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DEVELOPMENT OF MECHANICAL TECHNOLOGY FOR LOW-BUSH BLUEBERRY CULTIVATING IN THE PLANTATION ESTABLISHED ON MILLED PEAT FIELDS

MECHANINĖS TECHNOLOGIJOS IŠVYSTYMAS APLEISTŲ DURPIŲ LAUKUOSE ĮKURTOSE ŽEMAŪGIŲ MĖLYNIŲ KRŪMŲ AUGINIMO PLANTACIJOSE

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This article provides an overview of the technological peculiarities of a blueberry plantation established on exhausted and abandoned milled peat fields and the development of relevant machine cultivation technology and technological devices. The soil properties of exhausted and abandoned milled peat fields are specific to establishing blueberry plantations. This article outlines the problems that need to be resolved, tasks, generated technical ideas and methods of fulfilling these. In the framework of product development the following technological devices have been developed: a portable spot-fertilizing device; a portable contact-type weed control device; a motoblock-type blueberry harvester; and a blueberry sorting device. It also discusses the peculiarities of implementing these devices.

Low-bush blueberry, mechanical cultivation technology, engineering design and development, fertilization, weed control, berry harvesting.

Introduction

Growing commercial blueberries is a developing arm of the global berry-growing industry (Strik, 2005). In most countries commercial blueberries are consumed freshly as delicious berries. They boost health and provide essential nutrients needed by the human body. Blueberry cultivation is rather new in Estonian conditions, yet it is a continuously widening and developing plant growing industry. Thereby the biggest blueberry plantations in Estonia have been established on exhausted milled peat fields. Unfortunately, development of this field of activity is limited as there is no machine cultivation technology available for this. The machines currently used in blueberry cultivation cannot be used on abandoned milled peat fields. One of the reasons is that the machines are meant for harvesting high-bush blueberry species and are thus big, sturdy and heavy and cannot be used on turf soil in bog conditions.

In Estonia, commercial blueberries can be grown on exhausted and abandoned milled peat fields, where the layer of residual turf is sufficiently thick. Blueberries are not demanding plants and prefer acidic soils, the optimal pH level is between 4.5 and 5.5 (Hall et al., 1964; Holmes, 1960; Starast et al., 2009). The area of exhausted and abandoned milled peat fields in Estonia is approximately 8000 ha, of which over 2000 ha is suitable for blueberry cultivation (Ilomets, 1996; Paal et al., 1998). 73 ha is already in use, but this represents an insignificant proportion of production capacity.

At present, blueberry cultivation on exhausted and abandoned milled peat fields is done manually in Estonia. This has been the major obstacle in the development of blueberry plantations on exhausted and abandoned milled peat fields.

Blueberry cultivation consists of the following work phases: soil preparation; planting; plant fertilization; plantation maintenance; weed control; plant protection; and crop harvesting, which is followed by post-harvesting processing of the crop. The lifetime of a blueberry plantation is approximately 30-40 years.

The wider objective of this study is to assist in developing mechanical cultivation technology for low-bush blueberries on exhausted and abandoned milled peat fields in Estonia. Although the aim is to offer advanced solutions for a new and economically efficient arm of berry cultivation, it also has a significant positive impact on the environment. Because of turf production there are thousands of hectares of abandoned milled peat fields in Estonia. On bare and plant-free milled peat fields turf is constantly mineralising, in the process of which carbon dioxide is emitted. As there is no vegetation locally, huge quantities of CO_2 are intensively emitted directly into the atmosphere. Thus it is considered very important to find solutions to introduce new vegetation to exhausted milled turf areas. Establishing a low-bush blueberry plantation on abandoned turf areas would help significantly in restoring balanced carbon circulation in exhausted peat fields. Developing special machine technology for blueberry cultivation that have significantly reduced production costs would facilitate even wider use of peat fields. Technological solutions developed could also be implemented more widely. Also, other countries leading in turf production are facing a need to solve similar environmental problems. Like Estonia, blueberry cultivation with the aim of reducing environmental risks has started in Finland, Latvia, Lithuania, Belarus, Canada and elsewhere.

In a narrower meaning this article focuses on mechanical or machine-based blueberry harvesting and maintenance during growth, since these are major cost sources of crop-giving plantations – manual work is not economically profitable and there is insufficient labour for manual harvesting.

