CONTRIBUTION OF THE RESEARCH INSTITUTE OF AGRICULTURAL MACHINERY DURING 50 YEARS OF ITS EXISTENCE

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Abstract. The Research Institute of Agricultural Machinery was founded in 1960 at Ulbroka as a Research Institute of Agricultural Mechanisation and Electrification. In order to hasten the introduction of scientific developments into agriculture, a department of design engineers and an experimental workshop were formed at the Institute. The main directions of its action were mechanisation of field crop growing and harvesting, livestock farm mechanisation and designing, efficient maintenance and repair of the tractor and machinery fleet, electrification and automation of the technological processes, popularisation and implementation of the scientific development and advanced experience in agricultural production. During the 50 years since the Institute was founded its research activities had been developed in more than 40 directions. The results of scientific investigations have wide introduction in agriculture, increasing the efficiency of agricultural production. Since 1998 the Institute is integrated into the Latvia University of Agriculture. In the latest years studies have been conducted to raise the quality of the products, to reduce the energy requirement and costs. Motivation is given for the design parameters of the soil tillage mechanisms, more efficient soil tillage methods and technical means. Mathematical methods have been developed for the investigation of the technological processes of soil tillage and the choice of rational technologies for growing agricultural crops. Investigations have started lately in the application of the GPS technologies in precision agriculture and assessment of the ecological aspects of soil tillage mechanisation. The work has started in the recent years at the development of technologies and means of mechanisation for growing non-conventional crops: cranberries, high-bush blueberries, sea buckthorns, etc., and for processing their products. As a perspective direction can be noted a theoretical and practical research into energy saving technologies, rational use of the sources of renewable energy and their practical application. Experimental collector equipment has been developed, which follows the movement of the sun, for the use of the energy of solar radiation. Solutions are sought to use the plant biomass for the production of energy. Equipment has been made for heating piglets in the piggeries. The work is going on at the issues of mechanised growing and harvesting technical crops: flax and sugar beet. Various flax harvesting technologies have been worked out and economically motivated depending on the specificity of the flax growing farms and their financial resources.

Key words: agriculture, mechanisation, technology, energy saving, renewable energy sources, agricultural machinery, terra-mechanics, cattle farms, piggeries.

Introduction

It is considered that the beginning of the investigations in agricultural machinery in Latvia should be connected with the start of testing agricultural machines at the Baltic Machine Testing Station founded in 1911 [1-3]. Further investigations followed at the Department of Agricultural Machines at the University of Latvia, then at the Latvian Academy of Agriculture [3].

After the second World War the technical policy in agricultural mechanisation was implemented through the machinery fleets at the Machine-Tractor Stations (MTS). Several studies in agricultural machinery were carried out at the newly founded Faculty of Agricultural Mechanisation at the Latvian Academy of Agriculture, at the State Special Design Office, at the Departments of Mechanisation of the Research Institute of Agriculture, as well as at the Institute of Zootechnics and Zoohygiene [3]. However, these studies were poorly interrelated.

In the late 1950-ties after the liquidation of the MTS agricultural machinery passed over to agricultural farms. In most cases they had no experience and possibilities for rational use of this machinery and its technical maintenance, they were short of machinery suitable for the conditions of Latvia. There were few mechanisms and devices suitable for the operations on cattle farms and piggeries. That is why there was low labour productivity in agriculture and high output costs. This caused a need for a scientific research establishment which would conduct complex urgent studies connected with the mechanisation of agriculture.

The Research Institute of Agricultural Machinery was founded in 1960 in Ulbroka on the basis of Riga MMS as the Research Institute of Agricultural Mechanisation and Electrification. During its existence the Institute has changed its name several times. Since 1998 the Institute is integrated into the Latvia University of Agriculture (LUA) as an independent legal entity, and since September 29, 2004 it operates in its present legal status as a LUA Agency – the Research Institute of Agricultural Machinery (RIAM, further – the Institute).

The article presents only a brief description and evaluation of the contribution made by the Institute during the 50-year period of its activity. Wider information on the activities of the Institute in the period from 1960 till 2000, and in the recent 20 years, can be found in the publications [4, 5] devoted to it, and collections of papers [6].

