Norway grants

The National Centre for Research and Development

Improving plant quality and economy for a more sustainable and efficient berry production

WP1 – WP7

Acronym: QualityBerry

Contract number: NOR/POLNOR/QualityBerry/0014/2019-00

National Institute of Horticultural Research, Skierniewice

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WP1. Environmental effects on flower and dormancy initiation and breaking of dormancy in *Rubus* and *Ribes* species (WP Leader Anita Sønsteby)

Task 1.3. Dormancy breaking of established cultivars and advanced selections of *Rubus* and *Ribes* (NIBIO and INHORT)

2021: Raspberry

Shoot/canes collection and storage beginning: 9th Feb. 2021

Different dormancy breaking temperatures (-5, 0, 5°C) for 7, 14 and 21 weeks

Assessment beginning: 31th March; 19th May; 7th July.

Cultivars: Tulameen, Veten, Willamette, Schönemann, Glen Ample, Przehyba, Polana,

Assessment done in 2021: recording of the number of bursting buds every two days, starting from the date they were taken out of the cold store; bud dissection and assessment of the stages of bud development directly after the end of the storage

Results:

Buds - after 7 weeks of storage took the longest time to reach the breakage phase (from 8 days for Schönemann and Tulameen to 16 days for Przehyba).

Buds - stored for a period of 14 weeks burst after 6 (Schönemann) to 14 days (Przehyba) after being transferred to the greenhouse.

After 21 weeks of storage, a large number of buds were observed that had not start developing at all; the remaining buds burst after 5 (Willamette) to 9 days (Schönemann and Przehyba).

In 2022: Additional date of the assessment – 0 (directly after taking the shoots for storage)

Some raspberry cultivars more for the studies

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2021: Results - raspberry.

A bud dissection and evaluation of the development stage done directly after the end of the storage. After 7 weeks of storage, the buds were at stage 2-3, regardless of temperature. After 14 weeks of storage - large differences in bud development: from stage 1 (Willamette at +5°C) to stage 5 (Polana, Veten, 0°C). After 21 weeks of storage – bud development from stage 2 (Schönneman, +5°C) to stage 5-6 (Polana at -5°C, Willamette at +5°C, 0°C). After 21 weeks, many buds were dried up, and they fell apart during isolation.

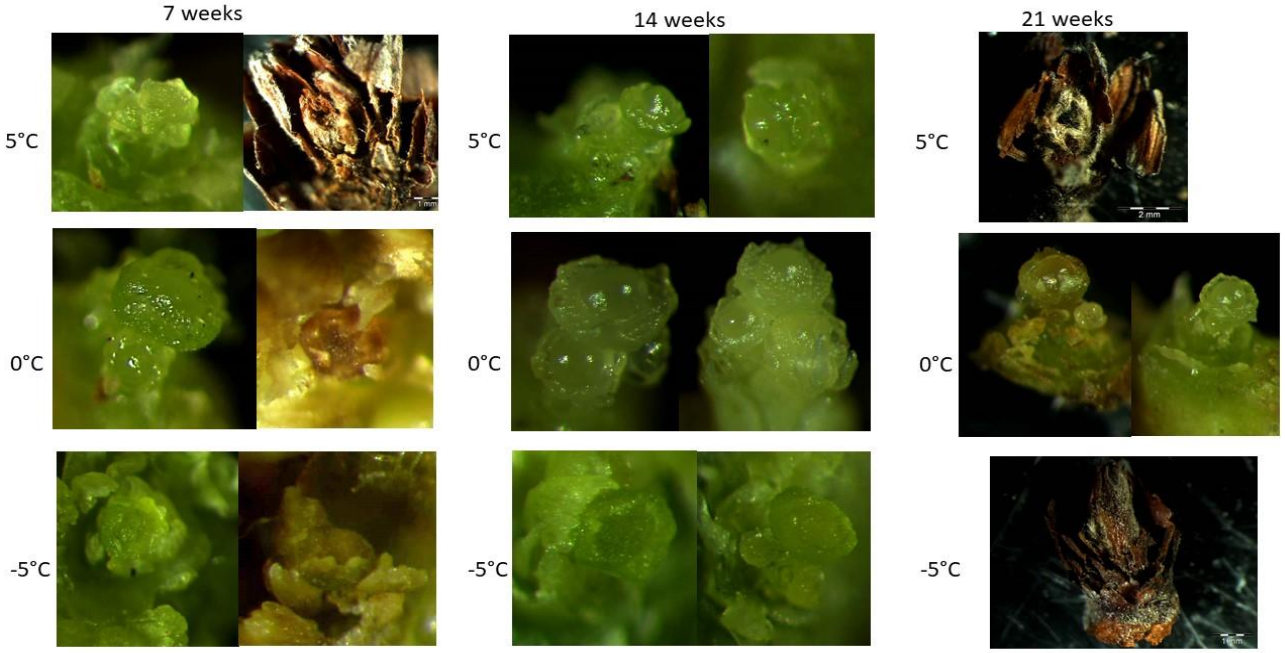

Fig 1. Dormancy breaking in Przehyba

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WP1. Environmental effects on flower and dormancy initiation and breaking of dormancy in *Rubus* and *Ribes* species (WP Leader Anita Sønsteby)

Task 1.3. Dormancy breaking of established cultivars and advanced selections of *Rubus* and *Ribes* (NIBIO and INHORT)

2021: Blackcurrant

Shoot/canes collection and storage beginning: 10th Feb. 2021.

Different dormancy breaking temperatures (-5, 0, 5°C) for 7, 14 and 21 weeks

Assessment beginning: 1st April; 20th May; 8th July.

Cultivars: Polares, Narve Viking, Ben Tron, Ben Lomond, Tihope, Bona, Gofert

Assessment done in 2021: recording of the number of bursting buds every two days, starting from the date they were taken out of the cold store; bud dissection and assessment of the stages of bud development directly after the end of the storage

Results:

After 7 weeks of storage, single blackcurrant buds developing immediately after transferring of shoots to the greenhouse were observed for Gofert stored at 0°C and 5°C. The most developed buds were observed after 7 and 11 days regardless of the storage temperatures.