Description of technology

Plantation preparation includes minimal cultivation work, which in any production strategy involves the cleaning of draining ditches, the excavation of water furrows, the removal of stubs from the surface layer and shaping of the soil. For soil preparation, machines and technological solutions well known in soil improvement can be used.

Plants are planted in a row with a plant step of 0.9-1.0 m and a distance between rows of 0.9-1.0 m. The plants are planted manually or with the help of a planting machine.

Fertilizing a blueberry plantation. The fertilizer level of an abandoned milled peat field is close to zero. Broadcast fertilization of a blueberry field with a centrifugal-type disc spreader is not feasible, since it would also encourage weed growth on the field. Nevertheless, the plants must be fertilized. According to the data of Noormets et. al. (2002) and Paal et al. (2011) the fertilization of young low-bush blueberry plants resulted in a crop yield of 2190-2930 kg ha^{-1}, whereas the crop yield of unfertilized plants was just 173 kg ha^{-1}. These data speak for themselves. Use of a compound fertilizer (N19, P24 or K48) resulted in bigger berries and higher crop yield.

Blueberry plants must be fertilized twice a year:

1) in spring (April) – granulated fertilizer as top dressing; and
2) during formation of the berries (June) – liquid fertilizer as leaf dressing.

Maintenance of plantation – weed control. A small planation of no more than a couple of hectares can be maintained manually. If the plantation is bigger, manual maintenance is unreasonable since it is very labour-intensive. Where weeds are concerned, Tussoc cotton-grass and birch prevail. Plantation maintenance includes weeding and, if necessary, trimming. So far, plantation maintenance on Estonian low-bush blueberry plantations has been done manually.

Plant protection. At the outset, plantations established on exhausted milled peat fields are free from plant diseases and plant pests. At present, plant protection products sprayed from sprayers carried on the back during spraying and/or contact plant protection products are used on Estonian blueberry plantations.

To date, blueberries have been harvested manually in turf moss.

The maturing signs of a blueberry bush are the splitting of the branch bark and its darkening and drying. The number of new growth branches is reduced. Also, lighting conditions within old bushes are reduced, which in turn reduces the intensity of photosynthesis. In order to prevent this, it is recommended to cut back the older branches of semi-high and low-bush blueberry species. In production plantations, cutting back single branches is very labour-intensive.

Considering the fact that berries grow on young branches, their growth must be promoted by means of cutting. In the case of free thinning, old branches are removed from the bushes. Approximately 4-6 strong one-year branches and 3-6 copiously branched several-year-old branches should be left in place. In a bush with a thin crown, all berries grow in good lighting conditions. Free thinning is labour-intensive and thus on bigger plantations rejuvenation cutting may be done. In this case all branches are cut to the ground in early spring, leaving stubs with a length of a couple of centimetres. It is important to leave stubs, since new shoots start growing from sleeping buds on the stubs.

Materials and methods

In the development of machine cultivation technology the well-known TRIZ method was used, which in this case consisted of the following basic steps (Pahl et al., 2007):

1) determination and formulation of the problem;
2) setting of the objective;
3) searching for typical problems similar to the objective set;
4) analysis of known technical and technological solutions;
5) generating and selecting ideas; and
6) choosing the most suitable solution for the problem needing to be solved.

The problems to be resolved and the development tasks were derived from the following:

1) in fertilizing blueberry plants – dosing of the fertilizer from both the quantity and precision of positioning perspectives and productivity of operations;
2) in maintenance – some weed species are also plants with two embryonic seed leaves like blueberry plants and thus well-known chemical weed control devices cannot be used;
3) in harvesting – jamming of a picking reel with metal tines of a motoblock-type harvester, which tears blueberry plants to pieces and pulls them out of the ground; and
4) the problem of post-harvesting processing – it is complicated to adjust well-known sorting devices to sort blueberry species of different sizes.

Determination of innovative objectives: Blueberry cultivation can be modernised by means of implementing machines. Use of machines in blueberry cultivation sets specific requirements (preconditions) on the plants:

1) mechanical harvesting is possible on constantly maintained and rejuvenated plantations;
2) to allow normal functioning of maintenance and harvesting machines the soil surface on plantations should be land-levelled and kept thus during usage;
3) to operate machines, service tracks (technological tracks) should be established; and
4) for successful machine harvesting, old branches should be cut back regularly – first rejuvenation cutting is done in the 4th or 5th year, afterwards every 2-3 years.