Materials and Methods

The first researchers of the newly opened Institute had no experience in scientific research work. Besides, in accordance with the agricultural needs and the numerous targets of the Misnistry of Agriculture, the scope of operations performed by the Institute was very wide and comprised almost all the branches of agriculture. Every researcher had to work at the solution of several themes simultaneously and there was no time for their deeper study. That is why the developments of the workers of the Institute at the initial stage were based generally on the knowledge acquired in the higher school, theoretical considerations, simplified calculations and the experience gained in practical work in production. They had mainly a character of practical recommendations how to raise labour efficiency and lower the costs, how to select, introduce, improve, maintain and better use the machines that are more adjusted for the conditions of Latvia [4]. However, gradually, through post-graduate studies and writing dissertations, methods were more widely acquired and applied that are characteristic for scientific research, as well as new, original methods were worked out which raised the scientific level of the developments in accordance with the modern requirements [6]. Their more concrete description is given in the following sections.

Results and Discusion

This section includes a brief layout of the most important studies and developments carried out at the Institute.

1. Mechanisation of field crop cultivation

Investigations in the mechanisation of the field crop cultivation were conducted in many directions. The main of them were: agricultural mechanics; energy-saving soil tillage technologies and machines; soil fertilisation; mechanised growing and harvesting of sugar beets, potatoes, cereals, flax and beries; introduction of powerful high-speed tractors and machines, precision agriculture, and GPS technologies.

Agricultural mechanics. Agricultural mechanics is a subdivision of science about the functional relationships of agricultural technological processes and machines. Their cognition provides a possibility to solve the mechanisation issues of agricultural production in a more motivated, economical and faster way. That is why the studies in soil tillage mechanics have been unofficially conducted already since the time when the Institute started its operation but officially as a theme of research since 1997. The development in agricultural mechanics was achieved in soil tillage (terra mechanics) [6-9], field crop growing [7, 13], beet harvesting [7], the design of broad-grip machines and aggregates [6, 18], in finding new relationships of technological processes and functioning of machines and their working parts [9, 13].

Energy–saving soil tillage technologies and machines. The theoretical and experimental investigations into the energy requirement of soil tillage processes, as well as the technical solutions and recommendations for its reduction have been included into several dozens of publications with a common subject matter in the Latvian, Russian, and, since 1997, also in the English language. Approaches have been formulated and motivated concerning the course of the soil tillage technological processes and energy requirement. In contrast to the previous views, a hypothesis was advanced and proved that the draft resistance of the operating parts of the machines and the respective soil tillage energy requirement depend on the impact of dual forces upon them: the forces which are determined by the mechanical properties of soil (the mechanical strength (hardness) of soil which causes resistance to the penetration of the operating parts into soil, as well as resistance to its deformation), and the forces which depend on the physical properties of soil (the forces of gravity and inertia caused by the transferred mass of soil, as well as resistance to friction and adhesion). Guided by this conclusion, relationships of the strength of materials and theoretical mechanics are applied for analytical determination of the forces acting upon the operating parts of the machines and their elements [6-8]. The obtained analytical relationships are used for the determination the optimal parameters of the operating parts of the machines and the draft resistance in connection with the technological properties of soil [11]. These methods and the obtained relationships allow motivation for the solution of an energy–saving technology and design of the operating parts, the development of highly efficient, economic machines and aggregates for the basic soil tillage and its pre-sow preparation, as well as finding ways of their efficient application [6, 10, 17].

Approximately half of the draft resistance of the soil tillage machines (ploughs) arises due to the resistance of soil sliding along the surfaces of the operating parts. In order to study this phenomenon more extensively and intensively, a computerised tribometric stand was developed in 2003 and used by the students of the master and doctoral studies for working out the promotion papers, as well as for other investigations connected with the tillage and the physico–mechanical properties of soil.

Motivated, more efficient energy saving technologies and machines have been worked out on the basis of the research materials for the basic and pre–sow tillage of soil. 16 kinds of machines are developed for more efficient soil tillage under zonal conditions, for example: ploughs with a gently sloping helicoidal or semihelicoidal share-moulboard surface of their bodies [6, 8, 9], cultivators having S-type spring tooth with narrow frontal surfice and shallow adjust angle of shovel [4, 6], rotary knife harrows [6], drag-luseners [6], combined machines and aggregates [17] and others. The developed and recommended solutions are applied in the machine designs at the enterprises of Latvia and other states (CIS).

A new improved method has been worked out for the optimisation of the functional parameters of soil tillage aggregates [6, 10]. The optimum parameters: the speed and the working width of the machine to gain maximum efficiency of the soil tillage aggregates with minimum energy (fuel) consumption, the relations of the draft power of the tractor and the specific resistance (power) of the machines being as the functions of speed. In order to achieve high specific efficiency of the soil tillage aggregates with a minimum consumption of energy, machines should be used with a low coefficient of the dynamic resistance. By means of this method the optimal parameters of harrowing, ploughing and cultivation are determined. They are applied to substantiate the working width of the designed machines and aggregates, as well as to choose and complete sets of machines for the high–speed and powerful tractors [10].