After 14 weeks of storage in a cold store at 0°C, all cultivars (except Tihope) developed their first buds immediately after being transferred to the greenhouse, while after storage at 5°C, developed buds were observed in Bona, Gofert and Polares. After 14 weeks of storage, regardless of the temp., most of the buds developed just 2 days after being placed in a greenhouse.

After 21 weeks of storage in a cold store at 0°C and 5°C, a large number of buds developed already on the day following their removal from the cold store. The highest number of buds, regardless of the storage temperature, was recorded 4 days after they were transferred to the greenhouse.

WP1. Environmental effects on flower and dormancy initiation and breaking of dormancy in *Rubus* and *Ribes* species (WP Leader Anita Sønsteby)

Task 1.3. Dormancy breaking of established cultivars and advanced selections of *Rubus* and *Ribes* (NIBIO and INHORT)

2021: Results – blackcurrant.

After 7 weeks of blackcurrant dormant shoot storage - buds in stage 1 were observed only in Polares (5°C), stage 2 was recorded in Ben Tron (0°C), Polares (0°C and -5°C), Gofert (5°C and 0°C) and Ben Lamond (5°C and 0°C) whereas stage 3 were visible in Ben Tron (5°C) and Tihope (-5°C). Single buds in stage 6 were already observed after 7 weeks of storage for Ben Tron (5°C), Polares (0°C and -5°C), Bona (5°C, 0°C and -5°C), Gofert (5°C, 0°C and -5°C), Ben Lomond (5°C, 0°C and -5°C), Narve Viking (5°C, 0°C and -5°C) and Tihope (5°C, 0°C and -5°C).

After 14 weeks of storage - at 5°C majority of buds in Polares were at the stage 2 and in Bona in stage 3. At -5°C buds of all cultivars were in stage 6 with the exception of Ben Lomond (stage 3).

After 21 weeks of storage all cultivars had fully developed flowers (stage 6), with the exception of single flowers in Ben Lomond at 5°C (stage 3), Ben Tron at -5°C (stage 3), Polares at 0°C (stage 3) and Narve Viking at 0°C and -5°C (stage 3).

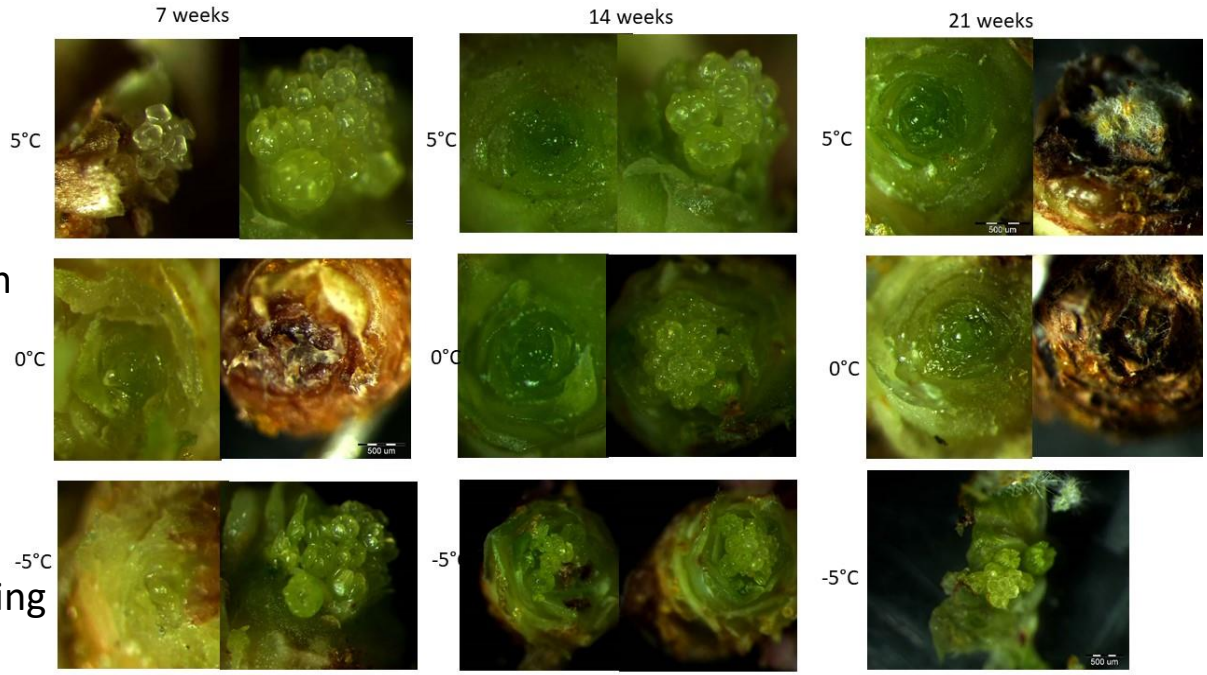

Fig 2. Dormancy breaking in Ben Tron

Task 1.4. Phenotyping overall plant performance (INHORT and NIBIO):

Raspberry cultivars: Tulameen, Veten, Willamette, Schönemann, Glen Ample, Przehyba, Polana

Results:

Beginning of the vegetative bud breaking ranged from 81.7 days (March 23-24) for the cultivar Polana to 89.5 days (March 30-31) for Tulameen.

Beginning of flowering was 147.1 days for Polana (27th May) to 152.5 days for Schönemann and Veten (1st June).

The fruit harvest began on July 5th (Przehyba) and ended on August 25th (Glen Ample, Veten and Polana).

Polana - the highest productivity, but the smallest and the darkest fruits.

Tulameen and Przehyba - the largest fruits with an intense red colour, but with a low gloss. The fruits of Przehyba were the most firm.

From August 3rd to October 5th, the height of young shoots was measured at weekly intervals.

Systematic growth of young shoots - until September 21st.

The longest shoots (over 120 cm) - were formed by Tulameen and Willamette , while the shortest ones – by Polana and Glen Ample (below 70 cm).

Blackcurrant cultivars: Polares, Narve Viking, Ben Tron, Ben Lomond, Tihope, Bona, Gofert

No assessment in 2021. Field experiment was established in the spring of 2021.

