - относителният дял на междуремонтния ресурс на елементите.

Изменението на годишния фонд от резервни елементи за поддържане на работоспособността на машините при удължаването на \( \Delta T_c \) и \( K_g \) нараства (фиг.1), като интензивността на нарастване се увеличава с увеличаването на \( \Delta T_c + K_g \), т.е. изменението на К е неравномерно в зависимост от \( \Delta T_c \) и \( K_g \) при \( \eta = const, v_m = const \).

Фиг.1. Изменение на годишния фонд от резервни елементи за поддържане на работоспособността на машините (K) в зависимост от относителното удължаване на експлоатационния срок (\( \Delta T_c \)) и относителния дял на доремонтния ресурс на елементите (\( K_g \)) при неизменно равнище на коэффициента на вариация на междуремонтния ресурс на елементите (\( v_m \)) и относителния дял на междуремонтния ресурс (\( \eta \)).

Аналогично с характерът на изменение на K в зависимост от \( \Delta T_c + \eta \), при \( K_g = \text{const} \) (фиг.2), но влиянието на \( v_m \), с незначително (фиг.3), в сравнение с влиянието на \( \eta \) и \( K_g \) (фиг.1 и 2).
Фиг.2. Изменение на годишния фонд от резервни елементи за поддържане работоспособността на машините (К) в зависимост от удължаването на експлоатационния срок (ΔТ) и относителния дял на междуремонтния ресурс на елементите (η) при постоянно равнище на отклонения на вариация на ресурса на елементите (vₘ) и относителния дял на доремонтния ресурс на елементите на обекта (Кₑ).

Следователно, за да се компенсира нарастването на разхода на резервни елементи при удължаване на експлоатационния срок на машините върху разхода на резервни части за поддържане на работоспособността им е необходимо да се подобри качеството и оптимизира периодичността на техническото обслужване и ремонта на машините или доремонтният ресурс на елементите.

Получената аналитична зависимост за отчитане на влиянието на удължаването на експлоатационния срок на машините върху разхода на резервни елементи необходими за поддържане на работоспособността им може да се използува при техно-икономическата обосновка на корекцията на нормативния срок на машините.

Фиг.3. Изменение на годишния фонд от резервни части за поддържане работоспособността на машините (К) в зависимост от относителното удължение на експлоатационния срок (ΔTₑ) и коэффициента на вариация на ресурса на елементите (vₘ) при постоянно равнище на отклонения на относителния дял на доремонтния ресурс на елементите (η) и относителния дял на междуремонтния ресурс (Kₑ).

Изводи:
1. Изведена е аналитична зависимост за отчитане на влиянието на удължаването на експлоатационния срок на машините върху разхода на резервни части за поддържане на работоспособността им.
2. Построени са графични зависимости на влиянието на доремонтния ресурс, междуремонтния ресурс и коэффициента на вариация на ресурса на елементите върху годишния фонд от резервни части при увеличаване на експлоатационния им срок.

Литература
1. Тасев Г., М. Михов, Д. Станев Номенклатура и изходна информация за определение на нормативи за обменни агрегати и възли за обменни агрегати и възли на тракторите. С., 1989.
3. Тасев Г., Е. Видинова Влияние на удължаването на срока на експлоатация на обектите върху разхода на резервни елементи. БАН Централна лаборатория по системи за управление С., 1992
4. Тасев Г., М. Михов Исследване и определяне показателите на безотказност на ремонтируемите обекти-ССТ, 1996, 7-8, с.46-51.
THE EFFECT OF TILLAGE AND PLANT DENSITY ON YIELD AND YIELD COMPONENTS OF SOYBEAN [Glycine max (L.) Merrill] GROWN UNDER MAIN AND DOUBLE-CROPPING SOYBEAN (Glycine max L. Merr.)

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Abstract
The aim of this study was to compare tillage methods and plant density on yield and yield components of soybean [Glycine max (L.) Merrill] grown under main and double cropping systems. The field experiments were carried out at the experimental area of Agricultural Faculty, Dicle University during 2013 and 2014. The experiments were conducted as split-split plot design based on randomized complete blocks with two sowing dates (normal and late) as the main plot, three tillage methods (no-tillage, reduced and conventional) as sub-plot, and three between row spacing (35, 55 and 70 cm) sub-sub plot factor. The experiments were performed in three replications and soybean cultivar Nova (MG III) was used. The combined analysis of the data showed that yield means of reduced tillage (2036.1 kg/ha) and conventional tillage (2036.1 kg/ha) were significantly different (P>0.01) compared with no-tillage (1881.1 kg/ha). Significant interaction was observed among experimental factors. The highest value was obtained at early sowing x conventional tillage x 70x5 cm as of 2206.1 kg/ha¹

KEYWORDS: SOYBEAN, SOWING TIME, TILLAGE, PLANT DENSITY, YIELD

1. Introduction

Due to the limited agricultural land in the world, the increasing food gap emerging as a result of increasing population should be closed with increased yield per unit area in the current agricultural fields. For this purpose, highly efficient and high-quality varieties are developed by improvements and agronomic practices such as irrigation, fertilization, sowing time, tillage and sowing time still continue intensively.

Considering that the ideal soil temperature for rapid germination and growth of soybean is 25-30 °C, the best sowing time in Southeastern Anatolia Region part of Turkey is mid-May when soil conditions and potential plant diseases are considered, and it is known that it can be grown as a double crop after harvest of cereals and legume grains (mid-June/ later of June). In the double-crop agriculture, seeds are planted without wasting any time due to the short growing season after harvest of wheat (Sanford et al., 1986).

In the agricultural production, conservation tillage, including reduced tillage and no-tillage are applied as an alternative to conventional tillage system within the context of sustainable agriculture systems based on protecting and improving soil fertility. There are changes about tillage system in Turkey due to increasing environmental awareness and necessity of economic production and saving energy. Conservation tillage and especially direct sowing methods are spreading as an alternative to conventional tillage methods in worldwide and Turkey (Sessiz, 2010).

Previous crop residue of crop are important components of reduced tillage methods and they affect the crop yields, positively by adding nutrients to the soil (Erenstein 2003), balancing the soil temperature (Greb, 1966; Wilhelm et al., 1989) and reducing soil water evaporation (Biamah 2005). For most soils, crop residue can increase the water infiltration in the root of the plants (Bruce et al., 1987; Dick et al., 1987), which provide suitable conditions for agricultural activities by reducing soil erosion and runoff water and improve crop yield. Conservation tillage or reduced tillage practices allow crop residues left on the soil and these remains suppresses the weeds out (Crutchfield et al., 1985; Putnam et al., 1983). Reduced or tillage methods can provide expansion of the under double crop since sowing season is advanced.

In the agricultural ecosystem, plant growth and development is influenced by cultural practices such as row spacing and number of plants. In the narrow row spacing, larger number of plants are planted, earlier canopy formation is provided and first pods are formed at higher levels and water in the soil is less evaporated, and a better root development is provided and less soil erosion occurs (Palmer and Privette, 1992).

In recent years, increased use of soybeans as a source of renewable energy in the biodiesel sector led to a rise in commodity prices and it is expected to rise further in the coming years. Therefore, producers need alternative agricultural practices with lower production costs and highest yield potential. In these alternative agricultural practices, determination of the lowest optimal number of plants and the most appropriate tillage methods that can provide fuel savings have become the priority research topics in recent years (Peterson and Higley, 2001).

Although the Mediterranean, Aegean and Southeastern Anatolia Regions of Turkey have favorable ecological conditions for soybean production; unfortunately, the cultivation area and production amounts at very low levels. In this study, in which the proper tillage and plant density will be investigated for soybean that has a growth potential as both main and double crop; it was aimed to determine effects of different tillage methods on growth and development, yield and quality of the plant by using appropriate row spacing if soybeans are grown under main and double-crop production conditions.

2. Materials And Methods

The study was carried out at University of Dicle, Faculty of Agriculture, Field Crops Department, Diyarbakir located in South East Anatolian Region of Turkey in 2013 and 2014. The region has a warm climate in summer, and the mean annual rainfall is around 450 mm, most of which fall in a major cropping season which extends from November to June. Experimental soil has a heavy built (fine textured), it is poor in terms of organic matter and phosphorus with medium lime and moderate alkaline reaction and high cation exchange capacity no salt (Anonymous 1995). The
experimental area is located at 37° north latitude and 40° east meridian at 670m height in city center of Diyarbakır, Turkey. The treatments were replicated three times in split-split plot based on randomized complete block design with sowing time (early and late) in the main plots, tillage methods (no-tillage, reduced tillage and conservation tillage.) in the sub-plots and plant density of 35x5 cm, 55x5 cm and 70x5 cm with 571 400, 363 600 and 285 700 plants ha$^{-1}$ in the sub-sub plots. The conventional tillage treatment (plow + disc harrow + harrow) and reduced tillage (cultivator + harrow) were involved before sowing. All plots were fertilized with 20-20-0 pure compound fertilizer 100 kg ha$^{-1}$; 10 kg of pure nitrogen prior to sowing then all plots were fertilized with 33% ammonium nitrate 100 kg ha$^{-1}$ at R1 growth stage. Soybean cultivar NOVA (MG III) was sown as early sowing on MAY and late sowing on June. The irrigation was performed within 9-10 days depending on need of the plants with sprinkler system. All plots were harvested from two central rows at early sowing (mid-September), late sowing (mid-October).

Data was subjected to an analysis of variance (ANOVA) using a statistical software package (JMP version 5.0.1a). Least significant difference (Tukey’s HSD test) was used to compare treatment means at P=0.05.