The normatives of the energy requirement of technological processes and fuel consumption have been worked out and the specific consumption of fuel calculated for growing the field crops by the intensive, conventional, simplified and minimised technologies, as well as the amount of fuel which is necessary for Latvia [12].

On the whole, by using the revealed solutions in the conventional soil tillage technology it is possible to save 24-36 % of energy (46-110 $kWh \cdot ha^{-1}$ and the corresponding 12-27 $kg \cdot ha^{-1}$ of diesel fuel), to raise the labour efficiency by 16-32 % and decrease the costs by 14-26 %) [10]. By optimising the operation of the sugar beet harvester it is possible to lower its energy intensity by 20-30 % and save 5-8 $kg \cdot ha^{-1}$ of diesel fuel [16].

Investigations into mechanised sugar beet growing and harvesting. The development of a rational technology and machinery system for sugar beet growing under the conditions of Latvia was the first theme in Field Crop Mechanisation. The investigations comprised a wide scope of issues: the selection of sorts, seed preparation, soil tillage and fertilisation, cultivation of the sown areas, beet harvesting and delivery to the sugar refineries [4]. It was proved that a more expedient method also under the conditions of Latvia is separate harvesting of sugar beets with cutting and collecting of the tops from growing beets and subsequent lifting, cleaning and collection of the topless beets. The solutions found in creative cooperation with other scientific institutions, the machine builders of Latvia, Czechoslovakia and Germany in the late 1960-ties opened a possibility for complex mechanisation (except thinning and weeding) of sugar beet production, and sugar beet growing became an economically profitable branch of agriculture [4, 6, 16].

However, despite the lack of corresponding financing of this branch during the following 20 years, investigations in it were not interrupted. They were connected with the improvement of the growing technologies, the development and introduction of more efficient machines (6-row mobile sugar beet top and root harvesters, 36-row sowing and interrow cultivation aggregates) [4, 6, 16]. The technology and the machines were adapted also for mechanised growing of fodder and red beets [6].

A new stage started in the solution of the problems of mechanised sugar beet growing in 1990 when, due to the sugar deficit in the country, possibilities were sought how to avoid it and satisfy the needs of the population and food industry by means of self–made beet sugar. The production of beet sugar had fallen to 16 thousand tons a year, which ensured only about 20 % of the need for sugar in Latvia [4, 15]. Principal attention was paid to the reduction of labour consumption in thinning–weeding of sugar beets and the use of machinery that is more suitable for the conditions of the farms, to mechanised growing of the most suitable sorts of beets, their finding and introduction. In cooperation with SIA "Uzvara–Lauks" it was found out that, using quality seeds with a high germination power and appropriate precision seeders, it was possible to sow the seeds at extreme distances (16–18 cm) and thus go without thinning of the beets, and, applying efficient herbicides, also without weeding and inter–row cultivation of the plantations. As the most suitable for the farms one man harvesters which did not gather the leaves were recognised . They are harvesters coupled to a 2-3 row tractor for the farms with smaller sugar beet areas, and 6 row mobile harvesters for the large farms.

With the use of the methods of the probability theory and mathematical statistics distribution relationships of the plants and their density were theoretically determined in the sugar beet plantations, as well as their impact on the expected yield, which were confirmed in experimental investigations. It was found out that the distribution inhomogeneity of the plants was functionally dependent on the germination power of the seeds on the field: the higher was their germination power, the higher was their homogeneity of distribution, and vice versa [13]. The structure of the sugar beet production costs was analysed and recommendations were worked out for their reduction paying particular attention to more efficient usage of the more expensive machines [4, 16].

In 1995 a conception was worked out and successfully implemented for the development of the sugar beet production in order to fully ensure Latvia with home–made sugar up to 100 thousand tons a year [15]. In 1998 there were harvested 68 thousand tons of beet sugar, which was the highest achievement in comparison with the other pre–war and post–war production volumes. The technology and the level of mechanisation of the sugar beet production were approaching the standards achieved in the countries of Western Europe yet the efficiency of machine usage was better and the production costs were lower [16]. Unfortunately in 2007 sugar beet growing and sugar production in Latvia was unpardonably interrupted.

Mechanisation of the field fertilisation operations. Investigations were conducted and solutions carried out for the improvement of the quality of organic fertilisers with their composting, solutions and equipment developed for better mechanisation of the soil fertilisation operations [4, 6]. A rational complex of machines of 12-16 t load carrying capacity was created for high-power tractors for the distribution of solid and liquid manure and transportation of various cargoes, a hydraulic drive was designed for the distributor conveyers in order to increase their operational safety. A mobile gantry crane with a grab bucket loader was designed for the mechanisation of operations in dung-yards. Due to the supplies of liquid ammonium polyphosphate the issues of its transportation and introduction into soil were speedily studied, connecting them with the use of high-power wide-grip machines.