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Task 2.4. Use of environmentally friendly products:

Strawberry (4 cvs.): Grandarosa, Markat, Florence and Panvik *(control against P. macularis, M. fragariae, D. earliana)*

Three production systems: 1. Integrated Protection (IP) - standard fungicides recommended in integrated production (Luna Sensation, Topas, Nimrod, Scorpion), 2. Integrated Protection with the reduction of chemicals (reduced IP) - biological preparations with the support of IP fungicides in conditions of high disease pressure (Luna Sensation, Serenade, ZumSil, Scorpion) and 3. Biological Protection (ECO) - only biological preparations based on sulfur, essential oils and microorganisms (Limocide, Serenade, ZumSil) + 4. Control (without protection).

Assessment: the degree of plant infestation by leaf diseases (end of September 2021), numer of daugter plants

Results:

White leaf spot - the leaf infestation of Grandarosa was similar in all the production systems used, but significantly lower in IP and reduced IP systems compared with the control combination.

Leaf scorch - the infestation of Grandarosa leaves was significantly lower in the reduced production systems IP and ECO than in the control combination. The highest degree of leaf infestation of Markat was found in the control combination while the lowest -in the case of the IP and reduced IP systems.

Daughterplant number - no significant differences were found in the total number of daughter plants of three strawberry cultivars (Grandarosa, Florence and Panvik), depending on the production system: IP, reduced IP, ECO. Only for Markat, the total number of plants obtained in the ECO system was higher than in the IP system.

Task 2.4. Use of environmentally friendly products:

Blackcurrant (5 cvs.): Ben Gairn, Ben Tron, Narve Viking, Polares and Tihope

Three fruit production systems: 1. Integrated Protection (IP) – Zato 50 WG (trifloxystrobin) and Signum 33 WG (pyraclostrobin + boscalid); 2. Reduced Integrated Protection (reduced IP) - Zato 50 WG (trifloxystrobin) and Armicarb SP (potassium bicarbonate) ; 3. Biological Protection (ECO) - Limocide (orange oil) and Armicarb SP (potassium bicarbonate).

Assessment: the degree of plant infestation by leaf diseases (end of September 2021), number of young shoots

Results:

Powdery mildew (*Podosphaera mors-uvae*) - no symptoms of the pathogen (disease) were found on any of the blackcurrant cultivars, regardless of the production system.

Leaf spot (*Drepanopeziza ribis*) - symptoms observed on plants of all tested cultivars, regardless of the production system. The lowest intensity of the disease was found in the IP system. The least infected leaves were observed on the cultivar Ben Tron, grown in the IP system, and the most - on the cultivar Tihope grown in the reduced IP system and in the ECO system.

White pine blister rust (*Cronartium ribicola*) - severity of the disease ranged from 2.7 to 100% of infected leaves. The lowest disease intensity was found in the IP system. The lowest infection of leaves was observed on plants of Ben Gairn in the IP system. The most infected by this pathogen were Narve Viking and Ben Tron, grown in the reduced IP and the ECO systems.

Shoot number - the least shoots (1.8-2.8) were obtained from bushes of the cultivar Narve Viking, regardless of the production system, and the greatest number of shoots (8.2) from shrubs of the cultivar Polares grown in the IP system. The greatest number of shoots per shrubs in class I was obtained for the cultivar Polares grown in the IP system – 4.2 shoots and in the ECO system – 3.8 shoots.

Task 2.4. Use of environmentally friendly products:

Raspberry (5 cvs.): Polka, Poemat, Laszka, Ninni, Duo

Three production systems: 1. Integrated Protection (IP) - standard fungicides recommended in integrated production (Luna Sensation, Topas, Nimrod, Scorpion), 2. Integrated Protection with the reduction of chemicals (reduced IP) - biological preparations with the support of IP fungicides in conditions of high disease pressure (Luna Sensation, Serenade, ZumSil, Scorpion) and 3. Biological Protection (ECO) - only biological preparations based on sulfur, essential oils and microorganisms (Limocide, Serenade, ZumSil) + 4. Control (without protection).

Assessment: the degree of plant infestation by leaf diseases, number of young rooted shoots

Results:

Will be collected in 2022 and 2023

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WP3. Development and optimization of innovative cultivation techniques for season extension, quality improvement and safety of berries. (WP Leader Tomasz Woźnicki)

Task 3.1. Optimization of soilless growing methods of strawberry under cover using different growing media and plant types

Strawberry: Grandarosa, Markat, Panvik, Florence,
Substrates: peat substrate, coconut substrate, wood fiber and mixture of peat substrate and wood fiber 50:50
Two types of frigo plants: potted and bare root
Soilless cultivation: pots at gutters in the tunnel and under plastic canopies
Assessment: plant growth vigour, flowering intensity, fruit yield and its quality, disease severity
Results:

Plants of both types in peat substrate - the strongest growth vigour, the highest yield and fruit weight.
Fruits from bare-root plants in peat substrate under plastic canopies - the most attractive and firm.
Plants in coconut substrate - symptoms of chlorosis (iron deficiency due to too high pH).

Grandarosa - the best suitability for cultivation in the tunnel (the highest yield and average fruit weight, their attractiveness, shape, gloss, taste and firmness).
The best in cultivation under plastic canopies - Markat (highest yield, large fruit) and Grandarosa (greatest attractiveness and taste of fruit and fruit size comparable to Markat).
Florence fruit - a high content of extract, anthocyanins and ascorbic acid.
Markat fruit - the lowest extract and ascorbic acid content.
Grandarosa fruit - the lowest anthocyanins level.

Task 3.3. Suitability of selected strawberry, red raspberry and blackcurrant cultivars for IP, IP with limited chemical protection and organic production using preparations against fungal diseases (specified in WP2; INHORT)

Strawberry (4 cvs.): Grandarosa, Markat, Florence and Panvik *(control against P. macularis, M. fragariae, D. earliana)*

Three systems of fruit production: 1. Integrated Protection (IP) - standard fungicides recommended in integrated production (Luna Sensation, Topas, Nimrod, Scorpion), 2. Integrated Protection with the reduction of chemicals (reduced IP) - biological preparations with the support of IP fungicides in conditions of high disease pressure (Luna Sensation, Serenade, ZumSil, Scorpion) and 3. Biological Protection (ECO) - only biological preparations based on sulfur, essential oils and microorganisms (Limocide, Serenade, ZumSil) + 4. Control (no protection)

Assessment: the degree of plant infestation by leaf diseases, in 2022-2023 also fruit yield and its quality

Results:

Leaf white spot - the degree of infection of Grandarosa in all the production systems used was significantly lower than in the control combination. Significantly lower degree of leaf infestation by this disease was also found on Markat in the IP and reduced IP systems compared with the control combination and the ECO system.