Plants should be planted in beds which are separated with service tracks for technological machines. As the distance of the centre lines of the draining ditches dug between the fields established for excavating milled peat is 20 m and the width of the ditches is 1 m, the width of the fields is 19 m. If you leave a 0.5 m wide protection zone along the ditch, the useful width of the field is 18 m. On this field it is reasonable to make a 6 m wide bed in the middle and 3 m wide bed on the sides. The beds are separated with technological tracks (Käis & Olt, 2009).

Requirements of structure of spot-fertilizing device:

1) it must be possible to carry the equipment on your back and it must be ergonomic, comfortable and light;
2) dosing with sufficient precision – deviation from the stipulated value shall not exceed ± 3%;
3) stepless adjustment of bulk fertilizer quantity;
4) possibility to apply fertilizer to one plant at a time (precision fertilization); and
5) the device shall be portable.

Besides increasing crop yield, fertilization also influences the development of the plants – more precisely the length of the plant stems, whereas higher plants droop in every direction.

Requirements of structure of weed control device:

1) the device should allow contact treatment of weeds;
2) the device should be drip-free; and
3) the device should be portable.

Requirements of blueberry harvesting:

1) blueberries should be harvested in due time, when the berries are fully ripe – the most suitable time is considered to be August (in Estonian conditions berries ripen by the beginning or middle of August) and as approximately 90% of berries become ripe at the same time, harvesting should take place in one operation;
2) the duration of harvesting should be as short as possible – approximately 15-20 days;
3) under normal load conditions the harvesting loss of a blueberry harvester should not exceed 5%;
4) the ratio of impurities (leaves and other plant remnants) in the berries should not exceed 15%; and
5) the ratio of mechanically damaged (crushed) berries should not exceed 12%.

Innovative solutions for devices: During product development the following devices were developed:

1) a portable spot-fertilizing device (precise dosing);
2) a weed spot-control device;
3) a blueberry harvester equipped with a reel with flexible picking tines and interim tines; and
4) a stepless adjustment roller for a blueberry sorting device.

An innovative portable spot-fertilizing device consists of three main components (Fig 1): a fertilizer tank 2; a batcher unit including a drive 23; and a pipe-shaped fertilizer duct and handle with a button switch. A portable spot-fertilizing device (Fig 1, a) is provided with two cushioned straps for carrying the device over the shoulders. The straps are fastened to the fertilizer tank 2 of the spot-fertilizing device. The fertilizer tank 2 is equipped with a tank cap and is designed for storing granulated fertilizer. There is a batcher unit fastened to the bottom of the fertilizer tank of the spot-fertilizing device whose function is to measure the required quantity of granulated fertilizer and to forward it to the fertilizer duct. The batcher drive consists of a step motor together with control units and a power source. The step motor is activated by pressing a button 61 on the handle. Each time the button is pressed the fluted roller of the batcher rotates by the stipulated rotation angle and as a result the adjusted quantity of granulated fertilizer is sprayed each time. The size of the rotation angle of the shaft of the step motor is controlled via a control unit. The granulated fertilizer released from the batcher moves via a flexible section of a pipe-shaped fertilizer duct to the handle, which is equipped with a button switch provided with a signal sensor and further on through a fertilizer duct to the pipe-shaped rigid section of the fertilizer duct, via which the required quantity of granulated fertilizer finally reaches the fertilizing spot – the shoot of the plant.

a)

Figure 1. Portable spot-fertilizing device: a – model; b – spot-fertilizing device in operation, c – principle control scheme: 2 – fertilizer tank, 3 – batcher, 4 – drive, 5 – upper part of fertilizer duct, 6 – handle, 7 – lower part of fertilizer duct, 21 – housing of fertilizer tank, 22 – bottom of fertilizer tank, 23 – cover, 24 – cap, 36 – step motor, 41 – power source, 42 – control switch, 43 – micro controller, 44 – signal diodes of power source, 45 – signal diode set of position of fluted roller, 46 – main controller, 61 – button-switch.