Mechanisation of potato production. As the most essential investigations and developments in the sphere of potato production mechanisation, a technology and a conveyor equipment with plastic bags for potato couching, as well as heating of seed potatoes in order to gain earlier yield, planting, cultivation and harvesting of the couched potatoes should be mentioned first of all [4, 6]. The technology and machines were improved for planting potatoes and their growing on the crests of the ridges, more rational technologies and combine harvester designs for potatoes were explained. Designs of mechanised lines were worked out for further processing and sorting of potatoes and nonstandard equipment for specialised potato growing farms, as well as mechanised potato warehouses.

Mechanisation of growing, harvesting and post-harvest processing of cereals. Investigations have been made and technologies developed for mechanised production of cereals under the conditions of Latvia [4, 6]. Solutions were found for the introduction of seeds at the optimum depth. In order to promote better use of the grain harvesters during rainy autumns, already at the initial stage of the operation of the Institute, a construction and equipment design for highly efficient post-harvest processing, drying, sorting and storing of grain was developed and introduced on the collective farms Uzvara, Bauska Region, which served as a model for similar solutions on other farms.

After the year 1990 there are investigations going on in drying and storage of grain harvested by a combine in ventilated bins using the heat of the sun or a firewood furnace as the most acceptable solution for small and medium–sized farms [5]. In cooperation with the Institute of Solid State Physics, LU, a computerised equipment has been created for distance control (monitoring) and conducting of the drying process. This enabled production of the highest quality food grain receiving twice as high remuneration for it as for the unconditioned grain from the combine harvester [14].

Investigation of the technological variants of flax harvesting. The topicality of research in this direction was stipulated by the fact that harvesting is the most labour–consuming stage in the flax growing technology (approximately 70 % of all labour consumption) and this determines in many ways the prime cost and quality of the finished product and total consumption of energy. The main drawbacks of the present flax harvesting method by means of combine harvesters (flax pulling and combing is done simultaneously) are the great consumption of energy for the subsequent drying of the seedy part of the harvested flax and a significant loss of the germinating power of the seeds. Drying and threshing of the bundles of flax (a mixture of unthreshed pods, seeds and partly the flax straw) consume most of the fuel – 100-130 kg ha^{-1}, threshing and combing to remove the seeds – 10-15 kg ha^{-1}, processing of the ribbons, baling and transportation – 22-30 $kg \cdot ha^{-1}$ [20-21]. Due to the sharp rise in the prices of energy in the 1990-ties flax harvesting by combine harvesters became less efficient, and suggestions were needed how to improve it. There is increased interest in the recent years in the application of a two–phase harvesting technology used in several countries of Western Europe by which flax is threshed, at first, and spread in ribbons together with the seedy pods for drying and ripening of the seeds under natural conditions, after that, 6–10 days later, the flax is lifted, the seeds are threshed out but the flax straw is spread on the ground. This method presupposes approximately 2.6 times less consumption of energy for final drying of the seedy part of the yield, etc. The basic factor that restricts the introduction of this technology in Latvia is that it requires considerably more expensive machines and there is a higher risk that the seeds may be damaged in rainy weather. Studies were conducted to determine the limits of the efficiency of these two technologies under the conditions of Latvia.

The difference in the prime costs of the flax stalks using a combine harvester and a two–phase method of harvesting decreases with the increase in the yields. Summary calculations show that introduction of self–propelled machines for the two–phase flax harvesting technology can be justified for the time being only on condition that the yields are more than 5 metric tons from a hectare and the annual output of one machine is more than 120 ha. According to the prognoses in a ten–year perspective, both flax harvesting methods will be applied in approximately equal proportions.