Leaf scorch - the degree of leaf infestation of Markat plants was lower in the IP and ECO systems than in the control combination. The degree of leaf infestation of Panvik cultivar was significantly lower in the IP and reduced IP systems than in the control combination.

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Task 3.3. Suitability of selected strawberry, red raspberry and blackcurrant cultivars for IP, IP with limited chemical protection and organic production using preparations against fungal diseases (specified in WP2; INHORT)

Blackcurrant (5 cvs.): Ben Gairn, Ben Tron, Narve Viking, Polares and Tihope

Three systems of fruit production: 1. Integrated Protection (IP) - Zato 50 WG (trifloxystrobin) and Signum 33 WG (pyraclostrobin + boscalid), 2. Integrated Protection with the reduction of chemicals (reduced IP) - Zato 50 WG (trifloxystrobin) and Armicarb SP (potassium bicarbonate) and 3. Biological Protection (ECO) - Limocide (orange oil) and Armicarb SP (potassium bicarbonate).

Assessment: the degree of plant infestation by leaf diseases, in 2022-2023 also fruit yield and its quality

Results:

Powdery mildew (*Podosphaera mors-uvae*) – no symptoms were found on any of the blackcurrant cultivars, regardless of the production system.

Leaf spot (*Drepanopeziza ribis*) - the lowest intensity was found on shrubs of all cultivars in the IP system. The least infected leaves were observed on the cultivar Ben Tron, grown in the IP system, and the most - on the cultivar Tihope grown in the reduced IP system and in the ECO system.

White pine blister rust (*Cronartium ribicola*) - the lowest disease intensity on shrubs of all cultivars was found in the IP system. The lowest infection of leaves was observed on plants of the cultivar Ben Gairn in the IP system. The most infected was the cultivar Narve Viking, regardless of the production system.

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Task 3.3. Suitability of selected strawberry, red raspberry and blackcurrant cultivars for IP, IP with limited chemical protection and organic production using preparations against fungal diseases (specified in WP2; INHORT)

Raspberry (5 cvs.): Polka, Poemat, Laszka, Ninni, Duo

Three production systems: 1. Integrated Protection (IP) - standard fungicides recommended in integrated production (Luna Sensation, Topas, Nimrod, Scorpion), 2. Integrated Protection with the reduction of chemicals (reduced IP) - biological preparations with the support of IP fungicides in conditions of high disease pressure (Luna Sensation, Serenade, ZumSil, Scorpion) and 3. Biological Protection (ECO) - only biological preparations based on sulfur, essential oils and microorganisms (Limocide, Serenade, ZumSil) + 4. Control (without protection).

Assessment: the degree of plant infestation by leaf diseases, fruit yield and its quality

Results:

Will be collected in 2022 and 2023

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Task 3.4. Improving production technology to extend the harvest period and supply the market with fresh berries (INHORT and NIBIO)

Strawberry: Grandarosa, Markat, Florence, San Andreas and Albion

Biostimulants: Tytanit (titanium), SuperFifty Algae 500 SL (extract from *Ascophyllum nodosum* + K_2O) and macro- and micronutrients: Alkalin KB+Si (nitrogen-potassium-boron-silicon fertilizer), AminoUltra Cu (contains copper, nitrogen and glycine), Optycal (contains oxide calcium, boron, copper, iron, manganese, molybdenum and zinc) and ZumSil (growth stimulator containing orthosilicic acid)

Assessment: plant growth vigour, flowering intensity, fruit yield and its quality

Results:

SuperFifty Algae had a positive effect on increasing plant vigor and fruit yield, as well as reducing fruit rot (*Botrytis cinerea*).

ZumSil increased the fruit weight, firmness and taste, and reduced the share of distorted fruit in the total number of harvested fruits. The fruits of the combinations treated with the stimulant ZumSil were rich in ascorbic acid but poor in anthocyanins.

Alkalin KB+Si improved the anthocyanin content, but simultaneously decreased the level of ascorbic acid in the fruit.

Titanit improved fruit firmness and reduced its rotting, but delayed the date of fruit ripening.

San Andreas - the highest yield, high attractiveness and firmness of the fruit, but also the highest proportion of distorted and rotted fruits in the total number of harvested fruits (like Albion). Its fruits - poor in extract, acidity, and ascorbic acid.

Grandarosa fruits - contained the highest amount of extract and ascorbic acid

Florence fruits - had the highest content of anthocyanins.

Task 3.4. Improving production technology to extend the harvest period and supply the market with fresh berries (INHORT and NIBIO)

Raspberry:

Floricane - Canby, Laszka, Sokolica, Ninni, Duo;

Primocane - Polka, Polonez, Poemat, clones: MJ-14 and MJ-57;

Primocane-Floricane – clones: MLD-26, MLD-37, MLD-104, MLJ-278 and, MLJ-317.

After planting, all plants were pruned above the ground to make them better regeneration and to even out the growth force.

From 2022, different methods of pruning the shoots will be used: floricanes and primocane-floricanes - at a height of 180 cm, primocane - at a height of 0.0 cm, 5.0 cm and 10 cm above the ground.

Assessment in 2022-2023: fruit yield, attractiveness, colour, shape, taste and chemical composition of the fruit.

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Task 3.4. Improving production technology to extend the harvest period and supply the market with fresh berries (INHORT and NIBIO)

Blackcurrant - 3 varieties: Bona, Gofert and Tihope,

Red currant - 2 varieties: Rovada and Jonkheer van Tets

Three cultivation systems: bush form, row system and row system with polyethylene canopies

The field trial with black and red currants was planted in the spring of 2021.

Results:

One-year-old bushes did not produce fruit.