1 pav. Nešiojamas lokalinio tręšimo įrenginys: a – modelis; b – veikiantis lokalinio tręšimo įrenginys; c – principinė valdymo schema: 2 – trąšų bakas, 3 – dozatorius, 4 – pavara, 5 – trąšų vamzdžio viršutinė dalis, 6 – rankena, 7 – trąšų vamzdžio apatinė dalis, 21 – trąšų bakas, 22 – trąšų bako apatinė dalis, 23 – dangtis, 24 – bako dangtelis, 36 – variklis, 41 – maitinimo šaltinis, 42 – valdymo jungiklis, 43 – mikro valdiklis, 44 – maitinimo šaltinio signalų diodai, 45 – signalo diodų komplekto padėtis rifliuotame volelyje, 46 – pagrindinis valdiklis, 61 – mygtukas-jungiklis.

Data regarding productivity and costs of fertilizing technologies are shown in table 1.

Table 1. Comparison of the characteristics of fertilizing technologies
1 lentelė. Tręšimo technologijų charakteristikų palyginimas

Parameter	Manual technology	Mechanical technology (using portable spot-fertilizing device)
Productivity ha h^{-1}	0.008	0.06
Unit cost €	20.00	530.00
Labour cost € ha^{-1}	504.00	80.85
Specific cost € ha^{-1}	506.50	169.18

The portable weed spot-control device (Fig. 2) is designed for applying herbicides to weeds. It consists of a bottle-shaped herbicide tank, a manipulator-like contact head and a shallow connection pipe in between. The connection pipe is provided with a support handle with a trigger-shaped lever controlling the manipulator and a holding handle for directing the contact head.

a) b) c)

Figure 2. Portable weed spot-control device: a – device model; b – device in operation; c – working element of device.

2 pav. Nešiojamas kontaktinio tipo piktžolių kontrolės įrenginys: a – įrenginio modelis, b – veikiantis įrenginys; c – įrenginio darbinis elementas.

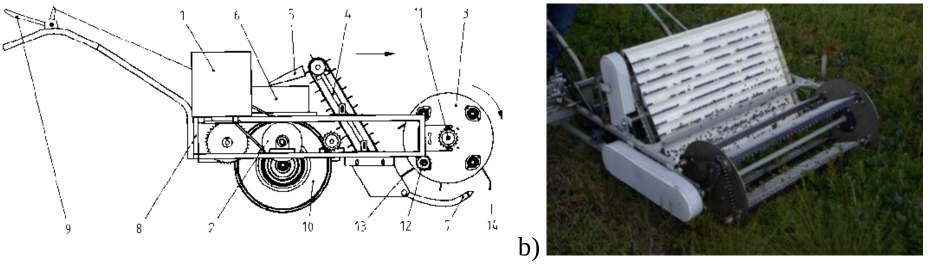
The device helps to apply the minimum quantity of pesticides to achieve maximum results. Minimum and contact use ensures that the plant protection product does not reach the ground, on the blueberry plants. This helps avoid pesticides getting into the soil and from there into ground water.

The device ensures minimum air pollution when working in strong wind conditions. The health of the operator is optimally protected. Data regarding productivity and costs of weed control are shown in table 2.

Table 2. Comparison of the characteristics of weed control technologies
2 lentelė. Piktžolių kontrolės technologijų charakteristikų palyginimas

Parameter	Manual technology	Mechanical technology (using portable weed spot-control device)
Productivity ha h^{-1}	0.006	0.031
Unit cost €	-	60
Labour cost € ha^{-1}	1075.2	129.8
Specific cost € ha^{-1}	1075.2	135.9

A blueberry harvester is a small self-propelled machine (Fig. 3) consisting of a drive 1 with power transmission elements 2, a parallelogram picking reel 3, a berry conveyor 4, a chute 5, a berry tank 6, a copying unit 7, a frame 8 supporting the machine elements and assembly units, steering levers 9 and wheels 10. An important advantage of the machine is the simplicity of the structural design of the picking reel 3 as well as its stem-saving workflow, user-friendliness and reliability.



a) b)

Figure 3. Blueberry harvester: a – principle scheme; b – blueberry harvester in operation: 1 – drive, 2 – power transmission elements, 3 – picking reel, 4 – berry conveyor, 5 – chute, 6 – berry tank, 7 – copying unit, 8 – frame, 9 – steering levers, 10 – wheels, 11 – reel shaft, 12 – picking rake, 13 – rake tooth, 14 – hook spring-tine.