In the 1990-ties the Institute was intensively engaged in the development of machines and implements for harvesting flax which would ensure lower consumption of labour and losses of its quality. The most popular machines among the ones which are used for processing the flax stalks are the fluffers of the flax ribbons with which almost all the flax seeders in Latvia were equipped (many of them are still operating today). Investigations were conducted into the efficiency of various flax processing methods during its maturing. The impact of fluffing on the quality of the product depends, to a great extent, on the crop capacity, i.e. the thickness of the layer of flax in the ribbon. In the experiments with flax the crop capacity of which was 2.8 $t \cdot ha^{-1}$ and the maturing period 19 days application of single fluffing ensured an increase in the sort number not more than by 12 % in contrast to the previously used maturing of flax without any special treatment; however, when the yield of the flax stalks exceeded 4.2 $t \cdot ha^{-1}$, even two–fold fluffing with a 10–day interval did not ensure uniform maturing (particularly in the bottom layer), and extra 5–8 days of maturing were necessary to complete the biological process in all the layers. When the ribbon of flax is turned over by 180°, it is separated from the ground and laid again on the surface of the field. In experiments with the flax the crop capacity of which was 4.2 and 6.0 $t \cdot ha^{-1}$ application of two–fold overturning with a 9–day interval, in contrast to flax maturing without special treatments, ensured an increase in the sort number by 18.1 and 28.5 %, respectively. It was established that, in case the yield of the flax stalks is higher than 3.0-3.5 $t \cdot ha^{-1}$, overturning of the flax ribbons must be included at any rate into the technology. The machines for the overturning process are considerably more complicated by their design and less efficient than the fluffers, which slow down their overall introduction into the flax growing industry in Latvia. A series of practical recommendations have been worked out, and a book under the title "Flax growing and pre–processing technologies and machines" was published in 2007 [22]. Further investigations are aimed at the study of optimal technologies for growing similar technical crops – oil flax and hemp.

Investigations and development of a system of machines for growing berries. There is increased interest in the recent 10–15 years in the cultivation of berry crops. However, the unsettled situation with the technological and technical provision of agricultural farms of different sizes hampered its implementation. On the basis of the investigations a system of machines has been worked out for laying out plantations of cultivated cranberries, their cultivation and gathering. Investigations have been conducted, preliminary designs developed and specimens of machines made for sand and peat application based on a distributor of organic fertilisers, two types of a manual applicator for the weed control with a contact method, machines for the preparation (collection) and planting of sprouts, implements for the water level adjustment on the cranberry plantations [5, 23]. On the whole, the total requirement for the capital investments which are necessary to start the production of cultivated cranberries on a 10 ha area is approximately 180 thousand euro, including approximately 30 thousand euro in order to purchase the necessary machines and implements. In the pre–storage stage the most essential part of expenditure (32 %) goes to the care after the plants and harvesting.

As a result of the investigations into the harvesting processes of sea buckthorn berries a technology has been improved and equipment designed for the separation of berries from the stalks and their cleaning, machines have been worked out for the care after strawberry plantations, etc. [24].

Acquisition and use of high-power, high-speed machinery. Contrary to the views dominating some time ago that the high-power tractors are not suitable for the Baltic conditions, a concept was advanced and substantiated in favour of efficient use of these tractors, and respective complexes of machines were created for soil tillage, fertilisation, sowing and transportation operations [4, 6, 18]. Basic principles were worked out for the formation of wide-grip aggregates working on uneven, territorially scattered fields. Corresponding to these principles, up to 18 metres wide couplings were designed for 3-4 machines, as well as wide-grip cultivators, rotary knife harrows, drag-harrows, etc. for the technical solutions of which 12 inventor's certificates were granted. In cooperation with the Specialised Cultivator Design Bureau in Rostov-on-the Don a combined three-section cultivator KŠP-8 was created with rational S-shape spring tines, which has found wide application in all the regions of the former Soviet Union.

Precision agriculture, GPS Technologies. In the recent years, in cooperation with the Institute of Soil and Plant Sciences, investigations are evolving in "Precision Agriculture". Owing to the possibilities of the new machines and equipment the GPS technologies allow with the help of the Global Positioning System to find, analyse and react in a corresponding manner to the qualitative properties of the cultivated plots of land and implement an agricultural farming system (soil tillage, fertilisation, selection of sorts, etc.) that is most suitable for them.

In order to coordinate the investigations in the development, introduction and determination of the efficiency of the technologies applied in precision agriculture, as well as to acquaint with them students, agricultural specialists and farmers, a "Research Centre for Precision Agriculture" is being formed on the basis of the Vecauce Research and Training Farm, LUA. A curriculum "Global Positioning Technologies in Agriculture" has been worked out for training the students of the LUA Faculty of Engineering, etc. For its better acquisition a manual is written and published with the help of the EU co–financing under the title "Global Positioning Technologies in Agriculture [19]. This direction is considered as perspective, and the work should be continued.