All blackcurrant bushes grew similarly and there were no significant differences in their height, both cultivars of redcurrant also obtained a similar and statistically insignificant result. No significant influence of the cultivation method on the growth of shrubs was found. Tallest shrubs in all cultivation systems were produced by blackcurrant (all three cultivars), while the lowest shrubs were obtained for the red currant cultivars: Jonkheer van Tets in the control combination and Rovada in the row system and the row system with polyethylene canopies.

The widest bushes were obtained by the Polish blackcurrant Bona in the control combination, and the narrowest ones for Tihope in all three cultivation systems, as well as Gofert in the row system and the row system with polyethylene canopies.

Both cultivars of red currant produced narrowest bushes, regardless of the cultivation system.

WP4. Adaptation of farming systems to changing climate conditions and weather extremes

Calibration of moisture probes for various types of soils and substrates used in berry production systems.

The calibration procedure involved determination of a relationship between relative permittivity (probe output) and actual water content for soils of different texture (light - loamy sand, heavy - loam) and soilless media (peat substrate, coco substrate, perlite). Dielectric probes were connected to the wireless data acquisition and processing module. The module enables for wireless (4G) measurements of soil/medium temperature, EC and water content. It can connect up to 6 probes. Measurements of relative permittivity were done for dried samples and samples with moisture approximating field/container water capacity. The next stage of the study will involve implementation of the elaborated calibration models in a form of software (web portal).

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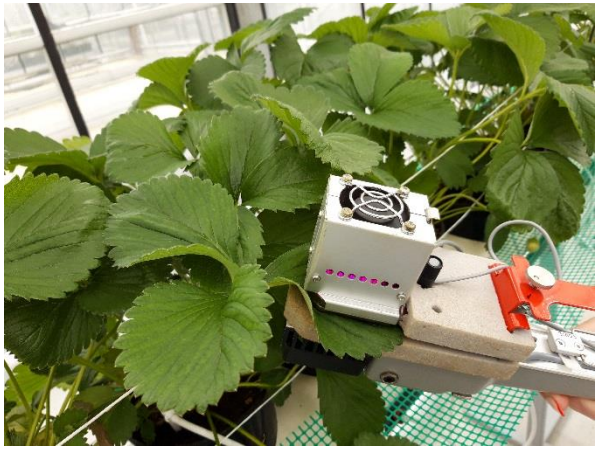
Development of a weighting system for estimating the irrigation needs of berry crops.

The irrigation needs of plants grown in containers can be estimated using weight systems. Measurement of irrigation requirements based on changes in the container (with a plant/plants) weight is precise because it directly determines the current water uptake.

Works on developing weighting system prototype have been initiated. The system consists of a measuring platform and a module recording the changes in weight of containerized plants. Data can be transmitted using a wireless technique. The prototype will be tested in growing conditions (cultivation of strawberry under greenhouse conditions).

Suitability of strawberry and red raspberry cultivars for growing under conditions of water deficiency.

The study was performed on strawberry and raspberry plants. The plants were grown in conditions of optimal irrigation (water potential of the growing medium was maintained at a level of approx. -10 kPa) or water deficit (water potential below -30 kPa). The irrigation schedule was carried out using moisture and water potential monitoring. Physiological response (photosynthetic apparatus efficiency, water relations), plant growth and productivity were assessed.



Genotypic differences in drought tolerance were observed. The study is continued.

WP5. Optimization of the berry production potential in terms of quantity and quality by using the metaxenia phenomenon (WP Leader Agnieszka Masny)

Task 5.1. Assessment of the possibilities to improve the strawberry, red raspberry and currant fruit characteristics by choosing the optimal pollen source for pollination of flowers (INHORT)

Strawberry (5): Grandarosa, Markat, Florence, Elsanta and Frida

Raspberry (5): Glen Ample, Przehyba, Willamette, Veten, Tulameen

Both pollination programs were carried out in a full diallel design (Griffing's method I)

Results:

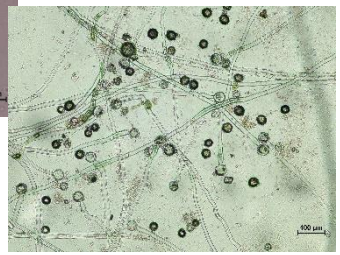
In strawberry cross breeding combinations, the pollination efficiency (% of obtained fruit in relation to pollinated flowers) ranged from 0 to 87.5 %. The lowest pollination efficiency was found in self-pollination of the cultivars Frida (0 %), Florence (7.9 %) and Markat (16.7 %) and in the crossings of Frida x Markat (2.5 %), Florence x Markat (5.4 %), Florence x Elsanta (10.0 %) and Florence x Frida (10.5 %).

In raspberry cross-breeding combinations, the pollination efficiency ranged from 54.3 % to 100 %. The lowest pollination efficiency was characterized by the cross combinations of Przehyba x Glen Ample (54.3 %) and Glen Ample x Przehyba (63.6 %). The self-pollination efficiency ranged from 79.1 % for Przehyba to 100% for Willamette.

In blackcurrant – it was not planned crossing programme, only plant material was prepared for 2022.

Task 5.2. Assessment of pollen viability of studied berry cultivars. (INHORT)

Strawberry (5): Grandarosa, Markat, Florence, Elsanta and Frida
Raspberry (5): Glen Ample, Przehyba, Willamette, Veten, Tulameen
Blackcurrant (5): Gofert , Bona, Ben Tron, Polares, Narve Viking.



Two methods of pollen assessment:

1. assessing the staining of pollen grains with 2% aceto-orcein to determine the viability of pollen grains
2. assessing the ability of pollen to germinate and produce a pollen tube in vitro.

Results:

Acetoorcein staining did not show large differences in pollen viability of the studied cultivars of a given species, these values are within the range of 85 % - 100 % for strawberry and black currant and 70 % - 100 % for raspberry. The germination of pollen on the media was lower than that observed after staining with acetoorcein.

Strawberry pollen tube germination on the control medium was close to zero for three cultivars - Grandarosa, Frida and Florence. Only for Markat, the germination capacity of 27 % was observed in conditions with limited availability of nutrients stimulating their growth. The medium enriched with sucrose and boric acid stimulated the pollen tubes to grow in the range from 23 % for Grandarosa to 66 % for Markat.