3 pav. Mėlynių kombainas: a – principinė schema, b – veikiantis mėlynių kombainas:1 – pavara, 2 – energijos perdavimo elementai, 3 – skynimo ritės, 4 – uogų konvejeris, 5 – latakas, 6 – uogų bunkeris, 7 – kopijavimo įrenginys, 8 – rėmas, 9 – vairavimo rankenėlės, 10 – ratai, 11 – ritės velenas, 12 – skynimo grėblys, 13 – grėblio dantis, 14 – spyruoklinis kablys.

To avoid the working elements of the blueberry harvester becoming jammed and to prevent damage to the blueberry plants, the picking reel 3 is equipped with elements 14 to direct blueberry branches into the path of the picking rake 12, where the rake teeth 13 of the picking rake 12 are designed to be flexible in order to avoid damaging the plants. Elements 14 for directing the blueberry branches into the path of the picking rake 12 are designed as hook spring-tines. These elements are rigidly fastened to the holder of the picking rake 12, where the function of each element is to direct the blueberry branches into the path of the next picking rake 12 during rotation of the picking reel 3.

For the harvesting of the blueberry crop, the blueberry harvester is moved in a shuttle pattern starting from the edge of the blueberry field or technological track. A parallelogram picking reel 3 gets its rotation from the power transmission 2 of the drive 1; the picking reel 3 is rotated in the same direction as the wheels of the machine. During rotation of the picking reel 3 the elements designed as hook spring-tines 14 direct the blueberry branches that otherwise point in different directions into the path in which the machine is travelling and the rake teeth 13 moving behind the spring tines are directed between the blueberry stems. This operation minimizes the risk of the stems getting between the rake teeth 13. After this the rake teeth 13 start tearing the blueberries off the blueberry branch. The rake teeth 13 forward the released berries to the berry conveyor 4 which transports them from the harvesting zone through a chute to the berry tank 6. When the berry tank is full, the operator of the blueberry harvester replaces the full tank with an empty one and the operation continues.

If the flexible rake tooth 13 of the picking rake gets stuck on a plant stem or a plant stem in the way of the picking rake 12 gets stuck in the tip of the rake teeth, additional load is applied to the rake teeth 13 when the picking reel is rotating and the rake tooth bends and assumes position 13b (Fig. 4). When the rake teeth 13 are bent, the plant stems are released from the tips of the rake teeth. When the plant stems are released, the rake tooth 13 resumes its initial position 13a.

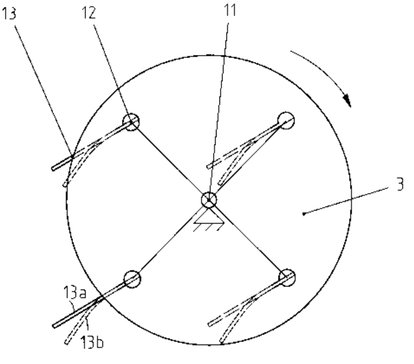


Figure 4. The principal scheme of the picking reel of blueberry harvester
4 pav. Mėlynių kombaino rinkimo būgno principinė schema

ERTACETAL C with the chemical structure of POM-C, $(CH_2O)_n$ was chosen for the material of the teeth of picking rake 12. Technical specification of the material ERTACETAL C chosen for the tooth of picking rake is shown in table 3.

Table 3. ERTACETAL C Technical Specification (Quadrant EPP…)
3 lentelė. ERTACETAL C Techninė specifikacija (Quadrant EPP…)

Property	ISO Methods	Units	ERTACETA L C
Colour	-	-	White
Density	1183	g cm^3	1,41
Trensile strength	527	N mm^2	68
Trensile modulus of elasticity	527	N mm^2	3100
Elongation at break	527	%	35
Hardness	Rockwell M	-	84
Melting point	-	ºC	165

ERTACETAL C is an elastic material. Its product range includes a choice of material of circular cross-section of 4 mm and 5 mm in diameter (Table 4). In order to determine the suitability of these choices, a laboratory experiment was conducted.

Table 4. Characteristics of the specimens of rake tooth
4 lentelė. Grėblio dantų charakteristikos

Parameter	Units	Parameter	
Material	-	POM-C	
Working length	mm	125	
Diameter	mm	4.0	5.0
Price*	€ m^{-1}	0,22	0.33
Relative price per volume unit	%	100	96

Note: *materials' prices per meter are given without VAT

The height of the picking reel 3 of the blueberry harvester from the ground can be adjusted by regulating the position of the copying unit so that the picking reel can also pick the berries closest to the ground. The pins of the copying unit 7 slide between the plants when the blueberry harvester moves on the field and help to lift plant stems which have fallen down. Data regarding productivity and costs of berry harvesting are shown in table 5.