2. Mechanisation of the technological processes in cattle breeding

Forage gathering and storage. The research work was mainly directed at a mechanised technology of hay, haylage and silage preparation and the development of rational machine sets meeting the requirements of the large cattle breeding complexes. Mechanised technologies were worked out and sets of machines were perfected for hay preparation in loose, pressed and cut forms using active ventilation and storing in mechanised hay barns and towers. There were widely applied telescopic ventilation channels and grab-type loaders developed on a bridge crane or monorail basis. A multipurpose pickup trailer was worked out with a 60 m^3 volume for the preparation of cut hay and straw removal. Corresponding to the created mechanisms and aggregates, hay barns and tower-type hay storage facilities were designed. Techonologies were improved for the haylage and silage preparation by equipping the grass shredders with the dispensers of liquid and solid preservatives, and providing the rammers with the levellers of the mass to be ensilaged. Since artificial drying of grass was applied in the grass meal production process, a technology and equipment were developed for the introduction of the stabiliser diludine into the grass meal. The rising prices of energy resources and the course towards their economic utilisation led to a sealed roll technology in the grass fodder preparation. The first researchers that tried this technology in Latvia were the scientists of the Institute together with the scientists from the Institute of Cattle Breeding and Veterinary who were active in the evaluation of the other developments as well. A part of the results of these investigations are compiled in a monograph [25].

Fodder preparation for feeding and distribution. Formerly, when the pigs were traditionally fed with multicomponent fodder (meal, potatoes, beets, green forage), the processing of the fodder components before feeding was labour-consuming. As a result of the analysis of the technological process a technical solution was given for mechanised fodder preparation with a corresponding set of mechanisms: a roort crop and potato washer, a steamer, a shredder of root crops, green forage, and a mixer of the processed fodder components equipped with a fodder pump. The use of the set of these mechanisms facilitated essentially the work of the operators, reducing the average labour consumption for the preparation of 1 t of fodder by 10-15 manhours. A similar solution for the preparation of fodder mixtures was elaborated and introduced also on cattle breeding farms.

The conducted studies in the transportation of flowing fodder mixtures through ducts by means of pumps provided a possibility to facilitate essentially fodder distribution in piggeries and on cattle farms. With the improvement of the forage resources it was necessary to solve the distribution of the thick fodder mixtures. A series of mobile fodder distributors were worked out for various uses. Here one should mention the hitched tractor-drawn fodder distributors, including a fodder distributor-disintegrator for cattle farms, a distributor developed on the basis of a self-propelled undercarriage, electrified distributors with a cable drive and fodder distributors developed on the basis of electric cars. On the farms with developed grain production, predominantly in Zemgale, feeding with dry fodder has started. Its mechanised loading into troughs was solved using an auger conveyer. This was the beginning of automated fodder distribution on the farms. Later on possibilities were sought for the application of cable-and-scraper conveyors to distribute dry fodder to various groups of animals. Introduction of mechanisation into the pig breeding branch reduced labour consumption to obtain a 1 cnt increase of live mass from 52 manhours (the year 1960) to 15 manhours (the year 1985) i.e. more than 3.5 times. Labour consumption in pig breeding complexes decreased to 6-8 manhours per centner of the increase in the live mass [26].

Manure removal, storage and utilisation. At the initial stage of the operation of the Institute, when farms with a small number of animals were predominating, the solutions for mechanised manure removal were generally adopted in close connection with the possibilities to build new animal houses or the reconstruction of the existing ones. The first studies were made in the liquid manure removal by gravity flow along the channels under the floor or by regular flushing. Such a solution required also adequate reconstruction of the animal house to ensure optimal microclimate. Several designs of the liquid manure pumps were worked out which performed also disintegration of the rough bedding and fodder residues. Additional problems were created by the sediments of the liquid manure in the storage facilities during their emptying. Here one of the solutions was the liquid manure fractioning implemented on the pig breeding farms “Ulbroka”, “Ogre”, “Vecauce”. Another, different solution appeared with keeping animals on a layer of peat litter. It was related to the attempts to raise the soil fertility. Application of this technology was justified on the farms with a high technological discipline of production. An electrified reloader was worked out on the basis of a gantry crane for the operation in storage facilities containing solid manure.

Concerning the designs of new animal houses and mechanisation of the technological processes the solutions began to dominate which had undergone detailed testing in the world and found wide approval. Restructuring of the scientific activities changed also further operation of those subdivisions of the Institute which conducted research in the field of livestock breeding mechanisation. As the technological processes in the livestock breeding branches were connected with the consumption of energy resources, further research work was aimed at the possibilities of their reduction.