Germination of blackcurrant pollen grains on the control medium ranged from 0.3 % for Ben Tron to 14 % for Polares. Observations of the germination of the pollen tubes on the modified medium showed a growth capacity of the pollen tubes from 29 % for Ben Tron to 55 % for Gofert.

Raspberry pollen grains showed a much higher ability to germinate on the control medium (15 % - 40 %) than in the other two species. The use of a nutrient richer medium allowed the observation of an increase in the germination capacity of the pollen tubes from 41 % (Tulameen) to 60 % (Veten, Przehyba, Willamette).

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Task 5.3. Evaluation of selected fruit characteristics of strawberry, red raspberry and blackcurrant (INHORT)

Strawberry (5): Grandarosa, Markat, Florence, Elsanta and Frida

Raspberry (5): Glen Ample, Przehyba, Willamette, Veten, Tulameen

Blackcurrant (5): Gofert , Bona, Ben Tron, Polares, Narve Viking.

Results:

The largest strawberry fruits from the crosses: Elsanta x Florence and Elsanta x Frida.

The smallest fruit from self-pollination of Grandarosa, crosses of Markat x Frida and Frida x Markat.

The differences in the weight of the fruit produced by the same maternal cultivar, but pollinated with pollen from different paternal cultivars, are twice (for Elsanta and Florence) to 9 times for Grandarosa.

The highest amounts of extract in fruits from Grandarosa x self, and the least - from the crossing of Elsanta x Frida.

The weight of raspberry fruits from the crossbreeding program ranged from 1.78 g for Veten x self-pollination to 4.23 g for Glen Ample x self-pollination.

The difference in the weight of fruits produced by the same mother form, but pollinated with different pollen, was maximum 1.5 times (for Glen Ample).

The highest content of the extract - in the fruit of Willamette x Przehyba crossing.

The most rich in ascorbic acid - fruits of Przehyba x Tulameen, in anthocyanins – fruits of Willamette x Veten, and phenols - Willamette x self.

Blackcurrant – no results were obtained due to no crossing programme conducted in 2021

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WP6. Improvement of postharvest treatments and storage technologies to extend shelf life of berry fruits (leader Anna Skorupińska)

The main goal

Optimization of storage conditions and postharvest treatment of berry fruit, ensuring the longest supply and shelf-life, while maintaining high quality of fruit.

2021

The storage experiments were carried uot with strawberries, raspberries and black currants to extend the shelf life of these fruits (Task 6.1)

Storage technologies and post-harvest fruit treatment used in experiments:

- regular atmosphere conditions – control (RA)
- controlled atmosphere conditions (CA)
- forced air cooling (FC)
- Ozonation (O)
- MAP packaging (MAP)
- ethylene absorbing sachets (S)

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Studied species:

- strawberry (cultivars: Grandarosa, and Florence)
- raspberry (cultivar: Sugana)
- blackcurrant (cultivar: Tihope)




The fruits were evaluated immediately after harvest, and then after storage and after the period of simulated commodity turnover at two temperatures (10°C and 18°C)

Fruit assessment:

- overall fruit quality (appearance, occurence of storage disorders and dieases, texture, soluble solids content, acidity)
- sensory quality
- intensity of physiological processes (respiration intensity and ethylene production)
- content of health promoting compounds (L-ascorbic acid, sugars, organic acids, and polyphenols) – fruit samples were frozen and analyzes are in progres

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STRAWBERRY `GRANDAROSA` and 'FLORENCE' - STORAGE

- Temperature - 0°C
- CA conditions – 15% CO_2 + 5% O_2
- MAP packaging – Xtend bags dedicated for strawberries
- Storage time for 'Grandarosa' - 8 and 14 days
- Storage time for 'Florence' - 9 and 15 days
- Shelf life at 18°C - plus 1 day at 18°C
- Shelf life at 10°C - plus 2 days at 10°C

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STRAWBERRY `GRANDAROSA` - RESULTS
Rotten fruit (%)

Storage	8 days of storage	8 days of storage + 1 day at 18°C	8 days of storage + 2 days at 10°C	14 days of storage	14 days of storage + 1 day at 18°C	14 days of storage + 2 days at 10°C
RA – control	0	17,6	13,1	7,6	14,2	7,4
RA + FC	0	12,2	10,2	9,3	13,7	9,3
RA + O	0	16,3	20,4	5,9	13,3	7,1
CA	0	9,9	17,1	8,9	7,6	8,4
CA + FC	0	9,1	16,3	8,4	5,8	8,2
CA + O	0	7,3	3,3	7,3	2,6	2,5
MAP	0	8,1	1,2	9,7	10,7	14,0
MAP + FC	0	3,6	5,4	11,3	16,2	17,9
MAP + O	0	9,7	11,7	5,6	8,5	13,0
MAP + S	0	9,8	9,3	7,8	10,0	9,4
MAP + O + S	0	9,0	8,3	14,8	4,3	15,6

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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STRAWBERRY `FLORENCE` - RESULTS
Rotten fruit (%)

Storage	9 days of storage	9 days of storage + 1 day at 18°C	9 days of storage + 2 days at 10°C	15 days of storage	15 days of storage + 1 day at 18°C	15 days of storage + 2 days at 10°C
RA – control	4,6	21,9	32,4	37,4	55,0	48,8
RA + FC	8,3	21,1	28,9	41,2	60,2	53,6
RA + O	2,7	23,3	19,7	32,5	55,1	47,1
CA	0,8	22,1	24,0	10,9	29,2	7,6
CA + FC	9,2	13,5	18,2	13,9	17,8	9,6
CA + O	7,5	24,8	33,9	12,9	26,0	21,1
MAP	11,3	15,9	24,3	18,2	47,6	45,9
MAP + FC	10,1	20,1	31,5	15,0	51,1	38,5
MAP + O	8,2	28,6	32,0	26,0	46,9	47,1
MAP + S	9,7	18,1	22,8	21,4	47,5	47,1
MAP + O + S	16,4	23,9	36,8	39,9	69,2	56,7

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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STRAWBERRY `GRANDAROSA` - RESULTS
Overall sensory quality (scale 1-10)