Table 5. Comparison of the characteristics berry harvesting technologies
5 lentelė. Uogų derliaus nuėmimo technologijų charakteristikų palyginimas

Parameter	Manual technology	Mechanical technology (using blueberry harvester and ATV)
Productivity kg h^{-1}	4	414
Unit cost €	12	13700
Labour cost € kg^{-1}	1.35	0.04
Specific cost € ha^{-1}	1.353	0.088

Conclusion

This article describes the development methodology of blueberry machine cultivation technology and the results thereof. During product development a portable spot-fertilization device, a portable contact-type weed control device, a motoblock-type blueberry harvester and a blueberry sorting device were developed. An important advantage of the novel picking reel of blueberry harvester is the simplicity of constructive solution, stem-saving workflow, user-friendliness and reliability. Saving the stems was achieved through introducing elastic rake teeth produced of Polyoxymethylene (POM-C). Elastic rake teeth do not tear the plant stems into shreds nor pull the plants out of the ground, but bend when a barrier occurs and return to their original shape after overcoming barrier resistance. The conclusion is that implementation of this equipment has a positive impact. Also, the logistical issues of the technology have been solved.

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MECHANINĖS TECHNOLOGIJOS IŠVYSTYMAS APLEISTŲ DURPIŲ LAUKUOSE ĮKURTOSE ŽEMAŪGIŲ MĖLYNIŲ KRŪMŲ AUGINIMO PLANTACIJOSE

Santrauka

Šiame straipsnyje apžvelgti nualintų ir apleistų durpių laukuose įveistų mėlynių plantacijų technologiniai ypatumai ir pateiktas atitinkamų auginimo technologijų ir technologinių įrenginių išvystymas. Dirvožemio savybės nualintų ir apleistų durpių laukuose yra specifinės, dėl to jas būtina įvertinti įveisiant mėlynių plantacijas. Šis straipsnis išryškina problemas, kurias reikia išspręsti auginant mėlynių krūmus apleistuose durpynuose, užduotis bei gautas technines idėjas ir metodus. Siekiant tobulinti auginamų produktų gamybą buvo sukurti šie technologiniai įrenginiai: nešiojamas lokalinio tręšimo įrenginys; nešiojamas kontaktinio tipo piktžolių kontrolės įrenginys; motobloko tipo mėlynių kombainas ir mėlynių rūšiavimo įrenginys. Taip pat buvo aptarti šių įrenginių įdiegimo ypatumai.

Žemaūgiai mėlynių krūmai, mechaninio auginimo technologija, inžinerinis projektavimas ir kūrimas, tręšimas, piktžolių kontrolė, uogų derliaus nuėmimas.

Юри Ольт, Маргус Арак, Алгирдас Ясинскас

РАЗРАБОТКА ТЕХНИЧЕСКИХ СРЕДСТВ МЕХАНИЗАЦИИ ДЛЯ ВЫРАЩИВАНИЯ ЧЕРНИКИ В ПИТОМНИКАХ НА ЗАБРОШЕННЫХ ТОРФЯНЫХ ПОЛЯХ

Резюме

В данной статье проведен обзор технологических особенностей плантаций черники, посаженых в деградированных или заброшенных торфяных полях и представлено развитие соответствующих технологий выращивания и технологического оборудования. Свойства почв деградированных и заброшенных торфяных полей являются специфичными, потому это необходимо оценить перед посадкой плантаций черники. В этой статье освещаются проблемы, которые требуются решить при выращивании кустов черники в заброшенных торфяниках, а также задачи и полученые технические идеи и методы. В целях повышения производства выращиваемых продуктов были разработаны эти технологические устройства: портативный удобритель, портативное контактное противосорняковое устройство, черникоуборочная машина и устройство для сортировки черники. Кроме того были обсуждены особенности внедрения этого оборудования.

Карликовые кусты черники, технология механического выращивания, инженерное проектирование и разработка, внесение удобрений, борьба с сорняками, уборка урожая фруктов.