3. Results and Discussion

According to the results of the experiment, the two-year average values showing the effects of tillage methods and plant density on the yield and agronomic characteristics of soybean grown as the main and double-crop soybean are given in Table 1. Considering the two-year average plant height values; they reached 63.84 cm in normal sowing and reached up to 61.04 cm in late sowing. Since soybean is a short day plant, vegetative growth drops down after June due to the effect of short-day conditions in the planting and eventually plant height becomes shorter in the late sowing method. Cinsoy et al. (2005) conducted a study under the main and second product conditions and stated that the height of the plant gets shorter as the sowing time is delayed. The results of this study are supported by Ansari et al. (1997), Söğüt et al. (2005) and Arıoğlu (2007). The effect of tillage on plant height was found to be significant based on a two-year average. According to two-year average values; the highest plant height was obtained from conventional tillage practices (67.11 cm), and it was followed by reduced tillage practices (62.54 cm) and the lowest values were obtained from no-tillage practices (57.68 cm). Although our data on plant height are consistent with results of Arslan and Arıoğlu (2001), they are inconsistent with findings of some researchers such as Temperly and Borges (2006). Temperley and Borges (2006) state that taller plants (88. 7 cm) can be grown by no-tillage method and there is a significant difference compared to conventional tillage method (82.5 cm). Considering two-year average values indicating that height of the plant increases as plant density is increased; no difference was found between plant height values with 35x5 cm and 70x5 cm row spacing, they were found to be higher compared to 55x5 cm row spacing. These data were also supported by Board (2000) and Green-Tracewicz et al. (2011), stated that there is an increase in the height of soybean due to the light competition in parallel with increased number of plants per unit area. The number of lateral branches per plant obtained That normal sowing founded higher than late sowing (2.12 unit plant$^{-1}$). These findings in regard with the effect of sowing time on the number of lateral branches are found to be consistent with results of Söğüt et al. (2005) and Cox et al. (2008). According to the two-year average values, no difference was found between effects of tillage methods on the number of lateral branches. The number of lateral branches varied between 1.63-1.98 unit plant$^{-1}$. These findings in regard with the effect of tillage methods on the number of lateral branches seem similar to the findings of Sessiz et al. (2009). Considering the effects of plant density on the number of lateral branches per plant; the number of branches varied between 1.64-1.91 unit plant$^{-1}$, the number of lateral branches were reduced as the plant density increased. These result are similar to those obtained by other authors Öz (2002) and Cox et al. (2008). The number of fruits per plant is found to be 43.75 units/plant in normal sowing and 42.32 units/plant in late sowing, respectively. According to these data, there is a decrease in the number of fruits as the sowing time delays. This finding is consistent with results of Cox et al. (2008). The effects of tillage on the number of fruits were found to be significant and the number of fruits obtained from conventional tillage practices was found to be higher compared to the number of fruits obtained from reduced tillage and no-tillage practices (46.17 units plant$^{-1}$, 42.03 units plant$^{-1}$ and 40.90 units plant$^{-1}$, respectively). These results are consistent with results of Sessiz et al. (2009). Considering the effects of plant density on the number fruits per plant; according to the two-year average values, although no significant difference was seen, it varied between 41.80– 44.76 units plant$^{-1}$ and a slight downward trend was seen in the number of fruits as the plant density increases. This is thought to be caused by smaller number of branches in plants grown with narrow row spacing. Our findings are consistent with results of Cox et al. (2008) and Daneshmand et al. (2013). According to the effect of sowing time on the weight of seed is considered to be important. Weight of seed is considered to be important. Weight of seed is found to be 11.37 gr in normal sowing and 12.60 in late sowing, respectively. In this regard, it can be suggested that the weight of 100 seeds is increased as the sowing time delayed. These results are in line with findings of Pedersen and Lauer (2004a), Bastidas et al. (2008) and Daneshmand et al. (2013). The effect of tillage practices on the weight of 100 seeds is considered to be important. According to the two-year average values, the difference between tillage practices is considered to be important and the seed weight ranged between 11.37–12.56 g. The highest seed weight was obtained from conventional tillage practices (12.56 g).
However, Pedersen and Lauer (2003) and Singer et al. (2008) found different results. According to the results of their studies, the effect of plant density on the weight of 100 seeds is found to be insignificant and the seed weight ranged between 11.87-12.06 g (35x5: 12.06 g, 70x5:11.87 g). Although similar results were obtained by De Bruin and Pedersen (2008), Daneshmand et al. found different results. Considering the seed yield; according to the two-year average values, the effect of sowing time on the yield is not found to be significant the seed yield was found to be 1932.05 kg ha⁻¹ in normal sowing and 2021.06 kg ha⁻¹ in late sowing. Although Daneshmand et al. (2013) determined that the seed yield obtained from late sowing is 14.5% higher than the seed yield obtained from early sowing, Sarmah and Chaudhry (1984), Bruin and Pederson (2008b) state that late sowing has negative effects on the seed yield. The effect of tillage practices on the seed yield is found to be significant. The seed yield varied between 1881.11-2036.15 kg ha⁻¹ and no significant difference was found between reduced tillage and conventional tillage methods and the highest yield was obtained from no-tillage practices. Similar to our results, Sabo et al. (2007), Sessiz et al. (2009) and Mazzoncini et al. (2008) determined the highest yield from conventional tillage practices. However, Özpmar and Cay (2005) and Six et al. (2002) obtained different results. The effect of plant density on the seed yield was is not found to be significant according to the two-year average values. The seed yield varied between 1951.26 - 2023.19 kg ha⁻¹. According to many studies conducted on the yield of soybean, 27% higher yield is obtained from plants with 25 cm row spacing compared to those with 76 cm row spacing (Costa et al. 1980). In addition, Board and Harville (1992); Bullock et al. (1998) reported that soybean plants with narrow row spacing use the light more efficiently compared to those with wider row spacing and therefore the yield of plants with narrow row spacing is found to be higher. Similar to our results, Lee et al. (2008) stated that the yield of soybean is reduced as plant density increased. Considering the harvest index; according to the two-year average values, the effect of harvest index is not found to be significant and it was found as 37% in normal sowing and 39% in late sowing. Although these findings about sowing time seem similar to the findings of Söğüt et al. (2005), the results of Pedersen and Lauer (2004) seem different. The harvest index results varied between 37-39% in tillage practices were found similar to results of Pedersen and Lauer (2004). Plant density has no significant effect on the harvest index, and varied between 36-39%. According to these findings, there is an inverse relationship between harvest index and plant density. Although these findings seem similar to the findings of Öz (2002), Edwards and Purcell (2005) and Rahman et al. (2013), Board (2000) and Green-Tracewicz (2011) obtained different results. According to the two-year average values, the fat content is found to be 22.88% in late sowing, and 20.23% in normal sowing. According to these results, there is an increase in the fat content as sowing time delays. According to the earlier studies in regard with fat content, there are different results in the literature. Hu (2013) reported that sowing time has no effect on the fat content and the fat content is reduced with a delay in the sowing time (Kumar et al., 2006; Tremblay et al., 2006); Daneshmand et al. (2013) determined that the highest fat content was obtained from late sowing. The effect of tillage method on the fat content is considered to be significant. No significant difference was found between conventional tillage (22.10%) and reduced tillage (22.00%) practices and higher fat content was obtained from these practices compared to no-tillage method (20.57%). Similar results were obtained by Singer et al. (2008) and Sabo et al. (2007). The effect of plant density on the fat content is considered to be significant; the lowest fat content was obtained from 35x5 cm plant density (21.27%), while the highest fat content was obtained from 70x5 cm plant density. Although there are inconsistencies, the fat content seems to be decreased as the plant density increases. According to sowing time has no significantly effect on the protein content. The seed protein content were found as 37.68% (early sowing) and 37.27% (late sowing), Although there are no significant differences between practices in terms of protein content, there is a slight downward trend with a delay in the sowing time. Although Hu (2013) and Pedersen and Lauer (2003) indicated that the effect of sowing time on the protein content is not significant, Helms et al. (1996) reported that a delay in the sowing time reduces the protein content in the soybean, which seems to be different from our results. The effect of tillage practices on the protein content is not found to be significant according to the two-year average values. According to the two-year average values 39% protein content was obtained. Higher protein content was obtained by strip tillage (Hu, 2013) and conventional tillage (Osborne and Riedell 2006) methods compared to no-tillage method. The effect of plant density on the protein content is not found to be significant according to the two-year average values. According to the two-year average values 39% protein content was obtained. Higher protein content was obtained by strip tillage (Hu, 2013) and conventional tillage (Osborne and Riedell 2006) methods compared to no-tillage method. The effect of plant density on the protein content is not found to be significant. The two-year average values were found to be very close to each other. In the studies conducted on effect of plant density on fat and protein contents, it was reported that both fat and protein contents increase with increased plant density (Weber et al. 1966). Similar results were obtained by Cober et al. (2005) and they determined that the protein content is often affected by the plant density.
Table 1. In the soybean grown as the main and second product, the effect of tillage methods and plant densities on the Plant height (cm) Lateral Branch, Fruit and Seed Numbers, 100 Seed Weight, Seed Yield, Harvest Index, Fat Content, Protein Content and Biological Yield of the product.

<table>
<thead>
<tr>
<th>Practices</th>
<th>Plant height (cm)</th>
<th>Lateral Branch Number (no plant-1)</th>
<th>Fruit Number (no plant-1)</th>
<th>100 seed mass (g)</th>
<th>Seed yield (kg ha-1)</th>
<th>Harvest Index (%)</th>
<th>Oil content (%)</th>
<th>Seed Protein content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing Time</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Normal</td>
<td>63.84</td>
<td>2.12 A</td>
<td>43.75</td>
<td>11.37 B</td>
<td>1920.05</td>
<td>0.37</td>
<td>20.23 B</td>
<td>37.68</td>
</tr>
<tr>
<td>Late</td>
<td>61.04</td>
<td>1.51 B</td>
<td>42.32</td>
<td>12.60 A</td>
<td>2021.06</td>
<td>0.39</td>
<td>22.88 A</td>
<td>37.27</td>
</tr>
<tr>
<td>LSD (% 5 %)</td>
<td></td>
<td></td>
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<td>Tillage</td>
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</tr>
<tr>
<td>No-Tillage</td>
<td>57.68 C</td>
<td>1.83</td>
<td>40.90 B</td>
<td>11.37 C</td>
<td>1881.11 B</td>
<td>0.38</td>
<td>20.57 B</td>
<td>37.45</td>
</tr>
<tr>
<td>Reduced Tillage</td>
<td>62.54 B</td>
<td>1.63</td>
<td>42.03 B</td>
<td>12.04 B</td>
<td>2015.40 A</td>
<td>0.39</td>
<td>22.00 A</td>
<td>37.26</td>
</tr>
<tr>
<td>Conventional Tillage</td>
<td>67.11 A</td>
<td>1.98</td>
<td>46.17 A</td>
<td>12.56 A</td>
<td>2036.15 A</td>
<td>0.37</td>
<td>22.10 A</td>
<td>37.69</td>
</tr>
<tr>
<td>LSD (% 5 %)</td>
<td>1.66</td>
<td></td>
<td>2.73</td>
<td>0.38</td>
<td>56.85</td>
<td></td>
<td>1.08</td>
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<tr>
<td>Plant Density</td>
<td></td>
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<tr>
<td>35x5 cm</td>
<td>64.26 A</td>
<td>1.64</td>
<td>42.54</td>
<td>12.06</td>
<td>1951.26</td>
<td>0.36</td>
<td>21.27 B</td>
<td>37.55</td>
</tr>
<tr>
<td>55x5 cm</td>
<td>59.65 B</td>
<td>1.88</td>
<td>41.8</td>
<td>12.03</td>
<td>1958.23</td>
<td>0.39</td>
<td>21.36 B</td>
<td>37.54</td>
</tr>
<tr>
<td>70x5 cm</td>
<td>63.41 A</td>
<td>1.91</td>
<td>44.76</td>
<td>11.87</td>
<td>2023.19</td>
<td>0.38</td>
<td>22.04 A</td>
<td>37.33</td>
</tr>
<tr>
<td>LSD (% 5 %)</td>
<td>2.73</td>
<td>0.55</td>
<td>-</td>
<td>0.35</td>
<td>56.95</td>
<td></td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>General Average</td>
<td>62.44</td>
<td>1.81</td>
<td>43.03</td>
<td>11.98</td>
<td>1977.29</td>
<td>0.37</td>
<td>21.55</td>
<td>37.47</td>
</tr>
</tbody>
</table>

4. Conclusions
In this study, which was conducted during years 2013 and 2014; considering the two-year average values, the sowing time has significant effects on the number of branches, 100 seed weight, seed yield, oil content. Early sowing time has significant effects on the number of branches. Late sowing time has significant effects on harvest index and fat content. On the other hand, late sowing time has significant effects on 100 seed weight and fat content. According to the average values of two years; tillage methods have significant effects on plant height, number of fruits, 100 seed weight, seed yield and fat content. The conventional tillage method has significant effect on plant height, number of fruits, seed yield, harvest index and fat content of the plant. Considering the effects of plant density, according to the two-year average values, the plant density has significant effects on plant height and fat content. 35x5 cm plant density has significant effects on plant height while 70x5 cm plant density has significant effects on the fat content of the plant. According to the results of the study, which was conducted under early and double crop conditions, the seed yield was not negatively affected by late sowing time. There are significant differences between tillage methods in terms of yield. There was more yield determined in conventional tillage method according to no-tillage practices. The best plant density found as 70 x 5 cm (23.0 plant m^-2) which was conducted under the field conditions. According to the results of the study, which was conducted under years 2013 and 2014; considering the effects of plant density, according to the two-year average values, the plant density has significant effects on plant height, number of fruits, seed yield, harvest index and fat content of the plant. Considering the effects of plant density, according to the two-year average values, the plant density has significant effects on plant height and fat content. 35x5 cm plant density has significant effects on plant height while 70x5 cm plant density has significant effects on the fat content of the plant. According to the results of the study, which was conducted under early and double crop conditions, the seed yield was not negatively affected by late sowing time. There are significant differences between tillage methods in terms of yield. There was more yield determined in conventional tillage method according to no-tillage practices. The best plant density found as 70 x 5 cm (23.0 plant m^-2) which was conducted under the field conditions. According to the results of the study, which was conducted under years 2013 and 2014; considering the effects of plant density, according to the two-year average values, the plant density has significant effects on plant height, number of fruits, seed yield, harvest index and fat content of the plant. Considering the effects of plant density, according to the two-year average values, the plant density has significant effects on plant height and fat content. 35x5 cm plant density has significant effects on plant height while 70x5 cm plant density has significant effects on the fat content of the plant. According to the results of the study, which was conducted under early and double crop conditions, the seed yield was not negatively affected by late sowing time. There are significant differences between tillage methods in terms of yield. There was more yield determined in conventional tillage method according to no-tillage practices. The best plant density found as 70 x 5 cm (23.0 plant m^-2) which was conducted under the field conditions.