Storage	8 days of storage	8 days of storage + 1 day at 18°C	8 days of storage + 2 days at 10°C
RA – control	4,7	2,7	6,6
RA + FC	4,5	1,6	5,7
RA + O	4,2	2,7	6,5
CA	7,0	6,3	7,3
CA + FC	7,3	6,5	6,7
CA + O	6,7	7,1	6,1
MAP	6,9	6,4	6,8
MAP + FC	6,3	5,8	5,8
MAP + O	7,6	5,8	5,8
MAP + S	7,7	5,7	5,7
MAP + O + S	7,4	5,3	5,9

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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STRAWBERRY `FLORENCE` - RESULTS
Overall sensory quality (scale 1-10)

Storage	9 days of storage	9 days of storage + 1 day at 18°C	9 days of storage + 2 days at 10°C
RA – control	5,8	4,5	5,5
RA + FC	4,4	5,3	6,4
RA + O	6,5	4,1	4,8
CA	6,7	5,9	4,3
CA + FC	6,9	6,3	3,6
CA + O	6,5	5,5	3,1
MAP	8,4	6,3	4,2
MAP + FC	5,6	6,0	5,1
MAP + O	7,0	5,9	6,5
MAP + S	6,9	5,4	6,2
MAP + O + S	6,4	5,6	5,0

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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STRAWBERRY `GRANDAROSA` - RESULTS
14 days of storage + 1 day at 18°C

regular atmosphere – control

controlled atmosphere + forced air cooling

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STRAWBERRY `GRANDAROSA` - RESULTS
14 days of storage + 2 days at 10°C

regular atmosphere – control

controlled atmosphere

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STRAWBERRY `FLORENCE` - RESULTS
15 days of storage + 1 day at 18°C

regular atmosphere – control

controlled atmosphere + forced air cooling

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STRAWBERRY `FLORENCE` - RESULTS
15 days of storage + 2 days at 10°C

regular atmosphere – control

controlled atmosphere

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RASPBERRY `SUGANA' - STORAGE

- Temperature - 0°C
- CA conditions – 15% CO_2 + 3% O_2
- MAP packaging – Xtend bags dedicated for raspberries
- Storage time - 5 and 10 days
- Shelf life at 18°C - plus 1 day at 18°C
- Shelf life at 10°C - plus 2 days at 10°C

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RASPBERRY `SUGANA` - RESULTS
Rotten fruit (%)

Storage	5 days of storage	5 days of storage + 1 day at 18°C	5 days of storage + 2 days at 10°C	10 days of storage	10 days of storage + 1 day at 18°C	10 days of storage + 2 days at 10°C
RA – control	26,4	49,1	43,5			
RA + FC	17,8	34,7	38,2			
RA + O	34,2	52,7	52,7			
CA	5,6	19,9	42,0	9,7	31,1	51,7
CA + FC	6,3	21,2	34,8	6,8	14,3	44,1
CA + O	4,8	35,7	28,0	12,7	29,7	55,4
MAP	18,1	44,5	44,3	33,8	46,4	61,9
MAP + FC	20,6	32,9	33,7	17,0	30,9	28,4
MAP + O	19,1	41,0	43,6	33,5	41,5	57,9
MAP + S	13,7	43,4	49,7	28,8	40,8	48,4
MAP + O + S	19,5	37,9	35,5	35,7	46,7	57,0

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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RASPBERRY `SUGANA` - RESULTS
Overall sensory quality (scale 1-10)

Storage	5 days of storage	5 days of storage + 1 day at 18°C	5 days of storage + 2 days at 10°C
RA – control	5,4	-	-
RA + FC	5,8	-	-
RA + O	5,7	-	-
CA	4,1	-	-
CA + FC	5,5	-	-
CA + O	4,4	-	-
MAP	5,3	-	-
MAP + FC	5,6	-	-
MAP + O	5,3	-	-
MAP + S	5,3	-	-
MAP + O + S	6,2	-	-

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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RASPBERRY `SUGANA` - RESULTS
5 days of storage

regular atmosphere – control

controlled atmosphere

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RASPBERRY `SUGANA` - RESULTS
5 days of storage + 1 day at 18°C

regular atmosphere – control

controlled atmosphere + forced air cooling

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BLACKCURRANT `TIHOPE' - STORAGE

- Temperature - 0°C
- CA conditions – 15% CO_2 + 2,5% O_2
- MAP packaging – Xtend bags dedicated for blueberries
- Storage time - 8 and 14 days
- Shelf life at 18°C - plus 1 day at 18°C
- Shelf life at 10°C - plus 2 days at 10°C

BLACKCURRANT `TIHOPE` - RESULTS
Rotten fruit (scale 1-7)

Storage	8 days of storage	8 days of storage + 1 day at 18°C	8 days of storage + 2 days at 10°C	14 days of storage	14 days of storage + 1 day at 18°C	14 days of storage + 2 days at 10°C
RA – control	7	7	7	6,7	6,7	6,3
RA + FC	7	7	7	7,0	6,3	6,3
RA + O	7	7	7	7,0	5,7	6,0
CA	7	7	7	6,7	6,7	7,0
CA + FC	7	7	7	7,0	6,3	6,3
CA + O	7	7	7	6,7	6,3	6,0
MAP	7	7	7	6,3	5,7	6,7
MAP + FC	7	7	7	7,0	6,3	6,7
MAP + O	7	7	7	7,0	6,3	6,3
MAP + S	7	7	7	7,0	6,7	6,7
MAP + O + S	7	7	7	6,3	6,0	6,0

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

1 – all fruit damaged
6 – single fruit damaged
7 – all fruit healthy

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BLACKCURRANT `TIHOPE` - RESULTS
Overall sensory quality (scale 1-10)

Storage	8 days of storage	8 days of storage + 1 day at 18°C	8 days of storage + 2 days at 10°C
RA – control	5,0	6,2	5,4
RA + FC	5,5	5,2	5,2
RA + O	6,4	5,1	4,9
CA	5,9	5,4	5,5
CA + FC	5,5	5,2	4,5
CA + O	6,2	5,2	5,2
MAP	6,4	6,7	6,6
MAP + FC	6,6	6,5	7,1
MAP + O	6,3	6,6	5,9
MAP + S	6,1	6,3	6,4
MAP + O + S	5,8	6,2	5,9

regular atmosphere conditions in 0°C – control (RA)
controlled atmosphere conditions (CA)
MAP packaging (MAP)

forced air cooling (FC)
Ozonation (O)
ethylene absorbing sachets (S)

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CONCLUSIONS

- Storage in CA and use of MAP packaging limited fruit rooting during the shelf life of 'Grandarosa' strawberries. In 'Florence', the reduction in root was mainly in the combinations with CA.
- The use of controlled atmosphere and MAP packaging had a positive effect on the overall sensory quality of strawberries.
- CA and MAP reduced respiration intensity and ethylene production in strawberries during shelf life.
- Raspberry rooting was limited by using CA conditions.
- The use of MAP packaging (depending on combination) limited respiration and ethylene production in raspberry fruit
- Blackcurrant fruits stored in MAP packaging obtained the highest scores for overall sensory quality.