3. Rational use of energy resources and acquisition of alternative sources of energy

The course towards reduced consumption of energy resources in the processes of agricultural production started by turning to reduced consumption of energy for heating the piglet pens. As a rule, the heaters (lamps) of 1000 W power were used for their heating. More rational use of electric energy was achieved when a power regulator of the heaters was worked out and made on the tiristor basis with a block of automatic control. Application of the developed regulators and programmable control devices gave at least a 50 % economy of energy during the heating cycle of the piglets. The research results and the regulators of various modifications were introduced in the 1990-ties in many pig breeding complexes for total heating of approximately 1350 piglet pens. The new tendencies, directions and products in the world – the production of low-power economic heating lamps, introduction of water heated panels for heating the piglet pens – now reduce the necessity to use power regulators. Although the piglet pens are equipped with water heated panels, reduction of energy consumption remains an urgent issue and it is connected with the acquisition of alternative energy. Our recent investigations on the use of the heat transformed by the heat pumps to heat the piglet pens show that during the summer-autumn period the consumption of electric energy per hour for heating one panel decreases to 20-40 Wh. Research is conducted into increasing the efficiency of the air heat pumps in the cold weather periods, regaining heat from the air leaving the animal house during its aeration. Investigations with the heat exchangers "air-air" indicate that about 60 % of the outlet ventilation air can be regained for repeated utilisation when the outdoor temperature falls to –15 °C [28].

A practically inexhaustible source of alternative energy is the sun. The part of the power of the solar radiation energy which we receive in a particular place on the earth is about 1 $kW \cdot m^{-2}$, yet it depends essentially on the annual and day and night cycles. In order to receive and transform solar radiation energy, collectors following the direction of the movement of the sun have been worked out (7 patents) [29], including the ones in which, using mirrors, both sides of the flat collector adsorbent are radiated. A registration device of the meteorological parameters was developed, patented and produced for the measurements in order to specify the data as to what share of solar energy is used by te stationary collector moving in the direction of the sun. The mesurements by this device generally show that the surface following the sun's movement has received, on the average, 1.4 times more thermal energy during the data registration time but in the middle of summer 1.65 times more thermal energy than the stationary surface which is oriented to the south.

The results of the previous investigations indicate that it is necessary to study and substantiate scientifically the use of combined sources of renewable energy in order to provide houses with thermal energy for their heating and technological needs [27]. Calculations witness that this is possible, and the price of thermal energy will be even lower than in the case when we use the sources of fossil energy which are becoming more and more expensive.

4. Maintenance of the machine and tractor fleet

In the late 1950-ties and early 1960-ties the agricultural machinery passsed into the hands of collective farms. However, in most cases there were no resources, or projects at the disposal of the farms for its service and technical maintenance, there was no adequate maintenance technology worked out, they had an insufficient number of instruments and devices for the maintenance, no idea about the required spare parts and the stores of maintenance materials. There was no experience also in the sphere of rational use of the machinery. Since the foundation of the Institute the solution of these issues became one of the important directions of its activieties, and it remaind topical till the change of management system in the 1990-ties. After shifting to the machinery produced in the EU with a wide scope of offers and its service being ensured by the supplier companies an issue became topical of the adequacy of these machines to particular conditions, as well as elaboration of the models and assessment methods for the choice of machines to be used on the farms of various sizes and farming intensities.

Initially the research work was based on the compilation of the existing experience in order to work out technological schemes and flow sheets, which formed the foundation for the implementation of the projects of a concrete technical basis on the farms with subsequent clarification of rational maintenace variants. After that a certain number of machines were regularly inspected on the farms evaluating the technical condition of the units and aggregates thus specifying by statistical methods the need for spare parts and maintenance materials. At present an important methodological aspect is clarification of the objective results of the work of various kinds of machinery – their efficiency, specific fuel consumption, repair and maintenance costs, that affect essentially the labour costs and hence the prime cost of the product.

According to a flowsheet worked out at the Institute an experimental technical maintenance centre was built on the collective farm “Krasnij Oktjabrj”, Preiļi Region, in 1963, but in 1969 a technical maintenance complex on the farm “Zelta zvaigzne”, Liepāja Region. Nonstandard equipment was made at the Experimental Machine Building Workshop of the Institute. These objects became the basis for the investigations in the maintenance sphere of the machine fleet during the respective period. Flowsheets were developed for periodic technical maintenance, the necessary instruments and the stock-lists of the spare parts were determined, recommendations were prepared for the improvement of the standardised projects. An important role was allotted in this period to the research of the position and significance of the dispatcher’s service in leading the production processes, including a method worked out to determine the parameters of the tractor work at a 3-5 km distance. By a similar method today, using the GPS possibilities and the principles determined then, one can ensure full control over any machine on which an internal combustion engine is installed.