5. Acknowledgement
DUBAP (Dicle University Scientific Research Projects) unit is acknowledged for financial support.

6. Literature
12. Bruin, J., Pederson, P. 2008 Soybean Seed Yield Response To Planting Date And Seeding Rate In The Upper Midwest. Agronomy Journal 100:696-703


POSSIBILITIES OF USING SOLAR POWERED COOLING SYSTEMS IN AGRICULTURE

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Abstract: A significant part of the electrical energy used for the heating and cooling, produced from fossil based sources. The decrease of fossil based fuels and the price rises forced people turn to other energy sources. Renewable energy sources are shown as a good alternative to fossil energy sources cause of the environmental its potential. Compared to solar energy become prominent by having easy operation and lower installation costs, as one of the alternative energy sources compared with other renewable energy. Solar energy mostly used for heat water and environment. Cause of the lower solar radiation when much-needed period of habitat heating, solar power cannot be used as efficient for heating. In the summer, while the most intense and prolonged period of solar radiation there is no need for heating, instead an arising need for space cooling. In the summer, using solar power for cooling could be a significant saving method. Especially in the sun-rich regions it is possible to take advantage of solar energy for climatization plant and animal production facilities.

In this study, it is aimed to explain using solar cooling systems in agricultural applications and solar cooling technologies.

Keywords: SOLAR POWER, COOLING SYSTEMS,

1. Introduction

One of the conditions for leading a comfortable life for humans, animals and plants, all living creatures in short is being able to fulfill the needs of heating and cooling. The energy used for cooling and heating constitutes a big portion of the total energy consumption. A large portion of the used energy is derived from fossil fuels, and this means greenhouse gas emission like CO₂ and CO, leading to global warming [1]. This means fossil-based energy sources affect the increase in global temperature. As with heating, fossil fuels are also important sources in cooling; but the gradual decrease in fossil fuels is leading humans to other sources of energy. Especially renewable energy sources, with their environmental aspects and potential, are considered to be a good alternative to fossil energy sources.

Solar energy, which is another alternative energy source, when compared to other renewable energies, stands out more due to its easier application and lower setup cost. The greatest areas of application of solar energy has been the heating of water and ambient and the fact that solar radiation is low and cannot be efficiently used in times when ambient heating is most needed, continues to be a problem. Whereas in the summer time, when the solar radiation is at its peak and has the longest duration, there is no need for ambient heating, on the contrary there is a need for cooling. Making use of solar energy for ambient cooling in the summer months appears to be an important savings method.

It is important to make environmental and economic solar powered cooling systems used for ambient cooling become widespread.

2. Solar Powered Cooling Systems

Transfer of heat from a low ambient temperature area to high ambient temperature area does not occur by itself; the machines that provide this transfer based on the “Reversed Carnot Cycle Principle” are called “Cooling Machines”. Cooling cycles with vapor compression takes place with 4 main elements (Fig. 1). These are the compressor, condenser, regulating valve, and vaporizer. The refrigerant fluid enters the compressor as vapor and is compressed to the condensers pressure. The fluid comes out of the compressor with high heat, passes through the condensers pipelines while its heat to its ambient area and thus cools and condenses. After the condenser, the fluid enters a capillary tube and here with the effect of reduction, the pressure and temperature of the fluid decreases considerably.

The efficiency of a cooling machine is expressed with an activity coefficient and shown as COP (Coefficient of Performance). The aim of a cooling machine is to draw heat (QL) from the area to be cooled / refrigerated. The cycle is completed with the refrigerant fluid exiting the vaporizer and re-entering the compressor [2].

The low-temperature refrigerant fluid later enters the vaporizer, and vaporizes by absorbing heat from the area to be cooled / refrigerated. The cycle is completed with the refrigerant fluid exiting the vaporizer and re-entering the compressor [2].

\[\text{COP} = \frac{Q_L}{W_g - Q_L}\]

Since \[W_g = Q_H - Q_L\]

The coefficient of performance of a cooling machine can be expressed as:

\[\text{COP} = \frac{Q_L}{W_g - Q_L}\]

Studies on making the use of energy more efficient in the cooling sector is ever-increasing with new designs to replace electrical energy sources of cooling machines with solar powered sources. In order to use the energy coming from the sun for cooling, certain thermodynamic cycles are used. There are many cooling machines with solar powered sources that use the difference formed with these cycles. These cooling system can vary due to small changes and different denominations. Conventional solar panel vapor compression systems, single iterative absorption systems, double iterative absorption systems, adsorption systems, desiccant systems and vapor-jet system are examples of such systems. Especially the solar energy assisted absorption cooling systems are one of the most commonly used (Fig. 2).
The reason this system is so preferred is the low amount of energy the system needs. The fundamental difference between the absorption cooling system and conventional mechanic vapor compression systems in terms of cycles is that absorption system uses an absorber-generator duo instead of a compressor. This way, there is no need for the high electrical input of the compressor. In related studies, the achieved COP (Coefficient of Performance) values range between 0.3 and 1.2. The most important factor in the design of the absorption cooling system is the performance of the solar collector to be used. If liquid temperatures reach 150°C, then double iterative absorption systems that have high COP values can be used; if the liquid temperatures are around 90°C, then single iterative systems with lower COP’s can be used [3].

**3. Applications of Solar Powered Cooling Systems and Their Applicability in Agriculture**

There are various applications of solar powered cooling systems around the world. In a factory in Germany, 100 m² of heating collector is used in a single stage desiccant system to cool a 800 m² area. The system reached a lowest cooling temperature of 17°C. The COP value was determined to be 0.5 on average during the desiccant cooling process. In a public library in Spain, an area of 3500 m² was successfully cooled using a heating collector system with a collector area of 155 m². The COP value was determined to be 0.6 on average. In China, 3 vacuum tubed collectors were used to cool a laboratory with a volume of 72 m³. The system’s maximum cooling load was around 4.5 kW. The average COP value was found to be 0.95 [5].

In the Rethimno holiday resort south of Greece, an absorption cooling system was setup in 2001 (Fig. 3). The system was capable of both heating and cooling. The cooling capacity of the system was 105 kW, the cooled area having an area of 3000 m². The gross surface area of the planar collectors was 448 m², with the hotels cooling system also being used in the heating of the pools. The system was operated with the cooled water temperature to be within the range of 8-10°C and the cooling efficiency was determined to be 0.60. In cases where the sun was insufficient or there was clouding, a 600 kW capacity gas-fired broiler would provide the system with hot water [6].

In a wine cellar in France, a solar power assisted absorption cooling system was installed in 1991 and has been working as planned without any problems since that day (Fig. 5). In this system, it was aimed to store energy with the solar collectors, generate cold water in low temperatures and cool the surrounding air. The surface area of the system’s vacuum piped solar collectors are 130 m². The wine cellar, which can store up to three million bottles of wine has a total of 3 levels, with 2 levels being below the ground. The wine cellar has a total area of 3500 m². The system’s cooling coefficient was found to be 0.57 according to the readings obtained [7].

**Fig.2 Solar Power Based Absorption Cooling System**

In the solar system, the flat plate solar collectors can be used while the supply water temperature is between 60 to 90°C. Supply water temperature can be increased up to 120°C by planar solar collectors with selective surface. While using the stationary vacuum tube collector system, supply temperature will be between 97°C to 73°C. Moreover, with focusing parabolic collectors, temperature can reach 165°C [4].

**Fig.3 In the Rethimno holiday resort in Greece**

A system was installed for the cooling of a two-story office in Spain with an area of 10000 m². The system having 1632 m² of gross collector area, the ambient temperature was maintained at 23°C by utilizing a four pipe fan-coil (Fig. 4). The total cooling load of the building was determined to be 170 kW. The water heated with the installed solar power system was stored in 2 tanks of 30000 liters capacity each. In the winter, when the sun was insufficient, an electrical cooler would kick in. In the summer when the need for heated water would decrease, the absorption cooling system would kick in when the accumulated water temperature reached 80°C and thus the electrical cooler would operate less. The installed system would save 565060 kWh of energy per year [6].

**Fig.4 Two-story office in Spain**

In a wine cellar in France, a solar power assisted absorption cooling system was installed in 1991 and has been working as planned without any problems since that day (Fig. 5). In this system, it was aimed to store energy with the solar collectors, generate cold water in low temperatures and cool the surrounding air. The surface area of the system’s vacuum piped solar collectors are 130 m². The wine cellar, which can store up to three million bottles of wine has a total of 3 levels, with 2 levels being below the ground. The wine cellar has a total area of 3500 m². The system’s cooling coefficient was found to be 0.57 according to the readings obtained [7].

**Fig.5 The wine cellar in France**
Many studies are being conducted around the world regarding the economical use of energy. The integration of newly developed technologies in different industries is very important in terms of increasing the global energy savings. Solar power assisted cooling systems are developing every day and are appealing to many different industries. Agriculture, being one of these industries, uses small capacity cooling systems in many of its sections. Cooling systems are being used in the air-conditioning of special places such as agricultural seed and plant production rooms, hatcheries, and chick production facilities [8].

Cooling of milk storage facilities after milking is important in terms of health. In 2004, with the aim to cool milk, Pilatowsky and colleagues performed a theoretical thermodynamic simulation of an absorption cooling system in one of their studies (Fig. 6). In the study, the necessary heat was provided with a vacuum tube solar collector. The system was designed for Mexico’s countryside, and it was concluded that the system was applicable for cooling milk [9].

Greenhouse temperatures have a negative effect on plant development in regions with high yearly temperature averages. In periods where the ventilation and cooling are insufficient, production has to be halted and thus the producer loses money. Using solar powered cooling systems, greenhouses can be cooled with low operating costs when solar radiation is high. Cooling of building of agricultural enterprises and agricultural product storage areas can also be included in solar power applications.

4. Conclusion

In a world where fossil fuels are gradually decreasing and environmental energy is steadily gaining value, renewable energy sources are an issue that must be put emphasis on. Greenhouses, milk storage tanks, agricultural enterprise buildings and storage areas can be seen as suitable fields of application for solar powered cooling applications.

5. References

CONCEPTION OF NAVIGATION SYSTEM FOR AUTONOMOUS AGRICULTURAL ROBOT

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Abstract: The aim of the paper was to propose conception of the navigation system for the autonomous robot for sowing and wide row planting. Autonomous work of the robot in range of traction and agronomic processes will be implemented on the basis of data from many sensors (cameras, sensors position, sensors distance, and others). Positive test results will allow for the use of the robot in organic crops requiring mechanical removal of weeds or in crops with application of selective liquid agrochemicals limited to the minimum. The use of a vision system, based on the map coordinates of the position of the sown seeds, will allow for their care on an early stage of plant development. Main sensor system is based on a specialized GPS receiver providing position information with an accuracy of less than 100 mm. This system will be used to: control speed of the robot, guidance and maintenance robot on the designated path, precision seeding - the exact information on where sowing the seeds will be used to build maps of seeds, which will be used as supporting information for precision weeding, and to control the position of and operation of key components. The front camera view will be used to increase positioning accuracy of the robot. It will allow corrections of the robot path regarding the rows of plants. The vision system will also be used for detection of non-moving objects. Additionally information from the acceleration sensors and encoders built-in wheels will be used in navigation purposes. To determine the angular acceleration the IMU (Inertial Measurement Unit) will be required. During the preliminary phase of the project Authors are planning to test possibility of usage of several low cost sensors for collision avoidance system (moving objects detection).

Keywords: AGRICULTURE ROBOT, CARE OF PLANTS, AUTONOMOUS WORK, COLLISION AVOIDANCE METHOD

1. Introduction

Syndicate of Industrial Institute of Agricultural Engineering in Poznań, with the Institute of Vehicles of Warsaw University of Technology and PROMAR company from Poznań was started a design of autonomous farm robot for sowing and cultivation of wide row planting.