2022 and 2023

- The research on the optimization of berry fruit storage methods will be continued.
- The storage ability and shelf life of selected genotypes/cultivars will be evaluated.
- as well as the effect of cultivation methods on fruit storage will be investigated.

Task 6.2 - Assessment of storage ability of selected cultivars of strawberry, raspberry and currant

- The fruit of the studied genotypes/cultivars (WP 5) (strawberry, raspberry and blackcurrant) will be stored in a cold store with a regular atmosphere,
- Their quality will be assessed at harvest, after storage and after shelf-life

Task 6.3 - Assessment of the impact of cultivation technology on the fruit quality and shelf-life of selected cultivars of strawberry, raspberry and currant

- The fruit of selected genotypes/cultivars from selected cultivation methods (investigated in WP 3) will be stored using the best post-harvest treatment method (developed in Task 6.1),
- The fruit quality assessment (described in Task 6.4) will be carried out at harvest, after storage and after shelf-life,

The usefulness of selected genotypes/cultivars will be evaluated as well as the effect of cultivation methods for fruit storage

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WP7.

Optimization of processing technologies for development of innovative and functional berry fruit products

Task 7.1. Technological trials for the production of juices, purees and dried berry fruits

Task 7.2. Determining of the appropriate process parameters for the processing technologies selected in Task 7.1

Task 7.3. Development of prototype product formulas with addition of fruit of the tested berry species

Task 7.4 Sensory evaluation, storage stability and nutritional value of products developed in Task 7.3

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Task 7.1. Technological trials for the production of juices, purees and dried berry fruits

The suitability of berry species for the production of various products is tested.

RAW MATERIAL (season 2021):

Strawberries -'Grandarosa', 'Panvik', 'Rumba', and 'Florence'
Blackcurrant -'Tihope' and 'Tisel'
Raspberry - 'Polka'

CONDUCTED EXPERIMENTS

- **Cloudy juices** - produced using a packing press. During production, the various pre-treatment processes will be tested: *enzymatic maceration, temperature action, the impact of mechanical waves - ultrasounds*),

Our attention was focused on checking the possibility of ***producing juice from strawberry fruit***.

- It is impossible to squeeze the juice from the strawberry fruit without the use of an enzyme.
- Production including the enzyme phase of the strawberry fruit made it possible to obtain the juice with a very high pressing efficiency ~87%.
- The obtained juice had a very attractive color, a rich aroma typical of strawberries, and the sour taste was dominant, but it did not disqualify the product from direct consumption.

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Task 7.1. Technological trials for the production of juices, purees and dried berry fruits

CONDUCTED EXPERIMENTS

- **Purees** will be made using a pulper machine. The effect of *ultrasound* on the fruit will also be tested before making the puree in order to enhance the transfer of anthocyanin components from fruit peel (mainly currants) to the puree.

In a laboratory-scale experiment, we checked how **ultrasound used in the production of blackcurrant puree**s affects the content of anthocyanins and vitamin C in the final product.

Sonics ultrasonic probe

	Fruit heating		Ultrasound	
No	**Temp. °C**	**Time**	**Power**	**Time**
1	80	15 min	80%	brak
2	80	15 min	80%	15 min
3	80		80%	15 min
4	60		80%	15 min
5	80		80%	30 min
6	60		80%	30 min

CONCLUSION

The analysis of the content of anthocyanins and ascorbic acid showed that the use of UD in the production of blackcurrant purees allows for obtaining higher levels of these components. Both anthocyanins and ascorbic acid were most preserved in the product made of fruit heated to 60 °C and the application of UD for 15 minutes.

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Task 7.1. Technological trials for the production of juices, purees and dried berry fruits

CONDUCTED EXPERIMENTS

- **Dried fruits** from strawberry, red raspberry and currants will be produced using *convection, microwave-vacuum and hybrid driers or a freeze drier*.

At the moment, we tested the possibility of **subjecting strawberries, blackcurrants and raspberries to drying using the microwave-vacuum method**.

Strawberry turned out to be the most promising and useful for drying with this method. Work is now underway to optimize the process to obtain dried strawberries of the best consumer quality.

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PROBLEMS

1. Problem with phytosanitary and customs clearance of imported raspberry roots.
2. Young plants in the field experiments showed a different age, plant growth vigor and degree of regeneration, therefore most of the plants did not produce fruit yield (raspberry, blackcurrant) or the obtained fruit yield was insignificant (strawberry).
3. The last year was characterized by a higher level of rainfall (by approx. 15%) compared to the long-term average. Heavy rainfall was recorded especially in July and August (a total of 299 mm), which accounted for nearly 50% of the average annual rainfall for Skierniewice. This contributed to the slowdown in the growth of singular plants (strawberries and raspberries) or even their death.
4. Unfavorable weather conditions during harvest (extremely high temperatures, frequent rainfall) significantly affect the storage potential of the fruit. In 2021, long-term rainfall significantly reduced the quality and shelf life of raspberries, favoring the rapid rotting of the fruit.
5. There were delays in the implementation of tender procedures or inquiries on the Competitiveness Base platform (in accordance with the provisions of the "Public Procurement Law") due to the lack of offers from companies for the supply of ordered products (some plant protection products, biological agents and fertilizers) and the need to repeat these procedures for purchase of needed materials. The reason was probably due to delays in importing products from abroad by potential contractors or the instability of prices of these products due to COVID-19 pandemic.

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THANK YOU FOR ATTENTION!