In the second half of the 1970-ties and during the 1980-ties work was done at the improvement of the layout of the technical maintenance centres by differentiating them according to the number of the machines serviced, new kinds of technical diagnostics methods and equipment were acquired, as well as several devices and equipment were created to facilitate the technical maintenance processes and make them more precise. As the most successful development of that period could be mentioned an original washing technology of machines and the equipment with mud collection in containers. Some of such equipment have worked even two decades. A considerable proportion of the work were then the so called normative themes with an aim to specify the utilisation norms of the maintenance materials and spare parts. Implementation of the themes was connected with the collection of statistical data in the entire republic, and for this purpose the base farms had to be selected, accountancy and data collection had to be organised there. The work involved frequent and long business trips around the farms of the republic and processing of a huge amount of data. However, today the results of this work have lost their topicality.

At the end of the 1980-ties and in early 1990-ties intensive formation of small peasant and household farms started, and a special regional machine building programme existed at the Ministry of Agriculture to provide them with adequate machibery. Therefore in this period mainly machines and implements were developed and made in small series which were suitable for the farms mentioned. They were tested at the Baltic Machine Testing Station (MTS) according to an abridged methodology. In 4 – 5 years’ time the Institute of Mechanisation made and put in operation about 40 machines. As the most successful among the machines developed in that time should be mentioned the fodder roll disintegrator for the design and optimisation of the operating conditions of which the first Master’s paper was written and defended at the Institute. Disintegrators of a similar design are presently purchased abroad. Besides the machines worked out, the accomplishments of that period are reflected in the popular science publications, technical documentation, catalogues, prospects, recommendations. From the scientific point of view, this period should be regarded as unproductive since the old system of scientific activity was destroyed but the new one was still in the making.

In the middle of the 1990-ties the trends of agricultural development were outlined, the principles of financing scientific activities and the evaluation criteria of the results were determined. Therefore, the perspective directions began to loom out. At that time there were more than 100 thousand landed properties in the country, the offers of various machinery were ever increasing, since 1996 the government started subsididing technical modernisation of agriculture, including the purchase of the machinery. However, there were no criteria for the choice of the machinery and evaluation of the results to be expected from its use on the farms of various sizes and intensities. In 1997-98 a computerised method for technological calculations was worked out which allows calculation of the expected costs of a production unit by changing the data that characterise the technology [30]. The method being developed further, cost-efficiency nomograms were worked out for the production of the most important items [31]. Issues were studied on the energy provision of farms, i.e. the power of the tractors related to the cultivated area within the context of the development of the farms [32]. In another aspect these studies characterise also the development trends of the fleet of tractors [33]. One can conclude that the purchase of more powerful tractors will grow keeping pace with the concentration of production and the average specific energy provision kW/ha of the farms will diminish. At the expense of the liquidation of the worn-out tractors the rotal number of tractors will decrease, and after 5-8 years there might be 32-36 thousand operable tractors [34]. A mathematical model has been worked out for the minimalisation of the variable costs of the mechanised field operations using the programme MS Excel and solving it as a task of non-linear programming [35]. By applying this model, it is possible to choose a technology for a particular farm with minimal labour costs.

5. Contribution of the Institute during 50 years (summary)

During the 50 years since the Institute exists there were published more than 3000 scientific article, of them 470 after the year 2000. 55 books have been written and published, 7 of them after the year 2000. In 1967-83 the Institute published collections of scientific papers, 16 volumes in all [6], as well as five books of the scientific and practical collection "Recent Developments in Agricultural Mechanisation". For twenty five years (1971-96) the Institute organised exhibitions "Innovator" (in 1995-96 under the name "Knowledge"). Since the middle of the 1990-ties similar exhibitions take place at Rāmava. 100 inventor's certificates and patents have been granted, including 17 patents after the year 2000. There are 24 dissertations defended, including one after the year 2000. More than 100 machines and equipment have been developed and launched into production, most of all during the period from 1988 till 1995 when the State Regional Machine Building Programme was in force.

Conclusions

1. During the past 50 years the Institute has made essential contribution to the mechanisation of agricultural production, the development of technologies and machines, as well the improvement of their operation, promoting the output of competitive products meeting the modern standards.
2. The relationships obtained during the investigations have supplemented the theoretical basis of terramechanics. They can be applied to the simulation of the technological processes, substantiation of the optimal parameters of the machines and their operating parts, their energetic estimation.
3. The strategic development plan of the Institute sets the directions for its further activity: studies in the technologies and equipment of competitive renewable energy resources replacing the fossil fuel; improvement of field crop growing technologies that are efficient in production, ecologically safe resources for biological and conventional agriculture with the use of GPS technologies; participation in strengthening the intellectual potential of the nation by evolving engineering sciences, taking part in the implementation of national and international projects. As a result of the realisation of the strategic plan the Institute is to be transformed into an internationally acknowledged research centre in the directions mentioned above.

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