The aim of the project is to develop structures and operation procedures autonomous robot for sowing and wide row planting and conducting laboratory and exploitation tests on an experimental model. Autonomous work of the robot in range of traction and agronomic processes will be implemented on the basis of data from many sensors (cameras, sensors position, sensors distance, and others). Positive test results will allow for the use of the robot in organic crops requiring mechanical removal of weeds or in crops with application of selective liquid agrochemicals limited to the minimum. The use of a vision system, based on the map coordinates of the position of the sown seeds, will allow for their care on an early stage of plant development. The applicability of the robot to onerous work in organic farming may encourage farmers to discontinue the use of herbicides in crops include sugar beet, corn, etc..

2. Initial assumptions for robot

The autonomous farm robot should work in following working conditions:
- terrain: empowered field, field roads, mud, sand, grassy ground, rocky ground or other hardened,
- work in the open 24 hours / day,
- work in areas with varying degrees of lighting and visibility,
- temperature: 5 to 40 °C,
- weather: average rainfall, moderate wind, fog,
- typical obstacles in the open area.

Projected robot enables complex care field crops including: red beet, sugar beet, sweet corn, cabbage, lettuce, forest nurseries, orchard, production of vegetables and ornamental plants. Projected robot will enable complex care of field crops including: red beet, sugar beet, sweet corn, cabbage, lettuce, forest nurseries, orchard, production of vegetables and ornamental plants. Additionally it should enable the mechanical destruction of weeds and, if necessary, precise application of crop protection formulations and fertilizers. Robot constructed by us will be have a smart weeder, equipped in LPS system, which uses digital image analysis for steering working tools, for mechanical weed control.

CAD Model of the robot was presented at figure 1.

Fig. 1 CAD Model of the robot

3. Conception of navigation system

Main sensor system is based on a specialized GPS receiver providing position information with an accuracy of less than 100 mm. This system will be used to: control speed of the robot, guidance and maintenance robot on the designated path, precision seeding - the exact information on where sowing the seeds will be used to build maps of seeds, which will be used as supporting information for precision weeding, and to control the position of...
and operation of key components. For tests a typical GPS (10 Hz) will be used.

The front camera view will be used to increase positioning accuracy of the robot. It will allow corrections of the robot path regarding the rows of plants. The vision system will also be used for detection of non-moving objects. Simultaneously second vision unit will also be used for acquiring camera images immediately before active hoes and sprayer. Additionally information from the acceleration sensors and encoders built-in wheels will be used in navigation purposes. To determine the angular acceleration the IMU (Inertial Measurement Unit) will be required. This will enable a:

- trajectory correction of the robot,
- precise work of active hoe,
- position adjustment and precise dosing of liquid fertilizer plant health products.

The exact position of the robot is obtained from the fusion of signals from precision GPS (in the test version standard GPS receiver Ublox NEO7) and integrated system of inertial and magnetic sensors VN-100\(^3\). VN-100 is a complete AHRS (attitude heading reference system) system integrating measurements from three axial sensors: acceleration, angular velocity and Earth magnetic field. All of the sensors have temperature compensated sensitivity and common values. Moreover, all the skewness of axes were calibrated. VN-100 device provides accurate information from all the sensors and estimates of the spatial orientation angles, DCM (direct cosine matrix) transformation matrix, and estimated values of linear accelerations and angular velocities in the absolute coordinates (NED – north/east/ down) independent from the angular orientation of the sensor. It is planned that two AHRS systems will be placed on one machine: first related to the vehicle and the second with a connection to the tools (e.g. seeder). AHRS integrated with the vehicle will provide the detailed momentary angular orientation and acceleration of the body while the second set allows better estimation of the momentary position of the tool thus allowing precise localisation of the seeds. Detailed information about their positions, stored in the internal database, will be used in further fieldwork related to the care of plants.

During the preliminary phase of the project Authors\(^4\) are planning to test possibility of usage of several low cost sensors for collision avoidance system (moving objects detection):

- HC-SR04 (Cytron Technologies) ultrasonic distance sensor with range of 5m. The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats or dolphins do. It offers excellent range accuracy and stable readings in an easy-to-use package. Its operation is not affected by sunlight or black material.

- 360 Degree Laser Scanner Development Kit. RPLIDAR is a low laser scanner (LIDAR) solution developed by RoboPeak\(^5\).

**2D Laser Scanner (LIDAR) test**

360 Degree Laser Scanner Development Kit. RPLidar is a low laser scanner (Lidar) solution developed by RoboPeak. The system can perform 360 degree scan within 6 meter range. The produced 2D point cloud data can be used in mapping, localization and object/environment modelling. It measures just over 2,000 times per second with a very small measurement error of less than 1% - theory. Real mistake approx. 10%. Temperature -10 °C to 40 °C - theory. Research at -8 °C - refreshing decreased significantly, the error up to 20%.

RPLidar measurements with error were presented at Fig. 2 and in Table 1.

The advantages of laser RPLidar includes:

- Low cost

- Large technical support from the manufacturer
- Small dimensions
- Trouble-free detection of objects
- Detecting moving objects
- RPLIDAR Disadvantages:
  - Huge error of distance measurement
  - Improper operation in extreme temperatures and strong sunlight
  - Incorrect measurements with increased wind power
  - Vibrations of the drive mechanism

![Obstacle in a distance of 6000 mm](image-url)

**Fig. 2 RPLidar measurement**

<table>
<thead>
<tr>
<th>Real measurement</th>
<th>RPLidar measurement</th>
<th>Difference</th>
</tr>
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<tr>
<td>800</td>
<td>975</td>
<td>17</td>
</tr>
<tr>
<td>1600</td>
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</tbody>
</table>

**Tab. 1 Real vs RPLidar measurements difference**

3. Conception of the collision avoidance system

The collision avoidance problem can be divided into two different subproblems: detecting the obstacle and bypass the obstacle\(^6,7\).

The raw measurements from Laser scanner 2D are at first transformed into Cartesian coordinates\(^8\). The obstacles are detected from the transformed measurements using clustering method. The whole clustering process is illustrated in Fig. 3. The initial positions for the clusters are gained from the set of known obstacles. The
cluster initial position is added if known obstacle is in sight of the scanner.

The path tracking method is based on the Nonlinear Model Predictive Control. Vougioukas\(^2\) has used the Nonlinear Model Predictive Control (NMPC) method to control the position of the vehicle. Moreover, the collision avoidance was included into the controller by using additional cost from distance sensor readings. The controller was able to follow a predefined path as well as avoid collisions with static obstacles. The functionality was proven with simulations.

The clustering algorithm\(^4\)

In the NMPC, the control values are calculated, so that the given cost function is minimized. The constraints of the optimization problem are obtained from the system model and the constraints of the states and control values. There are different ways to include the object avoidance into the NMPC. One way is to add additional constraints to the state values. Another way is to add an additional cost from the obstacles or simply to modify the reference trajectory to go past the obstacle.

In this way, the modification of the cost function was chosen. The underlying path tracking cost function is not changed nor the reference trajectory, but the cost from state is modified. This is because of the calculation capacity and the possibility that the obstacles could move.

When the reference trajectory is near an obstacle, it cannot be followed without colliding to the obstacle. Therefore it is irrelevant to keep the cost from the reference trajectory. Instead a cost that makes the vehicle drive past the obstacle should be added. The obstacle is allowed to be closer on the side of the vehicle.

The calculated distance to the edge of the avoided area is used in the cost function, when the obstacle is inside the avoided area or the obstacle is closer to the avoided area than the vehicle is to the original reference trajectory. The cost is calculated only from one obstacle. If there are multiple obstacles inside the avoided area, the one with the largest value of the the distance from the obstacle to the edge of the avoided area is chosen. The same methods are also used for the cost from the trailer position.

4. Conclusions

Conception of the navigation system for the autonomous robot for sowing and wide row planting was presented.

Some elements of navigation system was tested: RPLidar 2D and ultrasonic distance sensor.

In the next stages of the project design tasks are planned: selecting the target concept robot based on numerical analysis and developing the concept of the control system and autonomous robot control algorithms.

References

THEORETICAL PREMISES FOR ENHANCEMENT OF EFFICIENCY IN THE USE OF REVERSIBLE PLOUGHS

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Abstract. Theoretical analysis has been undertaken to determine the effect of the plough’s structural layout on the total length of the tractor-implement unit’s turning path. Basing on the results of the analysis, the utility of employing a reversible plough instead of a conventional one has been assessed. Eventually, it has been found that, when ploughing a 68.2 m wide land with an area of 8.2 hectares, the total length of the path of travel on the headlands is 1980 m for the reversible plough unit and 2035 m for the conventional plough unit, which is an increase by 2.7%. At an average manoeuvring speed of 1.75 m/s (6.3 km/h), the total amount of time spent for turning by a unit with conventional ploughing tools will be greater by mere 0.5 min. If the ploughed land is magnified by almost 1.5 times (12.0 hectares instead of 8.2), the width of the field will reach 100 m. In this case, the ploughing unit with a conventional plough will travel an 850 m longer path on the headlands. At the above-mentioned average headland manoeuvring speed of 1.75 m/s the increase of time spent by this type of tilling unit for turning will amount to just 8.5 min. The only advantage of the reversible plough over the conventional one is the opportunity to avoid the appearance of crown ridges and dead furrows when tilling the field. Meanwhile, it is to be noted that with a sufficient qualification of the machine operator the said advantage of the newer tilling implements can be levelled down. Considering the equal productivity of the compared tilling units, a negligible difference between their rates of non-productive expenditure of working time as well as taking into account the infrequent performance of ploughing, i.e. once in several years, in view of the considerably (several times) higher cost of a reversible plough, the acquisition of the latter presents an economically inadvisable option.

KEY WORDS: PLOUGHING, PLOUGH, REVERSIBLE PLOUGH, TILLING UNIT, HEADLAND, FURROW.

Introduction
Statement of problem. Lately the agricultural industry has seen ever wider introduction of reversible ploughs, the main advantage of which is the ability to work the field without producing the crown ridges and dead furrows.

One would think that such evidently efficient performance attributes of this kind of tillage implements should promote the gradual displacement of conventional ploughs from the market. But, decisive preference can be given to reversible ploughs only following their thorough technical as well as field study with results that confirm the said attributes. Moreover, all this research is to be done taking into consideration the various types of tractor-implement units with reversible ploughs, tilled land dimensions, tilling unit travelling patterns etc.

At the same time, it should be noted that, whereas the tilling tractor-implement unit with a reversible plough uses the shuttle travelling pattern in its work process on productive runs, it still has to make loop turns at the headlands. While this type of tractor-implement unit manoeuvring is more difficult to perform than, for example, loop-free turning.

Also, although tilling with the use of a conventional plough can result in the development of crown ridges and dead furrows with all the ensuing well-known adverse effects, but the practice proves that these drawbacks can be virtually completely eliminated providing that the qualification of the tractor-implement unit operator is sufficiently high. That requires abiding by the scientifically grounded and methodically tried and tested recommendations described in the available publications [1-3].

The aim of this study is to substantiate theoretically the need to use efficiently reversible ploughs as compared to the conventional ones.

Materials and methods
The research has been carried out with the use of the methods supported by the theory of operating tractor-implement units, the theoretical mechanics, the higher mathematics, the principles of program construction and PC-assisted numerical computation.

Results and discussion.
For the purpose of the theoretical study, two tilling tractor-implement units have been taken as the subjects of research and compared to each other. The first of them comprises a Class 3 tractor with an articulated frame and a rear-mounted five-bottom plough. The second tractor-implement unit consists of the identical unitising power unit (tractor) and a rear-mounted reversible five-bottom plough, which has the same working span as in the first case – 1.75 m.

We have carried out the analysis and PC-assisted numerical computation of the total length of the path travelled by each of the above-mentioned compared tractor-implement units on the headlands, when they perform the tilling of lands with the same areas.

Provided that the average working speeds of travel of the said tilling units on the headlands are equal (which is absolutely realistic in the ordinary operation conditions), the difference between the found total lengths of travelling during the manœuvres will in practice define that non-productive shift time consumption, which just indicates the advantage of one of the compared tractor-implement unit options over the other one.

Further, in order to perform the investigation it is necessary to determine analytically the width of the experimental field plot (land) required for the operation of the compared tilling tractor-implement units. To do that, the following analytical dependence can be used:

\[ C_{opt} = \sqrt{16 R_i^2 + 2 B_s L_f}, \]  

where \( R_i \) – minimum radius of turning of tractor-implement unit (m);
\( B_s \) – working span of tilling unit (m);
\( L_f \) – length of land (experimental plot) (m).

The minimum turning radius \( R_i \) of the tractor-implement unit on the basis of an articulated frame tractor can be
found with the use of the following formula:

\[ R_t = \left( \frac{L}{2} \right) \cot \frac{\alpha}{2} \]  

(2)

where \( L \) – longitudinal base length of tractor (m); \( \alpha \) – maximum frame articulation of the power unit (i.e. such type of tractor) (deg).

Using formula (2), it is easy to calculate the minimum turning radius \( R_t \) of the tilling tractor-implement units, which at the following design parameters of the above-mentioned tractors: \( L = 2.86 \) m and \( \alpha = 30^\circ \) will be equal to \( R_t = 5.3 \) m.

To continue our investigation, we assume that the length of furrow in the field is \( L_f = 1200 \) m. Taking into account the fact that the five-bottom ploughs selected for the study have a working span width of \( B_s = 1.75 \) m, from expression (1) we obtain, after substituting in it the assumed values of design parameters: \( C_{opt} = 68.2 \) m.  

When tilling a land with a width of \( C_{opt} \), each tractor-implement unit completes \( n_c \) turns. At the same time, the ratio \( \frac{C_{opt}}{B_s} \) representing the number of working runs performed by the tilling unit on the headland must be a whole number. In view of that, the number of turns \( n_c \) can be determined with the use of the following formula:

\[ n_c = \text{Integer} \left( \frac{C_{opt}}{B_s} \right) - 1. \]  

(3)

The tilling unit with a reversible plough will perform only loop turns (\( n_l = n_c \)), each having a length of \( L_{lu} \) defined as follows:

\[ L_{lu} = (6,0 \div 8,0) R_t + 2E, \]  

(4)

where \( E \) – length of the unit’s exit from the land.

In our case \( E = 7.5 \) m.

For the following calculations expression (4) can be assumed in the following form:

\[ L_{lu} = 7R_t + 2E. \]  

(5)

Using expressions (3) and (5), we can find the total length of the loop turns performed by the tractor-implement unit with a reversible plough as the sum of \( L_{lu} \), i.e. as follows:

\[ \sum_{k=1}^{n} (L_{lu})_k = L_{lu} n_l = (7R_t + 2E) \left( \text{Integer} \frac{C_{opt}}{B_s} - 1 \right). \]  

(6)

The tilling tractor-implement unit with a conventional plough initially also performs loop turns. It continues doing them until the following condition is met:

\[ n_{lm} = B_s \geq 2R_t, \]  

(7)

where \( n_{lm} \) – number of working runs during the performance of loop turns.

The number of loop turns (\( n_{lc} \)) will be equal to:

\[ n_{lc} = \text{Integer} \left( \frac{R_t}{B_s} \right) - 1, \]  

(8)

while their total length will be equal to:

\[ \sum_{k=1}^{n} (L_{ll})_k = L_{lc} n_{lc} = (7R_t + 2E) \left( \text{Integer} \frac{2R_t}{B_s} - 1 \right). \]  

(9)

After condition (7) becomes fulfilled, the tilling unit will start performing already loop-free turns doing straight runs with a length of \( X_l \). The length \( L_{nl} \) of each such manoeuvre of the tilling tractor-implement unit can be defined as follows:

\[ L_{nl} = (1,4 \div 2,0) R_t + 2E + X_l. \]  

(10)

For the calculation purposes, we can express \( L_{nl} \) in the following form:

\[ L_{nl} = 1,7R_t + 2E + X_l. \]  

(11)

The number \( n_{nl} \) of the loop-free turns performed by the tilling tractor-implement unit will be equal to:
\[ n_{nl} = n_c - n_{lc} = \text{Integer} \left( \frac{C_{opt}}{B_s} \right) - 1 - \text{Integer} \left( \frac{2R_i}{B_s} \right) + 1 = \]
\[ = \text{Integer} \left( \frac{C_{opt}}{B_s} \right) - \text{Integer} \left( \frac{2R_i}{B_s} \right). \quad (12) \]

As regards the total length of the straight runs on the headlands, it will be calculated as follows:
\[ \sum_{k=1}^{n} X_i = B_s \sum_{k=0}^{n_{nl}} (n_{nl})_k. \quad (13) \]

Using expression (13), we can find the total length of the loop-free turns performed by the tilling tractor-implement unit equipped with a conventional plough:
\[ \sum_{k=1}^{n} (L_{ml})_k = (1,7R_i + 2E) \left[ \text{Integer} \left( \frac{C_{opt}}{B_s} \right) - \text{Integer} \left( \frac{2R_i}{B_s} \right) \right] + \]
\[ + B_s \sum_{k=0}^{n_{nl}} (n_{nl})_k. \quad (14) \]

Combining expressions (9) and (14), we obtain the formula that allows determining the total length \( L_G \) of the turns performed by the tractor-implement unit equipped with a conventional plough. It will be equal to:
\[ \sum_{k=1}^{n} (L_{cg})_k = (7R_i + 2E)n_{lc} + (1,7R_i + 2E)n_{nl} + B_s \sum_{k=0}^{n_{nl}} (n_{nl})_k. \quad (15) \]

The computation of the obtained analytical expressions (6) and (15) carried out on a PC with the use of a specially developed programme enabled plotting the graphical representations of the functions of the total lengths of the turns performed by tractor-implement units equipped with conventional and reversible ploughs.

As we can see from the presented graphs, when the width \( C_{opt} \) of the tilled land is up to 65 m, the total lengths of turns of the tilling tractor-implement units under consideration is virtually the same. When the width \( C_{opt} \) exceeds 65 m, the total length of turns travelled by the unit with a conventional plough starts increasing at a higher rate than that of the unit equipped with a reversible plough.
Thus, when tilling a land with a width of $C_{opt} = 68.2$ m and an area of 8.2 ha, the total length of turns travelled by the tilling unit with a conventional plough is equal to 2035 m, but with a reversible one – 1980 m. Nevertheless, this means a reduction by just 55 m or 2.7%.

In addition, we have found that the travelling speed of a tilling tractor-implement unit on headlands varies within 1.5…2.0 m/s. Hence, at an average manoeuvring speed of 1.75 m/s (6.3 km/h) the total time spent for turns by a unit equipped with a conventional plough will be greater by mere 0.5 minutes. In effect, when operating tilling tractor-implement units in ordinary conditions, the said time difference can completely disappear, since the average travel rate during a loop turn is lower than that during a loop-free turn.

After increasing the tilled land area by almost 1.5 times (i.e. 12.0 ha instead of 8.2 ha), the land width will be equal to 100 m. In this case, the tilling tractor-implement unit equipped with a conventional plough will travel on the headlands additional 850 m. Taking into account the above-mentioned average manoeuvring speed (1.75 m/s), the increase of the time spent for turns by this tilling unit will amount to just 8 minutes. On a working shift time balance scale, this time increase is negligible.

Moreover, it is to be taken into account that already the studies of recognized soil scientist W.R. Williams [4] proved that the main aim of ploughing was the periodical (but not annual!) restoration of the structural strength of soil. Hence, a scientifically grounded system of tillage should include ploughing performed once in several years. Thus, it is quite obvious that the tilling with a reversible plough, the cost of which is several times higher than the cost of a conventional plough, is not always an economically sound option. Such opinions have more than once been passed in scientific publications [5].

Conclusions

1. The apparent advantages of the reversible plough over the conventional one, which can be seen in the possibility to till the field without producing crown ridges and dead furrows, are not always feasible, for example, on account of the insufficient
qualification of the operator that performs the tillage with the use of a state-of-the-art tilling tractor-implement unit.

2. The completed analytical investigation has shown that, along with the virtually equal productivity of the compared tilling tractor-implement units equipped with conventional and reversible ploughs, a negligible difference is observed in the non-productive expenditure of working shift time by the units under consideration.

3. The results of PC-assisted numerical calculations have shown that, when the width of the tilled land $C_{opt}$ is up to 65 m, the total length of turns travelled by the tilling units with conventional and reversible ploughs is virtually the same. When the width $C_{opt}$ exceeds 65 m, the tilling unit equipped with a conventional plough travels a greater total length. But, the calculations have also indicated that at an average manoeuvring speed of 1.75 m/s (6.3 km/h) the total time spent for turning by the unit with a conventional plough will be greater by mere 0.5 minutes.

4. The analytical investigation has also found that if the tilled land area is increased by almost 1.5 times (i.e. 12.0 ha instead of 8.2 ha), the tilling tractor-implement unit equipped with a conventional plough will travel on the headlands additional 850 m, which is equivalent to an increase of the time expenditure by just 8 minutes, as compared to the tilling unit equipped with a reversible plough. On a scale of the working shift time balance, this time increase is negligible.

5. Taking into account that the scientifically grounded standards of modern soil management stipulate ploughing once in several years and reversible ploughs cost considerably (several times) more than conventional ploughs, the wide use of reversible ploughs is not technically or economically advisable.

References


THE BENEFITS AND EFFICIENCY OF PRECISION IRRIGATION

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ABSTRACT: The contribution was to develop methods for irrigation management using knowledge in the field of precision agriculture. In the monitoring points were established basic hydrolimits: Field capacity (FC) and wilting point (WP). Irrigation rate ranged from 0 to 40 mm for a specific term assessment of soil moisture. Throughout the growing season used to be applied precisely five irrigation benefits. A high savings were observed between conventional and precise irrigation (water, energy and economic savings). The results show that it is a fully effective system of precision agriculture, although the procurement and introduction of new technology and the software requires first expending a considerable financial cost. Higher demands are placed on the skill and education services.

KEY WORDS: PRECISION IRRIGATION, HYDROLIMITS, SOIL MOISTURE CONTENT

INTRODUCTION

Precision farming has different approach to the farming practices when compared with the traditional farming (Nozdrovický et al., 2010). The system precision irrigation can occur internal error affecting the accuracy of the control unit to comply with not only set a variable dose, but also the accuracy of the unit set to the value observed variability of the speed of movement of the irrigation system (Chavéz et al., 2010).

Precision irrigation as part of precision agriculture is just the beginning of an examination and application of water to a precise location and the exact dose. This also takes into account the reduction in consumption of irrigation water and thus meets the global trend resulting from a lack of strategic raw materials (Sourell, 2003). Evans et al. (2007) describes an automated sensing of soil electrical conductivity through a wireless network of sensors linked to a microcomputer control and spraying equipment.

The implementation of precision irrigation requires additional equipment to control water rates, information on soil properties and crop condition. The potential of irrigation water with variable dose is an increase in yield, quality and economic return (King et al. 2006). Lack of basic knowledge about the properties of spatially variable crop and soil, restrict the use of precision irrigation. Experiments were positive assessment of the implementation of precision agriculture in the management of irrigation (Sadler et al., 2002). Fraisse et al. (1995) simulate the variable application of irrigation followed with proven results. Uniformity coefficient reached over 90%.

The irrigating practice of irrigation water applied to land as a whole - uniformly. In real life, however, are very few parcels of land with high homogeneity. Hence the need to divide the land into individual subunits, which are independent of each other in terms of claims processing, nutrition and irrigation (Sourell, Al-Karadsheh, 2003). The paper aimed to develop methods and provide the benefits of introducing the principles of precision agriculture for irrigation.

MATERIALS AND METHODS

The processing and managing the work proceeded according to the method, as shown in Fig. 1. The first information say about the plot in terms of location and the area come from farms. Since the information is not sufficient for the introduction of the principles of precision agriculture is to be the geographical parameters (land area and its location, number and location of monitoring points) investigated the plot. In determining the boundaries used handheld satellite navigation device - Garmin Emap GPS navigator. Subsequently, it is possible to determine the starting points for monitoring soil properties (moisture and essential hydrolimits). The detection of soil moisture is using moisture meter HH2 with WET sensor (Fig. 2). After determining the input characteristics of move to construct the maps application on the basis of observed maps of spatial variability of moisture due to the work scope of sprayer, the number of sprinklers, the water supply options and implementation of irrigation.

Implementation of irrigation will be conducted by irrigation deployed on land. On the map are marked zone. In implementing the irrigation will be taken into account the possibility of connection to supply irrigation water to the status of irrigation (irrigation), the number of irrigation, which can irrigate at once (depending on the performance of the water source) and width of scope of work sprayer.

After determining the application the map is a table set schedule irrigation.

Finally, the work is completed the amount of fruit set and evaluate the economic benefit of the use of precision irrigation. To determine the size of the harvest will be the methodology proposed by the Department of machines and production systems. This methodology is based on sampling of produce from area 10 m² (in each monitoring point). The samples are placed in bags bearing the code number. You will then need to weigh the sample in the farm and the results entered in the table. In determining the operating costs of the algorithm is used by Rataj (2005).

The calculations will reflect the changes in input parameters (irrigation requirement, insurance of the tractor, the price of fuel, electricity price, the price of water, hourly wage, and plot size) associated with the selected plot and carry out the experiment given year.

Water for irrigation under the Act is not subject to fees. Subject to fees the cost of services for water supply.

In our case the team had their own wells and pumps. Team was thus the cost of electricity and the cost of water. Costs are calculated in case the team did not receive grants for water.

The irrigation variable is still value the cost of living work in case the team did not receive grants for water.

The annual cost to change the irrigation benefits of variable irrigation (relationship applies if a worker performs the work):

\[ \text{N}_{\text{m}} = \text{N}_{\text{sp}} \times 1,352 \times \text{W}_{\text{am}} \]  

(1)

where:

\[ \text{N}_{\text{sp}} \] – pay of the establishment, €.h⁻¹
\[ 1,352 \] – Coefficient on insurance tax
\[ \text{W}_{\text{am}} \] – total time of all changing irrigation depth, h.rok⁻¹
Time to change the benefits of irrigation will depend on:
- plot size (number of irrigation),
- time needed for one shift,
- time required to transfer between irrigation,
- number of changes for the entire irrigation period for all the irrigation equipment.

Precise comparison with conventional irrigation, the irrigation method will change the total cost. Will the following items:
- variable costs for irrigation (these costs are to change the annual use of electric pump),
- the cost of change is not considered) cost of water (amount of water consumed).

RESULTS AND DISCUSSION
Based on the experience of many years of good cooperation has been chosen as the holding Agrocoop Imel' to continue as a base for experiments. The firm is located in southwestern Slovakia in the district of Komárno. Landscape farm land is flat, with slopes in the range of 0-2°.

According to the soil and climate conditions are firm in corn production area. Rainfall can be classified into the arid, dry areas with strong long-term average annual rainfall of 547mm (for the period 1951-1980), the rainfall is unevenly distributed. The average annual temperature is 9.9°C and average temperature for the growing season is 16.6°C; precipitation in the growing season is 355 mm (years 1951-1980). Altitude area is around 107 to 110 m Total area of agricultural land, the company makes the 1,822 ha of arable land of 1,730 ha with a dominant clay-type soils to sandy loam. A very special place in agriculture takes up potatoes. They are an area of approximately 200 ha. Irrigation was performed with irrigation Bauer 90/300.

The position is focused on land with an area of Fig.3 and 22 ha with a number of monitoring points, 19th (the output of the program ArcView 3.2). Potatoes have been bred crop - the variety Victoria. The soil was alkaline (pH 7.4) and muck. Significant impact on crop production has rainfall. Precipitation team follows a classic. The results are reported in Table 1.
Table 1 Rainfall of localized field, 2005 and 2006

<table>
<thead>
<tr>
<th>Month</th>
<th>1/2</th>
<th>2/2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall 2005, mm</td>
<td>4.4</td>
<td>19.2</td>
<td>4.4</td>
<td>14</td>
<td>9.6</td>
<td>51.8</td>
<td>59</td>
<td>57.7</td>
<td>14.1</td>
<td>15.3</td>
<td>0</td>
<td>55.9</td>
</tr>
<tr>
<td>Rainfall 2006, mm</td>
<td>47.2</td>
<td>21.8</td>
<td>16.6</td>
<td>8.9</td>
<td>11.3</td>
<td>16.4</td>
<td>12</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Soil moisture and hydrolimits

The resulting map hydrolimits field water capacity (FC) is shown in Fig. 4. Field capacity ranged from (28.8 to 30.88) %vol. The largest representation was the interval (29.22 to 29.63) % 8.75 ha in area. Surface modification wilting point (WP) in the plot is shown in Fig. 5. Ranged (from 8.49 to 11.44) %vol. Interval (8.49 to 9.08)% showed up to 7.86 ha. All set hydrolimits volume% match water supplies in millimeters 10 cm layer of soil.

Research associated with precision irrigation and to implement hydrolimits Agricultural Experiment Station in Idaho. Deal with the field water capacity (25 to 44.6 %vol.), Wilting point (10 to 18.4 %vol.) and Available water holding capacity (13.9 to 28.4 cm/m) (King et al, 2006).

Field water capacity, wilting point and reduced water capacity of the nine areas examined for mapping variability as input values for precision irrigation management. In the first three zones was the pasture for a further three potatoes and for the last three grown corn. Values of field water capacity were 10 to 37 %vol., Wilting point 3-11 %vol., and reduced the water capacity of 7-31% vol. (Hedley et al, 2009).

In Fig.6 is shown the variability of soil moisture content map provided 7.6 2006th Humidity ranged in the interval (13.79 to 26.63) %vol. The measured values of soil moisture content were within limits which provide hydrolimits. The smallest representation had periods of moisture (21.5 to 24.05%vol) by area of 1.4 ha (5.7% of the land) and (24.06 to 26.63) % in area 1.3 ha (5.5 % of land). The largest representation was the interval (16.93 to 18.93) % to 12.2 ha area (55% of the land). The resulting map of the moisture it can be stated that it is necessary to irrigate approximately to 19.4 ha (88.18% of the area).

The next scheduled term of soil moisture measurements was set on 28/06/2006. The resulting map is shown in Fig. 7. Soil moisture varied in the range (9.79 to 26.32) %. The largest representation was the interval (16.41 to 19.71%) by area 10.8 ha (46.6% of the area). The smallest representation of the moisture has been shown in the interval (23.02 to 26.32) % in area 0.8 ha (3.4%). The resulting maps of moisture is evident that it is necessary to irrigate the 100% plot (22 ha) in the range (10-40 mm).

After application of irrigation benefits, it was decided to establish a map of soil moisture variability on the 13th term 7th 2006th Soil moisture as a result of pic.8 were in the interval (12.87 to 25.63)% volume. The measured values were within the range of border hydrolimits. The largest share of moisture has been shown in the interval (17.97 to 20.52) % in area 8.7 ha (39.3% from the third area of land). The smallest representation of the moisture had interval (23.08 to 25.63)% in area 0.7 ha which represents 3.18% of land area. The resulting map of soil moisture content reveals the need for irrigation water of 19,2ha (87.27% of the land).

Construction and application maps feasibility irrigation

For the land is available to a gas station. Since each service station is limited by its maximum performance, it was necessary to set limits to our field. Filling station consists of the motor performance of 55 kW and a flow pump 144m³/h. According to the technical parameters of the scheduled irrigation was using 20.0mm diameter nozzle and nozzle pressure of 0.3MPa to determine water flow 26.6 m³/h. To achieve the desired flow rate could be the one connected to a service station just five drips. After finding this information was necessary to map out the distribution of irrigation in order to irrigate the plot (obr.9). Spacing between adjacent tracks was 60m (range of jet spray is 30m). The maximum length of the runway end sprayer was 318m. Take advantage of all 12 positions for irrigation. In determining the benefits of irrigation it was based on maps of soil moisture and hydrolimits set for the plot. Irrigation started in places where it was needed most - places with the lowest soil moisture content.
The first irrigation rate ranged from 0 to 35 mm (lot 35, 25, 15 mm, Fig. 10). Applied was to an area of 19.4 ha (88.18% of the area). The diameter of the nozzle used for spraying was 20 mm with the nozzle inlet pressure of 0.3 MPa. Irrigation rate with a value of 35 mm was applied to the area of 1.6 ha. The surface area of 12.1 ha, the irrigation norm applied to the value of 25 mm. The rest of the land to irrigation dose was 15 mm (2.7 ha) and 0 mm. Before the application in practice and had to be constructed a table for the irrigators, which is controlled by different irrigation (Table 2-4). Each table is a paid position for a deployment of irrigation land. Tables are built so much as to exploit all the numbered positions irrigation status (1-12 to fig.9).
The second irrigation rate ranged from 10 to 40 mm (40, 30, 20, 10 mm, Fig. 11). The irrigation rate was applied to the whole plot (22 ha). The largest share was 20 mm irrigation rate of 10.8 ha area. The smallest representation of the irrigation dose was 40 mm (an area of 1.1 ha). 30 mm irrigation rate was applied to the area of 6.1 ha.
The area of 19.2 ha (87.27% of the land) is the third irrigation rate applied in the range of 0-35 mm (35, 25, 15 mm, Fig. 12). The figure shows that the applied rate of irrigation was 35 mm (an area of 3.6 ha), irrigation rate 25 mm (an area of 6.8 ha) and the remaining surface dose was 15 mm. Part of the area remained without applying the benefits of irrigation (3.2 ha). Since the surface area should be irrigated with sprinkler Nr. 1 rate of 15 mm is the minimum, are not used.
Fourth irrigation rate ranged from 0-35 mm (Fig. 13). The irrigation rate was applied to the area of 11.8 ha (54.09% of the area). Is the way to where it was before the irrigation rate 35 mm and 25 mm (Fig. 12, the irrigation norm 3) there is applicable, and where previously there dose of 0 mm was applied 25 mm (an area of 2.4 ha) or 35 mm (an area of 0.7 ha). 15 mm irrigation rate remained unchanged.

Last irrigation rate was applied to the area of 19.2 ha (87.27% of the total area) in the range 0-35 mm (Fig. 14). 35 mm irrigation rate was applied to the area of 3.7 ha. 25 mm irrigation rate was applied to the area of 6.8 ha.

Yields achieved in the plot and cost recovery
Harvest of potatoes was determined according to the methodology. The focus of the plot (22 ha) is grown only one variety - Victoria with the average yield 41.89 t/ha.

In terms of precision applications, we distinguish two basic applications of irrigation benefits:
- application of irrigation uniform dose to the whole plot,
- application of irrigation with a variable dose on the plot.

Irrigation application method significantly influences the cost. In the implementation of precision irrigation can be used only technology that the company was available as follows: From Zetor 7211 tractor and belt with irrigation Bauer 90/300 base-board computer equipped with basic software.

The calculation of cost and precision in the variable application of irrigation was carried out according to the methodology. The variable application of irrigation benefits is yet to be considered with the following input (the work is not considered or foreseen):
- Cost of the program to produce maps, for example, ArcView 3.2,
- Price GPS, for example, eMap Garmin,
- the cost of laboratory analysis, laboratory testing hydrolimits (FC, WP),
- costs for the determination of moisture, for example, rollers, WET sensor logger HH2,
- cost of living work in creating maps.

In conventional irrigation is considered a constant dose of 30 mm.

Target property measurements made in 2006. This year, the average price of diesel was 0.83 €/l. Insurance on the tractor 7211 from amounted to 42.62 €/year. Tractor hourly wage was 2.65 €/h. The hourly wage of an irrigator was € 2.65/ h. The Amendment irrigation benefits carried the irrigator and wages for this work carried out was also 2.65 €/h. The cost of garage machinery amounted to 2.16 €/m².

The plot area of 22 ha within the experimental precision application of irrigation water is consumed 1021.44 m³/ha water. Power consumption to drive the pump was 560.9 kWh/ha. The rate of uniform irrigation water consumption should amount in 1500 m³/ha of water. The application of a quantity of water (33,000 m³), the planned consumption of electricity was 17832.65 kWh (810.58 kWh/ha). Water savings amounted to 478.56 m³/ha (from 1500 to 1021.44). Saving energy was 249.68 kWh/ha. The total cost to implement the irrigation amounted to 1,709.83 €/year (excluding subsidies on electricity, without the cost of water). Unit costs were 15.54 €/ha. The cost of water consumed was 1,491.85 €/year (no subsidies for water consumed). The unit cost of water was 13.56 €/ha. Total unit costs were thus 29.1 €/ha. Total unit cost at uniform water rates during the business enterprise was 38.2 €/ha, saving was 9.1 €/ha.

The research into the precise irrigation, so the application of irrigation water depending on the specific field conditions in the world is the subject of widespread interest. Hedley et al. (2009) clearly identify the performance indicators of irrigation water of varying dose, detailing their work mapping method to describe soil conditions with respect to soil hydraulic properties. This allowed them to accurately quantify the amount of water consumed, water loss and soil nitrogen leaching, depending on the specific conditions of the selected fields. Saving water is 9-19% with a corresponding reduction in energy consumption.

Perry and Pocknee (2003) reached the water-saving irrigation in precision field crops. Application maps are transformed into the control unit Canlink 3000®. The research found that took place abroad (research institute FAL in Germany) accounted for the smallest cost of pivots irrigator – 191 €/ha. Irrigated surface area should be around 57.6 ha. The highest costs during the irrigation season were given to the stationary drop irrigation – 911 €/ha. Between these extremes were mobile with drop irrigation costs 267 €/ha (Debrala, Sourell, 2002, S.121).
Table 5 Cost of uniform and precision irrigation rate

<table>
<thead>
<tr>
<th>Indication</th>
<th>Item</th>
<th>Uniform irrigation rate</th>
<th>Variable irrigation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{ac}$</td>
<td>Annual cost f irrigation, €/year</td>
<td>2011,35</td>
<td>1709,83</td>
</tr>
<tr>
<td>$N_{cv}$</td>
<td>Annual cost of water, €/year</td>
<td>2469,56</td>
<td>1491,85</td>
</tr>
<tr>
<td></td>
<td>Sum, €/year</td>
<td>4480,92</td>
<td>3201,68</td>
</tr>
<tr>
<td></td>
<td>Saving of cost, €/year</td>
<td>1279,23</td>
<td></td>
</tr>
<tr>
<td>$N_{ac}$</td>
<td>Unit cost of irrigation, €/ha</td>
<td>18,28</td>
<td>15,54</td>
</tr>
<tr>
<td>$N_{cv}$</td>
<td>Unit cost of water, €/ha</td>
<td>19,92</td>
<td>13,56</td>
</tr>
<tr>
<td></td>
<td>Sum, €/ha</td>
<td>38,2</td>
<td>29,1</td>
</tr>
<tr>
<td></td>
<td>Saving of cost, €/ha</td>
<td>9,1</td>
<td></td>
</tr>
</tbody>
</table>

Hedley et al (2009) evaluate the benefits of using variable water rates for irrigation of selected crops (dairy pasture, potatoes, maize grain). The irrigation water savings were 9% (dairy pasture), 13% (potatoes) and 19% (maize grain). It also achieved savings of operating costs 35 NZ$/ha (potatoes), 88 NZ$/ha (pasture) and 149 NZ$/ha (maize). The maximum water saving was presented at the corn.

The peer comparison and precision irrigation of uniform deal to land in humid Iowa State University. Land area is 20.25 ha which is divided into 100 spatially variable grids. Simulate the three variants of irrigation and without irrigation, irrigation uniform dose and precision irrigation. 30 mm irrigations were applied when the percent of available soil water fell below 50%. Precision irrigation showed slightly higher yields than scheduled uniform irrigation. (DeJonge, Kaleita, 2006).
CONCLUSION

Currently are developing new directions in the economy, which raises new solutions in terms of economic use of inputs through information technology. The introduction of computer technology in principle allows us the operational management of production technology, technical support in various stages of production and ultimately leads to lower costs and saving resources, what is the aim of precision agriculture.

Variable irrigation was based on the measured data. Then were established the economic benefits of variable irrigation. The results obtained show that spatially variable technology allows precise application of irrigation water on soil and plant requirements. In this respect, it is a fully effective system of precision agriculture, although the procurement and introduction of new technology and the software requires first expending a considerable financial cost. The farm should therefore be in terms of the innovation process to take appropriate selection techniques such as initial investment, the task is to return the initial costs incurred for the purchase, management of resources for future investigation.

References


APPLYING SWOT ANALYSIS IN ASSESSING THE CAPACITY OF AGRICULTURAL PRODUCTION IN CONDITIONS OF DROUGHT AND CHANGING CLIMATE

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Abstract: Soil and water resources, used for the needs of farming production are strategically important on a regional, national and global scale. One of these resources – soils, has an extremely long recovery period, hence it is assumed practically unrecoverable. The second resource – water, has the property of not being wasted in nature; in fact, it only changes its physical state, and is purified if in movement. At the same time, due to considerably short-sighted human activity, a process of aeration sets over already fertile arable land, precipitation changes location, as well as intensity.

Analyzing strengths and weaknesses of applying technological processes in farming, especially in the conditions of prolonged droughts and changing climate, will be crucial to making the right decisions, concerning the development of farming production technologies. But mere analyses, no matter how detailed and accurate they are, will be useless without the next step-planning. Therefore, applying SWOT analysis as a tool can help the awareness of guidelines and failures during the strategic planning for the usage of these irreplaceable natural resources.

Key works: AGRICULTURAL PRODUCTION, SWOT ANALYSIS

1. Introduction

As with other systems, the technological processes in agriculture can be analysed when the four factors, identifying the object under review, are considered. They are: S (Strengths); W (Weaknesses); O (Opportunities); T (Threats), Table 1.

<table>
<thead>
<tr>
<th>Table 1. Main factors influencing the implementation of technological processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive influence</td>
</tr>
<tr>
<td>External environment</td>
</tr>
<tr>
<td>Internal environment</td>
</tr>
</tbody>
</table>

Investigating carefully the external and the internal environments, where the agricultural production is developing, is an important part of the process of its optimisation. Moreover, the optimization of the technological processes with the aim to prevent the negative impact of climate changes is a matter of strategic planning. Consequently, using the SWOT analysis, we can formulate the strategy for development of agriculture in the conditions of drought and changing climate. The Strengths and Weaknesses are internal factors, which create or destroy quality. They may include assets, skills and resources, which the agricultural producers have at their disposal as opposed to their competitors. These can be measured by using internal assessment or comparison to the best practices – internal or external for the system of agricultural production.

The Opportunities and Threats are external factors, which also create or destroy quality. They cannot be controlled by the farmers. They are outlined either by the dynamics of competition in the agricultural sector of the market, or by climate, demographic, economic, political, technological, social, legislative and other factors.

Through SWOT analysis information is presented, which is useful for the critical comparison of the resources and the potential of the agricultural sector to face the competitive environment in which it operates, fig.1.

The Strengths of agricultural production are the resources (soil, water, climate), and the abilities of specialists, producers and suppliers, which can be used as a foundation for creating a competitive advantage: producing healthy foods, their enhanced demand, availability of upgraded facilities, high VAT from implementation of innovations, relatively low cost of raw materials, farmers with established good reputation, price advantage of own know-how, exclusive access to real natural resources, etc. The Strengths are characteristics of the agricultural production that help to achieve the goal of this investigation – namely, improvement of the technological processes in the conditions of drought and changing climate. One of the answers can be sought in the ways of using these Strengths.

The Weaknesses of agricultural production can be viewed also as lack of compelling strengths; lack of protection of applicable technologies; poor reputation among customers; expensive equipment, which in some cases is an end in itself; no access to the best soil resources, etc. The weaknesses are characteristics of the agricultural production, which prevent the attainment of the goal. In this case, we should look for an answer to the question: How can Weaknesses become Strengths?

Through an analysis of the environment, and in terms of the opportunities provided by the agricultural production technologies, they can be identified as a means of economic growth and environmental renewal. It is possible, as a result of the environment analysis to find compelling new opportunities for improvement such as maintaining and increasing soil fertility, increasing the yields, conserving soils and water.
**Threats** for agricultural production can also be presented as changes in the external environment: climate change, changes in machine constructions, which require additional investments, developing alternative technologies, increased demands on protection of natural resources, etc. Threats are the external conditions, which can delay, hinder or directly interfere with the implementation of innovation technologies. When analyzing the threats, we should be looking for an answer to the question: How can agricultural production be protected from any threat?

Strategies for improving the technological processes through applying expanded SWOT analysis.

2. Materials and methods

A combination of internal and external factors can be used in the different strategies for improving the technological processes in the conditions of drought and changing climate, Table 2.

**Table 2. Possible strategies for improving the technological processes**

<table>
<thead>
<tr>
<th>SWOT analysis</th>
<th>Internal environment</th>
<th>External environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strengths</td>
<td>Weaknesses</td>
</tr>
<tr>
<td>Opportunities</td>
<td>S-O strategies: Using the opportunities for implementation of the strengths</td>
<td>W-O strategies: Eliminating weaknesses for creating new opportunities</td>
</tr>
</tbody>
</table>

The strengths of the SWOT analysis in agriculture must correspond and give answers to the following questions:

What are the advantages of the improved technological processes compared to the commonly used classical ones?

What is it that provides an advantage of the improved technological processes over all others?

Does agriculture have at its disposal unique or very good profitable technologies, which other producers do not have?

Which are the factors, helping the farmers to conserve the soils, preserve the soil fertility and increase their yields?

Which is the unique proposal, which can be used for improving the technological processes without waste of time and resources?

Strengths in a SWOT analysis in agriculture could be anything that forms a competitive advantage.

Weaknesses could include using inappropriate technologies or expensive resources, lack of patent protection, bad reputation among the producers, no access to quality natural resources, unfavorable access to information, etc. The analysis of the weaknesses should provide answers to the following questions:

What can be improved in the production technologies?

Which technologies, so far applied in agricultural production, should be avoided because they no longer provide high enough dividends?

What is a weakness of agricultural production according to those dealing with agriculture?

Which are the reasons for farmers to miss innovation moments?

In most of the cases a weakness can be the opposite of a strength. For example, the vast arable land of an agricultural production unit can be its strength, but it can turn into a weakness in periods when the company cannot use this land due to insufficient availability of equipment, climate changes in the form of intensive erosion rainfall and inability to carry out agrotechnical measures in optimal time, etc.

When the opportunities are reviewed, it is advisable to analyse the strengths, in order to determine whether they are a prerequisite for finding new opportunities. Alternatively, the weaknesses could be analysed to find out whether it would not be possible to find new opportunities by eliminating the weaknesses. The analysis of the opportunities should provide answers to the following questions:

What good opportunities exist for improving the technological processes in agriculture?

What interesting technological innovations come on the agenda?

In this case, the beneficial opportunities may come through changes in technology, the equipment used, etc.

The analysis of threats is crucial and must provide answers to a number of questions such as:

What obstacles do farmers face?

What is the competition doing?

Are quality standards and requirements for agricultural production changing?

How do changes in technologies and improvements of technological processes affect the agricultural producers?

Can any of the weaknesses threaten the positions of agricultural production seriously?

**Table 3. SWOT analysis of agricultural production (grain production)**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Long-standing traditions in the field of agriculture</td>
<td>• Continuous application of conventional technologies for tillage</td>
</tr>
<tr>
<td>• Continuous growth of food demand</td>
<td>• Annual deep tillage</td>
</tr>
<tr>
<td>• Good reputation of those dealing with agricultural production</td>
<td>• High yields due mainly to application of mineral fertilizers and pesticides</td>
</tr>
<tr>
<td>• Active relationship with the research institutes and universities</td>
<td>• Continuous decrease of organic content in the soil</td>
</tr>
<tr>
<td>• Favourable soil and climate conditions for the development of agricultural production</td>
<td>• Continuous increase of the weight of machinery used</td>
</tr>
<tr>
<td>• Availability of potential irrigation</td>
<td>• Using the machinery in conditions that are inadequate for the health of the soil (at degraded physical and mechanical properties)</td>
</tr>
<tr>
<td>• Upgraded tractor and equipment fleet</td>
<td>• Highly reduced use of organic fertilizers</td>
</tr>
<tr>
<td>• Availability on the market of good quality sowing material</td>
<td>• Morally and physically obsolete irrigation systems, which are already destroyed</td>
</tr>
<tr>
<td>• Well developed world chemical industry and presenting good quality pesticides on the market</td>
<td>• Reducing the productive soil layer as a result of erosion processes</td>
</tr>
<tr>
<td>• Opportunities for continuous improvement of skills and knowledge</td>
<td>• Growing of row crops on sloped terrains with tillage in the direction of the slope</td>
</tr>
<tr>
<td>• Opportunities for specialization</td>
<td>• Not using the ability</td>
</tr>
</tbody>
</table>
of the plants to cover the soil and protect it from degradation processes
- Not using the so-called „cover plants”
- Conservative attitude to implementing innovations in agriculture
- Presence of various forms of land management

### Opportunities
- Participation in the Common Agricultural policy of the European Union (politics, business and media impact)
- Developing pilot projects
- Development of technologies and innovations

### Threats
- Demographic collapse in the population, dealing with agriculture
- Climate change
- Prolonged droughts
- Presence of intense rainfall, causing erosion processes
- Desertification of vast regions, including Europe, and loss of arable land
- Soil degradation
- Reduced yields
- Reduced interest to agriculture

**Putting the SWOT analysis into action**

With this table full of information, it is necessary to prepare a list of ideas, which will be transformed into specific goals. The main objective is to concentrate on the relation “Strengths – Opportunities”, i.e. how the strengths of agricultural production can become most beneficial for the opportunities, which will become the target of technological innovations.

Another possibility for ideas is to review the weaknesses of agricultural production and to decide how to neutralise them, taking into account the strengths.

A third possibility is to review the opportunities for farmers and to decide whether they themselves have a hidden potential for eliminating some threats.

Generally, Albert Humphry recommends the development of objectives and action plans in six fields. These six fields (categories) outline the frame for practical use of the SWOT analysis, Table 4.

In this case, the SWOT analysis is applied for optimization of the technological processes in agriculture.

<table>
<thead>
<tr>
<th>Spheres</th>
<th>Directions for development</th>
</tr>
</thead>
</table>
| Product       | The product “Technology for soil conservation through reducing the number of treatments and using the so-called “cover crops”.
| Product       | How is the product offered? The technology and the set of machinery are offered as demonstration in real conditions. |

**User**
- Who is it offered? It is offered to all concerned such as farmers, scientific organisations, sponsoring institutions, regional directorates, offices for counselling services in agriculture, the Ministry of Agriculture and foods (MAF)

**Distribution**
- How to reach the user? Through demonstrations on the spot, applying mass planting, involvement in demonstration trials of leading seed producing companies, councils, advertising materials, etc.

**Finance**
- Prices, investment costs.

**Management**
- How to manage the product offered?

Putting the SWOT analysis in action through the six categories, provides the direction needed for research, since these six categories identify what a farmer should do. Thus in all six categories accurate measurements can be used, and the analysis becomes more focused, specific and controllable.

**Combining the elements of the SWOT analysis**

Using the four elements of the SWOT analysis—strengths, weaknesses, opportunities and threats, we can trace the results from combining those elements in pairs. In each pair there is one element, inherent to the internal environment (strength or weakness), as well as one element, inherent to the external environment (opportunity or threat).

**Combining Strengths and Opportunities**

It is exactly here that the priorities in the development of technologies should be used. On the basis of their strengths and the existing opportunities, farmers should plan activities, from which to derive maximum favourable outcomes. It would be favourable in that it would most probably result in the highest possible yields. Besides, it will probably be the fastest and the easiest mode of action.

**Combining „Weaknesses and Opportunities**

Careful analysis of weaknesses can unlock interesting potential opportunities for development, which could bring good returns.

The Opportunities could also have higher return than that from the combination Strengths and Opportunities, due to the change and the unexpected benefits, which can be drawn from agriculture, if weaknesses are to be analysed and corrected successfully.

If farmers see realistic opportunities for eliminating their weaknesses and taking advantage of improvements that can bring sustainable benefits, then they should direct their efforts into doing this.

**Combining Strengths and Threats**

In this area, agriculture has easy opportunities for protection and counteraction to threats, due to its Strengths, which can be used to neutralise the threats. The investment of time and resources in such endeavours is reliable and secure in general.

**Combining Weaknesses and Threats**

The combination weaknesses and threats brings a potentially high risk to agriculture. The correct risk evaluation is of critical importance.

If the risk value is low, the farmers could ignore the threats and not to be distracted when undertaking any activity.

If the risk value is high, then actions should be planned for neutralising the weaknesses. These actions should be clear, specific and carefully considered, since the danger of failure and trouble is serious.
Every production unit (farmer, cooperation or another type of association) should strive for adaptation to the local environment. SWOT analysis is a very good tool for analysis of internal strengths and weaknesses and of external opportunities and threats. This is just the first step to taking the environment into account. The real adaptation to the external environment is often the hardest activity for the production unit.

In order to create a strategy, which takes into account the profile made through the SWOT analysis, a matrix of the identified factors should be developed – TOWS matrix. This matrix is viewed as a set of tools for combining internal and external factors, and it is sometimes called Opposing matrix. The SWOT analysis is an extremely useful tool for understanding different situations and making decisions for improving the technological processes in the conditions of drought and changing climate. It provides the necessary frame for reviewing the strategy and identifies the best direction for development of the technological processes in agriculture.

- The strengths and weaknesses are an integral part of the agricultural producers, who can be influenced and controlled directly. The opportunities and threats are external “things”, which should be taken into account, but cannot be influenced directly and they are out of control.
- After the strengths and weaknesses, as well as the opportunities and threats have been identified, the analysts should take advantage of the strengths, to decrease or neutralise the weaknesses, to invest in the opportunities and heed the threats.
- Concerning the internal elements of the SWOT matrix – the strengths and weaknesses, are identified on the basis of information from research, focus groups, levels of satisfaction, etc., information from employees, as well as on the basis of the capacity of farms, resources available and the internal processes occurring in them.

Another interpretation of the strategies reviewed is possible:

- Offensive strategy (S-O) – maximaxi strategy: agricultural production is a powerful system, and the external environment is quite favourable, which gives the possibility to adopt a more ambitious strategy.
- Adaptive strategy (S-T) – strategy maxi-mini: we have strong organisation of agricultural production and unfavourable external environment. This calls for adopting a strategy for overcoming the threats;
- Defensive strategy (W-O) – offensive strategy mini-maxi: agricultural production is weak, but the external environment is favourable – this combination shows that a strategy should be embarked on, which is related to strengthening agriculture through internal changes in the organisation;
- Survival strategy (W-T) – defensive strategy mini-mini: weak agricultural production and organisation in an unfavourable external environment. This combination would put agriculture in the most unfavourable situation and any action undertaken, would be doomed to failure.

Advantages of SWOT analysis:
- Easy to develop;
- Generates new ideas for taking advantage of the strengths and protects from threats;
- Awareness of the respective threats allows the development of preventive action plans.

Disadvantages of SWOT analysis:
- It can be understood as a list of ideas, without proposing what is really important for achieving of your goals;
- Presents the ideas uncritically and without clear priorities, so there can be weak opportunities for balancing strong threats;
- The result is usually a simple list of ideas, presented rather uncritically.

3. Conclusions

- The SWOT analysis is an extremely useful tool for understanding different situations and making decisions for improving the technological processes in the conditions of drought and changing climate. It provides the necessary frame for reviewing the strategy and identifies the best direction for development of the technological processes in agriculture.
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4. Reference

1. Александров, К.; „Маркетинг и изучavanе на пазара”; Унив. изд. „Стопанство”; С.; 1992 г.;
2. Ангелов, А.; „Ръководство за разработване на маркетингов план и план на продажбите във малкия бизнес”; С.; 1997 г.;
3. Ангелов, Д., М. Манолов, и кол.; „Организация на аграарното предприятие”; УИ Икономически университет – Варна; 2001 г.;
4. Андреев, А. и кол.; „Животновъдство”; изд. „Днинис”; С.; 1993
5. Бодурова, П. „Стратегически управление на фирмата”; изд. Ромина, 1999
6. Бодурова, П.; „Фирмено планиране”; ANG; София, 1999 г.;
7. Иванов, М.; „Започва заварването на агропредприятия, неотдаваща на изискванията на националния”; УИ Икономически университет – Варна; 2001 г.;
8. Котлер, Ф.; „Маркетинг и изучаване на пазара”; Изд. Икономически университет – Варна; 2001 г.;
9. Маринов, М. и кол.; „Аграрното предприятие и бизнес средата”; УИ Икономически университет – Варна; 2001 г.;
10. „Месечен макроикономически обзор”; Министерство на икономиката; 27 юли 2003 г.;
11. Младенова, Г.; „Стратегическо маркетингово планиране”; Унив. изд. „Стопанство”; София; 1998
12. „Макроикономически обзор”; УИ Икономически университет – Варна; 2001 г.;
13. Младенова, Г.; „Стратегическо маркетингово планиране”; Унив. изд. „Стопанство”; София; 1998
14. „Стратегическо управление на бизнеса”; УИ Икономически университет – Варна; 2001 г.;
15. „Месечен макроикономически обзор”; Министерство на икономиката; 27 юли 2004 г.;
16. „Макроикономически обзор”; УИ Икономически университет – Варна; 2001 г.;
17. „Макроикономически обзор”; УИ Икономически университет – Варна; 2001 г.;
18. „Макроикономически обзор”; УИ Икономически университет – Варна; 2001 г.;
ANALYSIS OF CURRENT ISSUES REGARDING DIAGNOSTICS, SERVICE AND OVERHAUL OF AGRICULTURAL MACHINERY

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Abstract: In the last decade in Republic of Macedonia and the Balkan region, the import and use of modern agricultural machines and equipment has been intensive. Some makes and models are manufactured by well known brands, there is also imports of generic construction via a fast manufacturing process. The trend of developing and perfecting of both is a complex process, and it is rare to find an exclusive distributor. Usually the dealerships do not pay attention to servicing and overhaul or instructions on proper handling during usage. Because of the wide selection of brands that have been imported, the issues with servicing and overhaul are not resolved on state or regional level which causes problems, delays and expenses during the life span of the machines. Until now there has not been a strategy made for overhaul centers.

Introduction:
With the import and use of the latest machinery and equipment, the lack of proper servicing and overhaul, as well as the availability of spare parts is increasingly noticeable. The purpose of this analysis was aimed toward resolving these issues, with implementing a new system that is required by the latest machinery models and equipment that meets the needs of its users and service centers. The necessity for such measures comes from these significant parameters that require new approach and new concept.

Results from the analysis:
In the past two decades in Republic of Macedonia, the structure of self-propelled and farm implements has changed. The absence of a law regarding agricultural machinery, and the lack of the ability to categorize and classify tractors and other self propelled machinery has allowed the import of machines of different brands, manufacturer as well as counterfeits of the leading brands. The unclear concept regarding the education program that is rarely carried out and the unavailability of spare parts makes the usage of these machines more difficult. Issues occur in the process of service, overhaul and supply of spare parts. The main goal of the larger firms is sales and distribution while there is not enough attention paid to service and overhaul centers with optimal amount of spare parts in stock where basic or specialized repairs can be made. The service and overhaul centers are necessary, especially now in an open market where the import of parts made by variety of manufacturers for machines and models is possible. The lack of spare parts creates a delay in the usage of the machinery which decreases their economic viability per hour and per hectare. It is possible to organize categorized service and overhaul centers at different locations in Republic of Macedonia or to group certain manufacturer brands to create a one center that will offer education service and overhaul.

As shown on the map of Republic of Macedonia, the location of the service center would be in the central area of the country, with adequate structure for communication, railway and road.

Conclusions and recommendations:
The service centers in Republic of Macedonia should be build according to the needs, structure and diversity of the agricultural machinery used by the farmers. The conducted analysis show that a suitable solution would be to build one service and overhaul center, in cooperation of the government, firms and manufacturers of agricultural machinery that would be interested. The functionality of the service center must match the application of new agricultural techniques and technologies, to have the necessary equipment and trained personnel. The service center should also offer educational training in collaboration with the trade high school that constantly produce personnel that is up to date with the latest technologies.

Building a service and overhaul center will contribute in easier and better use of agricultural machinery as well as lowering the cost per hour of using the machinery.